

Irus Braverman

## Fish Encounters: Aquariums and their Veterinarians on a Rapidly Changing Planet

**Introduction.** The extensive body of social science and humanities scholarship on zoos rarely discusses aquariums. Despite their independent historical trajectory and unique characteristics and challenges, aquariums are considered by many as the younger sister to the more established terrestrial zoo institutions. This perception of aquariums can be explained in various ways: aquariums do not have quite the same controversial colonial history as zoos, they are fewer in number and smaller in size, and they exhibit animals that are less “like-us,” and thus not as well-known to science. With the exception of certain marine mammals, aquarium animals have thus rarely been championed by animal rights campaigns, which have tended to focus more on captive zoo animals such as elephants and apes. Of 41,500 species assessed by the IUCN Red List in 2017, only 1,500 or so were marine species (Baylina, interview).

Aquarium establishments also necessitate complex physical and technical undertakings: huge water filtration systems, for example, and distinct expertise for handling marine creatures, many of whom simultaneously serve as commercial products in food industries. Aquaculture, which accounts for about half of the seafood consumed worldwide, is the fastest growing sector in the food industry and generates 50 to 170 billion farmed fish every year (Gunther). As one of my interviewees from the aquarium world put it: “it’s more complicated to explain conservation and protection and the need for sustainability and constraint in these contexts” (Baylina, interview). Also unlike contemporary accredited zoos, until recently many aquariums did not hire in-house veterinarians. In fact, the marine environment was so alien to western medicine that early veterinarian expertise did not cover it. This situation is rapidly changing. The annual meeting of the International Association of Aquatic Animal Medicine, established in 1968, is now attended by hundreds of veterinarians and includes both marine mammal and fish experts.

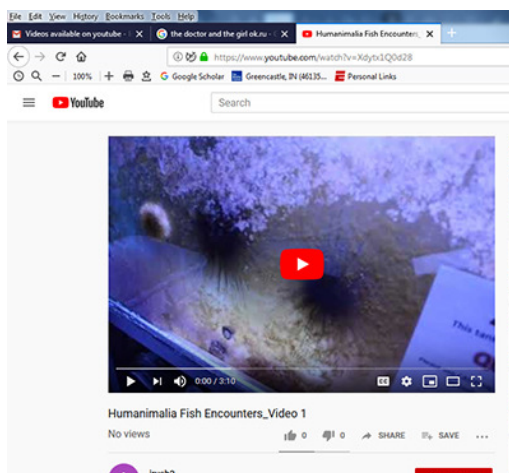
This article focuses on the novel profession of veterinarians in aquariums, discussing the challenges of this profession and the recent changes it has undergone. I draw on in-depth interviews with aquarium veterinarians in various locations — including the United States, Canada, Israel, Portugal, Denmark, and Germany — to document their

unique perspective and the challenges they face when attempting to manage the health and wellbeing of marine animals while simultaneously navigating conservation concerns. This can only be an initial study and thus highlights the need for additional scholarly work in the social sciences and humanities on aquariums, their wet forms of life, and the challenges — as well as the opportunities — that their management poses to the human caretakers of this space. This scholarly need is especially acute in light of the declining state of extant species and ecosystems in the world's seas. In this perilous time, aquariums and their veterinarians will arguably perform increasingly important roles in the conservation of our blue planet.

**Aquariums and their Veterinarians: A Brief History.** The earliest documented aquarists were the Sumerians, who kept fresh water fish in artificial ponds at least 4,500 years ago, and records of fish keeping also date back to ancient Egypt and Assyria (“Aquarium”). The ancient Romans were the first known marine aquarists: they constructed ponds that were supplied with seawater from the ocean. Although goldfish were successfully kept in glass vessels in England during the mid-1700s, aquarium keeping did not become well-established until the basic relationship between oxygen, animals, and plants became known in the mid-nineteenth century (ibid.). In 1853, the Zoological Society in London opened the first modern public aquarium, where it exhibited over 300 marine species in enclosed tanks referred to as the Fish House (Figure 1). The term “aquarium” (from classical Latin: a watering place for cattle) was coined by British naturalist Philip Henry Gosse and was adopted and popularized by the London Zoo shortly after (“History”). Similar institutions were later established in New York City, Boston, Vienna, Hamburg, Lisbon, and Berlin. By 1928, there were 45 public aquariums throughout the world, but growth then slowed down until after World War II (“Aquarium”). Today, many of the world's principal cities have aquariums (see, e.g., Video 1). Alongside public and private aquariums, there are also aquariums that serve chiefly as research institutions (e.g., Scripps Institution of Oceanography) and temporary aquarium exhibits such as those found at world fairs (ibid.).



**Figure 1: Inside the Fish House, circa 1875. (Courtesy of the London Zoological Society.)**



[https://www.youtube.com/watch?v=6\\_jCEpcKXoY&feature=youtu.be](https://www.youtube.com/watch?v=6_jCEpcKXoY&feature=youtu.be)

**Video 1: Behind the scenes with Director of Ocean Sustainability Science at the New England Aquarium, Michael Tlusty. (Video by author, May 11, 2016.)**

Toward the mid-twentieth century, the aquarium veterinarian profession became independent. Sam Ridgway was one of the founders of marine mammal medicine, and also the founding president of the International Association for Aquatic Animal Medicine (IAAAM), established in 1968. A veterinarian and expert in dolphin biology and communication, Ridgway emphasized that he does not see himself as an aquarium veterinarian — he fatefully stumbled upon dolphins when working with dogs and

supervising food inspections at a military base (Ridgway). “Nowadays, most of the aquariums have vets, but their presence is not as consistent as in zoos,” Nuno Pereira of the Lisbon Oceanarium told me. He and other aquarium vets I spoke with mentioned that, until recently, there were significant challenges in training for and practicing this relatively novel profession. They stressed how, until not too long ago, it was difficult to obtain proper hands-on training (e.g., LePage, interview). This is how Pereira explained the historical trajectory of acquiring a relevant education in this field:

Back in the days, veterinaries didn’t know how to work with fish; they had to teach themselves. There was literature but no formal education. [So] I went to aquariums in the United States and started to network and we started to help each other. Nowadays, it’s better: there are some veterinary schools that deal with fish medicine so you can start learning this at the university. (Pereira, interview)

Notwithstanding the increased opportunities for relevant education, all of my interviewees stressed the still-small number of aquarium vets and the emotional toll that the isolation of this community has had on their work. As one interviewee told me: “It’s quite strange to be one of three or four persons in this world who can handle this or that [fish] species. It’s kind of frightening.”

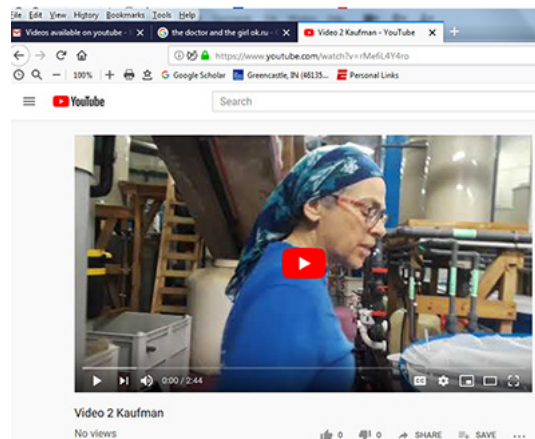
The veterinarians I spoke with also stressed the vast differences between zoos and aquariums and the immense challenges of managing aquariums. In the words of Núria Baylina, Curator and Head of Conservation at the Lisbon Oceanarium:

The pumps, the filters, the disinfection systems — everything [intended] to keep an aquarium with marine species is very comprehensive [see, e.g., Video 2] and is *much* more complicated than a zoo enclosure where you keep giraffes or elephants. So [aquariums already] start from a totally different place than zoos. The other thing that is very different is that in zoos, most of the exhibits focus on one species, while in aquariums, the majority keep mixed species exhibits.... [This is because] when people go to an aquarium, they want to see the environment, not just one species. It’s a little bit different when you go to the zoo — you go to see the elephants and giraffes and you can see them separately. Our theme here is One Ocean. Just because we call them different names, that doesn’t mean there are a lot of oceans — it’s only one mass of water. So it’s all connected and what we do in one ocean will impact the ocean on the other side of the

world. [Another important difference is that] you don't eat elephants and giraffes. [But] when you go to an aquarium you are showing species that most people in the world eat. (Baylina, interview)



Figure 2: Quarantine area at the Israel Aquarium (part of the Tisch Family Zoological Gardens) in Jerusalem. (Photo by author, July 7, 2019.)



<https://www.youtube.com/watch?v=rMefiL4Y4ro>

Video 2: Aquarium veterinarian Elizabeth Kaufman (DVM, CertAqV) shows me around the quarantine area of the Israel Aquarium in the Tisch Family Zoological Gardens in Jerusalem. (Video by author, July 7, 2019.)

Finally, while accredited aquariums in many developed countries are governed by the same industrial standards as zoos and by the same bodies – the Association of

American Zoos and Aquariums in North America and its equivalents in other regions — they have not been subject to the increasingly strict proscriptions against the sourcing of animals from the wild, which, for American zoos, date back to the 1970s (Braverman, *Zooland*). In fact, aquariums around the globe still acquire most of their fish and — with several significant exceptions — even their marine mammals, from the wild, as I will discuss shortly.

**Observation as Scientific Knowledge.** Elsewhere, I wrote about the enhanced importance of vets in zoo institutions and about their creativity in adapting their medical practice from cats, dogs, and cows to lizards, birds, and polar bears (Braverman, “Saving Species”). This is even more true about aquarium vets, whose everyday encounters include not only fish but also invertebrates, mammals, and birds. How do they care for such a wide variety of species, I repeatedly wondered in our interviews. Veterinarian and director of animal health and welfare at the National Aquarium in Baltimore, Robert Bakal, reflected: “One of my mentors in vet school taught me in dealing with exotic species — and it’s very true, all the way down to corals, and for other invertebrates for sure — [that] medicine is medicine and it doesn’t matter who your patient is” (Bakal, interview). As a vet, he told me, he was trained to stick with the procedures in order to determine the problem. In his words: “The tests for practicing medicine on a dolphin may be different, the diseases may be different, but the approach is still the same: you still do a physical exam [and] you still come up with a list of possible causes and a list of what tests you want to run.” Bakal referred to this unitary approach to animal care as the “interconnectivity” among all forms of life. Leigh Clayton, Vice President of Animal Care and Welfare at the National Aquarium, agreed. In her words: “I call it running the process. It provides a context when you don’t know what to do. Just run the process. The details when facing a sea star versus facing an elephant are different, but from the point of view of the general things you want to be taking into account, the process is the same.” Bakal wrapped up: “I guess if you approach it from a position of being limited, [then] you’re limited. [But] I never saw this as a limitation. I actually find it to be liberating.”

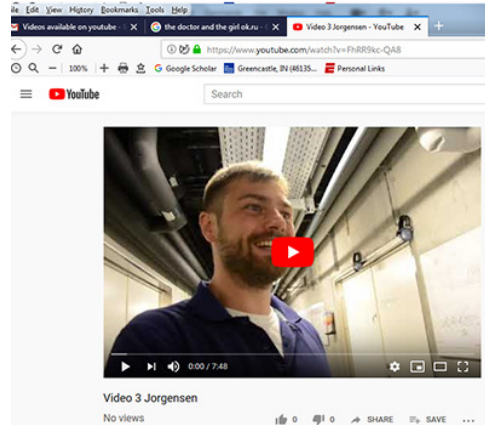
While many of the aquarium veterinarians I interviewed for this project emphasized the interconnectivity between the animals they care for and thus the importance of what they refer to as the “One Health” approach (Aguirre xii; Travis), they simultaneously stressed the uniqueness of aquarium veterinary medicine. Pereira of the Lisbon Oceanarium told me along these lines: “For ten years I worked with dogs, cats, and some wild animals. To start working with fish — well, it was difficult, because, physiologically, they looked like [they came] from another planet.” Such

otherworldliness is precisely what attracted most of the aquarium vets I spoke with to their profession in the first place.

The watery nature of the ocean environment has resulted in the evolution of particular life forms that have evolved there, I was instructed. The density of water is about 800 times greater than that of air, with multiple implications for structure and size (Balcombe 12). Pereira explained: “It’s not easy to live underwater, so [animals] have lots of strategies to be able to breathe with so fewer options than we have in the air. Imagine being a fish. Your skins and lungs [would be] in much closer contact with a fungus or bacteria. So they must have a very specialized immune system.” Veterinarian Kasper Jørgensen of the National Aquarium Denmark also emphasized the fish’s vulnerability. An expert in microbiology, Jørgensen told me that “the most fragile place on a fish is of course the gills. They breathe with their gills [so] the gills are their lungs — that’s where the oxygen flow is. So it’s like if you have your lungs sticking out of the window when driving your car.” For this reason, Jørgensen explained, fish are like canaries in the coalmine. “If you have a mixed species tank, you’ll see the more fragile fish acting weird first,” he told me. To distinguish the unusual from the normal, the veterinarian must learn how to carefully observe her medical subjects. In his words,

The thing about keeping animals in this area is you have to look at them every day because, to begin with, you don’t know what to look for, until the day that they are acting weirdly. [So I always] walk around. Otherwise, I wouldn’t be on top of my game, so to speak, because I have to know the fish pretty well. (Jørgensen, interview; see also Video 3)

During a visit to Toronto’s Ripley’s Aquarium, Veronique LePage, the institution’s veterinarian, invited me to witness the shark feeding. This hourlong practice involved a meticulous interpretation and documentation of each shark’s food intake. “Getting to know their day-to-day behavior, we can more easily identify when something is wrong with the animals,” LePage told me. Using straightforward observation methods, aquarium veterinarians — both directly and through other caretakers in their institutions — can learn quite a bit about their “patients,” which is how they refer to the animals under their care, again highlighting the unified approach toward animals underlying veterinary medicine (see also Jones 3).



<https://www.youtube.com/watch?v=FhRR9kc-QA8>

**Video 3: Veterinarian Kasper Jørgensen of the National Aquarium Denmark (in Copenhagen) discusses the water filtration system, among other issues. (Video by author, July 30, 2018.)**

When making medical observations, Jørgensen distinguishes between schooling and individual fish. As he explained, for evolutionary reasons certain animals, including those who travel in groups, will hide symptoms of illness. So when they die, “they will fall down suddenly.” Indeed, school fish “do everything they can to not change behavior, like cows,” he told me. “But if it’s [an individual] fish in its own environment, we can easily see if something’s wrong.” This is how their routine of fish observations unfolds in the everyday, according to Jørgensen:

From time to time, the keeper will call me and say, “Kasper, let’s look at Aquarium 5, something is odd.” And then we stand there and we can see [that] they’re not moving like they used to. So I take some scrapes. If one [of the fish] is dead then I can do a necropsy. I also have a small heating chamber where I can grow bacteria, or I send it off to the lab. For the parasites, the best sample you can get is the fresh one, so I will do that myself. Then we’ll figure out, “Oh yeah, they had this parasite.” ... But you can also see on the fish that they are not well, that something is wrong.... Maybe it’s a fish that lies on the bottom, [or] it’s swimming too much. You can see a fish jump out because it’s itching from a parasite; you can see them swim more poorly because they have a bacterial infection so their bladder is not working well, [in which case] the scale is a bit raised, you can see it sticking out from the body.



While they may seem incomprehensible to non-expert eyes, fish in fact display a range of behaviors that their human caretakers may learn to observe and then to interpret, understand, and act upon.

Initially, fish care was founded upon group, rather than individually oriented, medicine. According to Leigh Clayton of the National Aquarium, the tendency to study certain animals within groups and populations can be traced back to wildlife medicine. The transformations in this approach as pertaining to wild animals are increasingly relevant also to the care of marine animals. In Clayton's words:

There's a paper out there now on endangered species of frogs. The researchers found a frog with a tear in the body wall of the intestines so they cleaned it all up and shoved it in and glued it together and they wrote this paper. Typically, no wildlife biologist would treat an individual frog. They would just let it die on its own or whatever. But in this situation they did, because there's only 50 of them left. So, you've got this interesting shift: as the numbers go down, the surviving animals become more important as individuals. (Clayton, interview)

The group or population approach is still very much alive in the context of aquariums, Clayton told me, implying that it attaches less importance to the individual animal. "We talk about it all the time, that aquariums are twenty years behind," she responded when I asked her how aquariums compare with zoos, especially in terms of their role in conservation.

Among other reasons, the different ethical stance toward terrestrial versus marine animals are often explained by the category of the animals exhibited: while exotic zoo animals are often exclusively classified as imperiled (vulnerable, threatened, or endangered), exotic marine animals can be categorized as imperiled while also being subjects of human consumption. In other words, unlike most exotic animals exhibited in the zoo settings, many marine animals are also farm animals. The distinction between wild, farm, and even domestic animals (with certain fish designated as pet animals in the private sphere) in aquariums is thus much less pronounced than in zoos (Braverman, *Zooland*). Clayton explained in this context that

[a]quarium professionals, and even many aquarium animal care professionals, have looked at fish more like a commodity than as

individuals. It's been a really long time since lions or elephants were considered a commodity.... When you're talking about an individual sand tiger [shark], [that's one thing,] but when you're talking about 500 kilograms of fish from Chesapeake Bay that has millions of them, [that's a very different ballgame.] It's not that people don't care, they do care, desperately. But there hasn't been the pressure, internally or externally, to care about every single animal.

In other words, it is difficult to explain to the public why they should care about saving the same herring or lobster that they will later find on their plate. Clayton stressed, finally, that this situation is rapidly changing as fish are increasingly conceived as subjects of individualized care, as I will discuss below.

**Taking from the Wild: The Aquarium Veterinarian's Dilemma.** Initially, the zoo veterinarians' central if not exclusive focus was on the zoo animals' individual welfare. This focus has expanded and altered with the transition of zoos from institutions for public entertainment to promoters of animal and habitat conservation (Braverman, *Zooland; Wild Life; "Saving Species"*). Two questions that have been more or less settled in the zoo conservation context for the last few decades are whether to take animals from the wild (absolutely not) and whether to reintroduce wild animals back into the wild (a noble but challenging endeavor). For the most part, aquariums have been answering these questions differently than zoos, although this, too, is changing, as I will discuss here (Figure 3).

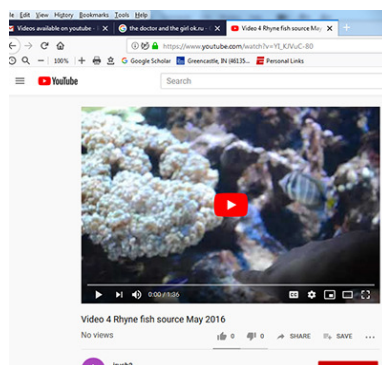


**Figure 3: Sea lion show at the Lisbon Zoo. Many aquariums (e.g., the National Aquarium in the United States) have terminated such shows for what has been perceived as their problematic anthropomorphizing of marine animals. (Photo by author, July 9, 2018.)**

Most marine animals held in aquariums are wild-caught. The United States imports 11 million tropical fish each year, who live in an estimated two million saltwater aquariums throughout the country, and the global saltwater fish trade nets as much as \$330 million annually (Weber). Director of Ocean Sustainability Science at the New England Aquarium Michael Tlusty and the institution's research scientist Andy Rhyne told me about the damages that the ornamental or pet fish industry — with its indiscriminate strategies of cyanide fishing and bottom trawling — has wrought upon fish, marine mammals, and their wet ecosystems. At the same time, they emphasized that this sorry situation of fish should not translate into a complete ban on taking aquatic creatures from the wild. In fact, they have been arguing that purchasing wild-caught corals is more conservation-friendly than buying corals from farms and aquarist tanks (Braverman, "Saving Species"; "Corals in the City"; see also Figure 4; Video 4).



Figure 4: Tanks behind the scenes, New England Aquarium, Boston, MA. (Photo by author, May 11, 2016.)



[https://www.youtube.com/watch?v=YI\\_KJVuC-80](https://www.youtube.com/watch?v=YI_KJVuC-80)

**Video 4: Andy Rhyne discusses fish sources, New England Aquarium. Video by author, May 11, 2016.**

Similar to the debates about corals, the debates about whether to source fish from the wild are ongoing and, as is often the case with animal-related issues, can be quite heated. While the vast majority of aquariums continue this practice, many have become much more selective about regulating how fish are captured so as to minimize harm to both the fish and their habitat. Indeed, the estimated mortality in the reef-to-retail chain ranges from 10 to as high as 80 percent for different marine species. Transport practices for the ornamental and pet industry have included starving the fish so that they do not foul their water, subjecting them to fluctuating temperatures, holding them in water of poor quality, and exposing them to harsh medications (Algae Barn). As a result, certain states, such as Hawai'i, have introduced laws requiring higher standards for fish transport (Weber).

Although the vast majority of aquarium animals are still acquired from the wild (Parsons, interview), aquariums distinguish themselves from the pet and ornamental industries by how they obtain their animals. Leah Neal, formerly Director of Husbandry at the Ripley's Aquarium in Toronto, Canada, described her aquarium's intensifying precautions with regard to fish sourcing:

We have vendors that we go through and we generally stick with those [vendors that] we know their supply chain. So we're not going to the mom and pop [pet] shop online. We also collect at the Florida Keys, where we have a "no-hands" rule: we use nets and try not to handle the fish at all. We also get to pick. We have permits, but [in addition], when we decide if to take small versus big animals, we [opt to] leave the reproducing ones on the reefs. That way, we are in control. In Baltimore [and also] in [the] New England [Aquarium] they go to the Bahamas once a year. Out in the West Coast, they [also] do their own collecting. We would like to know that we're handling those animals from start to finish. (Neal, interview)

Relatedly, and although this is also changing rapidly, most animal populations in aquariums are not part of captive breeding programs (such as SSPs in North America and EEPs in Europe). The aquarium vets I interviewed indeed pointed to the technical and scientific challenges of captive breeding marine mammals and fish, and also emphasized the high costs of these endeavors. Aquarium veterinarian Kasper Jørgensen and Copenhagen Zoo veterinarian Kathryn Perrin were discussing this point when I met both of them in Copenhagen:

Jørgensen: In Holland [there's] an aquarium that says we do not receive animals from the wild and that is very cool, except they just ask us if we have any animals. And for them it's not a problem to receive our animals that we retrieved from the wild and then it's as if they didn't take them from the wild.

Perrin: It would be really cool if you had an aquarium that genuinely did not source animals from the wild. That would be so cutting-edge.

Jørgensen: Yeah, I think that would be very nice to end up there, except that it would be stupid to not just bring the herring from out here because there's a lot of them — there's really a lot.

This brief exchange reveals a fundamental difference in approaches between veterinarians across distinct institutions and geographies, and especially between zoo vets and certain aquarium vets. Whereas both zoo vets and an increasing number of aquarium vets, represented here by Perrin, categorically prefer captive breeding over taking animals from the wild, certain aquariums have been promoting a less categorical approach, represented here by Jørgensen. In his view, certain fish can be sustainably harvested from the wild, in similar fashion to their harvesting for the food industry.

Those animals who transition from the wild into captivity are exposed to a variety of issues, Jørgensen further explained. He provided an example from the world of sharks to illustrate some of the veterinary problems that occur in the transition from wild to captive. In many public aquarium facilities, larger sharks are an essential part of the collection and represent one of the biggest draws for the public (Grassmann et al.). Jørgensen told me that the method of capturing them from the wild, which involves the unregulated application of certain antibiotics, introduces a host of problems for aquariums. In his words:

The fishermen [who] earn their money catching sharks keep them in small tanks and ship them out to different aquariums. Most of them keep the fish alive in these small places by adding a lot of antibiotics. When I receive a shark from Indonesia and they get a bacterial disease that needs to be treated, they are always resistant to Enrofloxacin, which is because the fishermen just poured it into the water. I am sure of it. And

Enrofloxacin is supposed to be a reserved antibiotic. It shouldn't be used as a first line antibiotic. You should save it for the infections you really need it for. It's very commonly used in exotic species because it's safe and it works.

As a result of these problematic capture practices, the recently acquired aquarium sharks could no longer be treated properly. As Jørgensen put it: "that shark is *gone*." He lamented, further, that the aquarium's human divers could get infected by the same resistant bacteria, which likely infiltrated the aquarium's water system. To avoid such messy zoonotic transmissions, the National Denmark Aquarium no longer gets them from that area and instead acquires its fish from Kenya. "We've been down there and we've seen the facilities and I've written the treatment protocols and told [the fishermen] what to do and how we would like the fish we are getting." Rather than deciding to stop taking fish from the wild altogether, even the conservation- and welfare-minded aquariums often prefer to adjust the geographic zone of the take and the protocols for how to more safely and sustainably take marine animals from the wild.

At the same time, captive breeding is becoming increasingly feasible for a growing number of aquatic species. This transition is most apparent with regard to marine mammals such as dolphins and whales (Schweig), as well as certain shark and ray species (Bakal, interview). Whereas captive breeding programs have existed in zoos since the late 1970s, public aquariums in Europe established their first two marine fish studbooks and collaborative breeding programs in 2007 — first for zebra sharks (*Stegostoma fasciatum*) and then for blue-spotted stingrays (*Taeniura lymma*). Núria Baylina is Curator and Head of Conservation at the Lisbon Oceanarium and the studbook keeper for the blue-spotted stingray breeding program. She told me in our interview that the rays' captive population of 130 individuals is currently managed among various European aquariums with an eye toward protection and conservation. "Ten years ago, we didn't know much about them and we couldn't figure out how to breed them," she said. "Now," she continued, "we're in the second or third [captive-bred] generation." "Compiling this information and using this network really helps to develop our knowledge about the species," Baylina summarized.

From Baylina's perspective, the knowledge developed about captive marine animals is valuable for the conservation of wild species, especially because biologists are unable to monitor them closely in the wild. In her words: "Aquariums have a very important role in conservation and in learning more about these animals because we are able to keep

these animals and study a lot of things that in the wild you would not be able to study because you would not have access to these animals and you would not be able to follow these animals in their life stages.” In the case of the blue-spotted stingrays, captive breeding in aquariums will likely also reduce pressure on the wild populations from the hobby aquarists. Furthermore, according to Baylina: “if this species will become threatened or endangered, we [would] have the knowledge to go for reintroduction program. So we’ll be prepared if we need to use these techniques for the species in the future.” She summarized: “a lot of people think we just keep the species for them to see, but that’s not the main goal of an aquarium.” In the United States, the American Association of Zoos and Aquariums recently established the program “SAFE: Saving Animals from Extinction,” which “takes a collaborative approach to recognize, promote and bolster conservation efforts for selected species” (“Ocean Conservation”). Four of the five focal species or species groups selected for 2015 are aquatic: African penguins, sea turtles, sharks, and vaquitas.

Additional changes are underway for marine management in aquariums. Some institutions, such as the National Aquarium in Baltimore and the Shedd Aquarium in Chicago, have recently announced that they will no longer exhibit dolphins and orcas and that they will send their captive animals to semi-wild sanctuaries. The Lisbon Zoo’s vet assured me: “In Europe, you won’t see a [newly] wild-caught dolphin in any accredited zoo or aquarium; not even one” (Bernardino, interview). Veterinarians are also calling for the captive propagation of certain marine animals, such as the endangered river dolphins, with the underlying understanding that suffering captivity is better than suffering extinction (Ridgway et al; see also Braverman, “Captive for Life”).

While they lag behind zoos in terms of prohibiting take from the wild and in their technical capacity to breed animals in captivity, aquariums seem to be particularly well-suited for moving animals in the other direction: from zoos back to the wild, a movement that under certain circumstances is referred to by conservation professionals as “reintroductions” (Braverman, *Wild Life*). Perrin of the Copenhagen Zoo shared in our interview that “every vet dreams about being involved with reintroduction and making an impact.” After personally observing the reintroduction of hellbenders (*Cryptobranchus alleganiensis*, the largest salamander species in North America) in Alleghany, NY, and Persian fallow deer (*Dama dama mesopotamica*) in the Jerusalem hills in Israel, I can attest to the emotional intensity present in the act of releasing animals

from captivity, which may be more aptly described using narratives of liberation that are characteristic of animal rights approaches.

However, the central reasoning behind reintroductions by zoos, and their foundation in captive breeding, is neither based in animal welfare nor in animal rights but rather in endangered species conservation. Accordingly, Jørgensen is convinced that in light of the degrading state of marine ecosystems due to pollution, overfishing, ocean acidification, and global warming, aquariums must urgently assume a novel institutional role as the new Noah's Arks. He explained in the context of sea otters, for example, that the captive populations are a "backup for the world." So "if catastrophe hits Alaska, we have fertile animals, and we know how to breed them" (he lamented, however, that the existing legal regime prohibits his aquarium and others to breed otters). Similarly, "with corals, aquariums are the backup. And the way that the world is going now, at some point we will need this backup." As for fish, in terms of inbreeding and genetic diversity they are better suited for captive breeding than any other taxa, Jørgensen told me. "With fish you can go through a lot of generations of inbreeding with no problem" (interview).

Alongside developing the capacity to breed marine animals in captivity, a crucial component of the aquariums' function as Noah's Arks is their ability to reintroduce the animals to ocean locations. While reintroductions have been a challenging endeavor for many terrestrial animals (Braverman, *Wild Life*), Jørgensen told me that "for fish, you can just take two hundred of them and put them out where they come from after three generations and they will live perfectly."

Nonetheless, reintroductions are prohibited in many countries, mostly due to concerns regarding pathogen introduction and genetic pollution. Despite the legal obstacles, Jørgensen believes that reintroductions will be necessary and that aquariums should be building up both medical veterinary knowledge and husbandry skills to execute them (see also Stokstad). In his words:

Aquariums should work toward releasing the animals that we produce instead of euthanizing them. It's fine for me to put them down if there are too many, but I'd rather just put them out in the wild. Because [we] can easily do that. You have [to undergo] some very strict quarantine procedures but ... it's possible. In Madagascar, for example, all the riverbeds are drying out and getting polluted. We have some cichlid [fresh water fish, IB] from Madagascar that are going to be extinct in the



wild in a few years. We are the only aquarium in Europe keeping these fish and we are trying to breed them just in case some government at some point allows us to let them out again.”

“I really think we should reintroduce a lot more fish or make it possible to do that,” Jørgensen said, and a growing number of his cohorts in aquariums would agree. In their view, contemporary aquariums should perform a more active role in marine animals’ conservation and, correspondingly, aquarium veterinarians should be better educated in the relatively new field of conservation medicine (Aguirre viii).

**Can Fish Feel Pain?** While the conservation of species is a relatively new focus for zoo vets and, even more so, for their counterparts in aquariums, the welfare of individual animals has always been the primary focus of zoo and aquarium veterinarians. The central, and most controversial, question that arises in this context is, therefore, whether fish — a taxa that includes some 34,000 species (FishBase) — feel pain. Perrin of the Copenhagen Zoo considered aloud: “Of course the elephant feels pain, but does a lobster feel pain?” She immediately replied that, “personally, I feel that there’s pretty good evidence that, sadly, animals from fish upwards feel pain. There is also increasing evidence that it’s more difficult with invertebrates to distinguish pain versus reflex.”

Apparently, the science is divided on this topic. Perrin explained that the crucial distinction here is between nociceptive reflex and cognitive pain, whereby “there’s some sort of mental process about it being a negative experience.” “If you don’t perceive it as painful, [then] it’s not the same thing,” she explained. The question is how to know and quantify these responses in animals, who cannot inform us about their feelings in ways that we can easily comprehend and measure (see also Dror). “You can’t really measure pain in animals because pain is the emotion associated with a negative stimulus,” Perrin continued. Instead, “you apply a stimulus that you assume is painful — heat, electric shock, or a chemical stimulus — to try and replicate a painful stimulus in a repeatable way that’s consistent, but very different from, pain.”

Specifically, with respect to fish, Perrin told me that “there was an assumption for some time that fish don’t feel pain.” In their 2013 article “Can Fish Really Feel Pain,” James Rose and his colleagues reviewed studies claiming that fish feel pain and found deficiencies in the methods used for pain identification, concluding that “claims that fish feel pain remain unsubstantiated.” They wrote:

In contrast, an extensive literature involving surgeries with fishes shows normal feeding and activity immediately or soon after surgery.... We evaluate recent claims for consciousness in fishes, but find these claims lack adequate supporting evidence, neurological feasibility, or the likelihood that consciousness would be adaptive. Even if fishes were conscious, it is unwarranted to assume that they possess a human-like capacity for pain. (Rose et al.)

The same article concludes that, “Overall, the behavioral and neurobiological evidence reviewed shows fish responses to nociceptive stimuli are limited and fishes are unlikely to experience pain” (ibid.). Along the same lines, in 2016 Australian neuroscientist Brian Key’s wrote the article: “Why Fish Do Not Feel Pain.” “It doesn’t feel like anything to be a fish,” he wrote elsewhere in this context (cited in Safina).

By contrast, Jonathan Balcombe’s book, *What a Fish Knows: The Inner Lives of Our Underwater Cousins*, speaks to the sentient and rich mental life of fish. “Scarcely a week now passes without a revealing new discovery of fish biology and behavior ... that defy the human conceit that fishes are dim-witted pea brains and slaves to instinct. Fishes are not just sentient, but aware, communicative, social, tool-using, virtuous, even Machiavellian” (19). Similarly, oceanographer Sylvia Earle stated that “I find it astonishing that many people seem shocked at the idea that fish feel. The way I see it, some people have wondrous fish-like characteristics — they can think and feel!” (cited in Safina). Fish “have senses we humans can only dream about,” she continued. “Try to imagine having taste buds all along your body. Or the ability to sense the electricity of a hiding fish. Or eyes of a deep sea shark” (ibid.). Indeed, recent studies show that pain in humans, too, is a very elusive phenomenon (Bourke; Moscoso; Wailoo).

Whereas the vets I interviewed all admitted that they do not have an unequivocal scientific answer to the question of whether or not fish feel pain, they have nonetheless opted to work under the premise that they do, either because they experience this to be true from their everyday acts of caring for fish, or due to the precautionary principle. “Most zoo vets err on the side of caution: if you suspect there’s pain, then you should be doing something about it,” Perrin told me. Ripley’s veterinarian LePage was even more explicit: “That there is still a debate about this topic is totally baffling to me. I just don’t get the obsession about sentience in this context. To me it is obvious: *Fish feel pain!*” (interview).

**Euthanizing Fish: A Regulatory Patchwork.** The question of whether fish (and then invertebrates) do, or do not, feel pain has substantial implications for the everyday work of aquarium veterinarians. Veterinarians are trained to treat all animals equally, Pereira of the Lisbon Oceanarium exclaimed. For this reason, he continued, veterinarians would never say, “Well, this is a sardine, I don’t have anesthesia so let’s use a hammer, or something like that.” Instead, even though “the anesthetic is quite expensive, if I want to euthanize a sardine, I [will] use the same anesthetic that I would use to euthanize a [grouper].”

The Animal Veterinary Medicine Association’s latest Guidelines for the Euthanasia of Animals (AVMA) adopted a similar approach. Using the “preponderance of the accumulated evidence” principle, these Guidelines state, broadly, that:

While there is ongoing debate about finfishes’, amphibians’, reptiles’, and invertebrate animals’ ability to feel pain or otherwise experience compromised welfare, they do respond to noxious stimuli. Consequently, the Guidelines assume that a conservative and humane approach to the care of any creature is warranted, justifiable, and expected by society. Euthanasia methods should be employed that minimize the potential for distress or pain in all animal taxa, and these methods should be modified as new taxa-specific knowledge of their physiology and anatomy is acquired. (13)

The Guidelines are quite specific about how this principle translates to action in veterinary work, as the following paragraph illustrates:

[T]he preparations for euthanasia of finfish should be very similar to the preparations for anesthesia of finfish. If possible, withholding food for 12 to 24 hours prior to euthanasia will reduce regurgitation, defecation, and nitrogenous waste production. The environment should be as quiet and non-stimulatory as possible given the circumstances. Light intensity should be reduced if possible.... Water quality should be similar to that of the environment from which the finfish originated, or optimized for that species and situation, for the duration of euthanasia.... If euthanizing a large population of finfish, it is important to monitor the anesthetic bath water quality (temperature, dissolved O<sub>2</sub>, and organic loading, in particular).... Euthanasia methods should be tested in one animal or a

small group of animals prior to use in a large population for an unfamiliar species. If handling is required, appropriate equipment (nets, gloves) should be used to minimize stressors. (68-69)

The level of detail provided in the Guidelines is stunning and contributes to a sense that euthanasia — the good or easy death — is at the same time a hyperlegal and scrutinized one. Veterinary care is very much about regulated procedures with attention to nuance, as is even more evident in the AVMA Appendices 2 and 3 (see Appendices, below). Yet, as LePage told me, “there are always the underdogs and, in the case of the veterinary standards, those are the invertebrates. Even if there is a standard [for invertebrates], there are no baselines to implement it in practice” (interview).

Broadly speaking, the veterinary standards assume that animal pain must be avoided or minimized, even at the cost of death. Such standards are not new, however. Analyzing the relation between science and law in the context of the British 1876 Vivisection Act, Shira Shmuely argues that “‘Ethical’ was generally understood to be the minimal infliction of pain necessary to achieve the objects of the experiment” (forthcoming, 3). More generally, she suggests that “law and science jointly created ethical scientific facts” (7).

The term “humane endpoint,” which was developed in the context of laboratory animals, is helpful in this context. The United States’ Department of Agriculture (USDA), which is the agency charged to implement the Animal Welfare Act of 1966, defines humane endpoints as points that are “chosen to minimize or terminate the pain or distress of the experimental animals via euthanasia rather than waiting for their deaths as the endpoint” (“Humane Endpoints and Euthanasia”; see also “Humane Endpoints in Laboratory Animal Experimentation”). Similarly, the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes states that “The well-being and state of health of animals shall be observed sufficiently closely and frequently to prevent pain or avoidable suffering, distress, or lasting harm” (Article 5). Finally: “At the end of the procedure it shall be decided whether the animal shall be kept alive or killed by a humane method” (Article 11). Multiple guidelines have been developed around “humane endpoints” for fish that distinguish between slaughter, killing, and euthanasia (AVMA; Yanong).

Because of the central role of veterinarians in the arenas of animal health and welfare, the AVMA Guide has become the foundational normative guideline regarding many species and scenarios that require euthanasia. But while the use of the AVMA Guide is

appropriate for vets working with fish species in controlled settings, they may conflict with circumstances in “the field,” and thus a different set of criteria and indications may be applied in such instances. For this reason and others, the complex network of guidelines and standards with regard to euthanasia of fish has been referred to as a “patchwork of regulations and regulatory agencies.” Critics have especially pointed to how the guidelines have “caused confusion regarding outcomes and intentions of fish slaughter, killing, or euthanasia among many professionals working with fish” (ibid., 4).

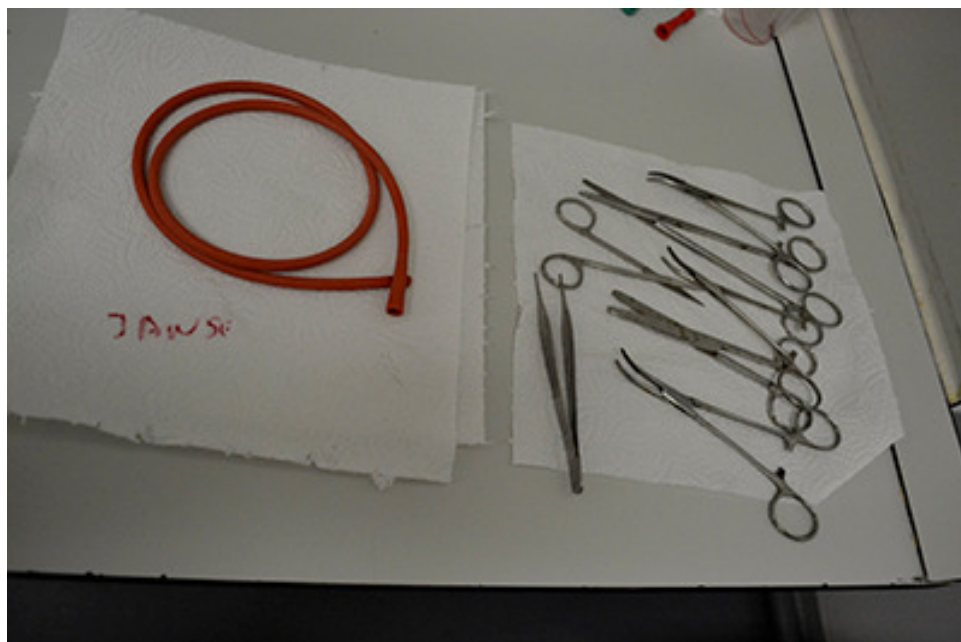


Figure 5: Surgical scissors, Lisbon Oceanarium. (Photo by author, July 10, 2018.)

Parallel to the many advancements in the field of fish and invertebrate medicine, animal rights advocates, too, have recently turned their attention to aquatic creatures, calling for the recognition of “fish rights.”

The animal rights organization PETA instructs, for example, that while the fish should not live in an aquarium but in the wild, when they end up in captivity people must resist the urge to liberate them. “Never flush fish down the toilet in the hopes of ‘freeing’ them, as seen in the popular movie *Finding Nemo*,” PETA’s website reads. “Even if a fish survived the shock of being put into the swirling fresh water, he or she would die a painful death in the plumbing system or at the water treatment plant,” the website explains (“Caring for Fish”). So in regards to the norm of not flushing fish

down the toilet, the welfare/individual rights approaches are in accord with the conservation framework (e.g., concerns about introducing invasive species of fish or novel pathogens into the wild).

But there are still myriad disagreements among the rights-welfare-conservation approaches to animal care. PETA's new campaign in Baltimore targeted the National Aquarium's display of, and Baltimore consumers' appetite for, blue crab when they posted on billboards: "I'm ME not MEAT" (McFadden; Clayton interview). Indeed, while advocates for fish rights typically oppose any type of fish consumption, aquariums and their veterinarians often promote sustainable fishing, not calling for vegetarianism altogether.

One of the veterinarians I interviewed, who preferred to remain anonymous, further emphasized the dissonances that emerge from a rights-focused thinking in the medical care for animals. In his words:

People sometimes want [to become vets] because they love animals. But I'm not sure it's the right [motivation]. They cannot see a dog or cat suffering, so they go to vet school to prevent that. What I usually say to these people [is]: Don't go to vet school. Because you won't be able to deal with some of the issues that a vet should deal with. For example: slaughter. Have you ever been to a slaughter house? This is very hard. But the veterinary work started like that — vets started as inspectors of the meat. Nowadays, you have veterinary students who say "I will not go inside that slaughter house." [But] how can you be a vet if you don't go there? This is a reflection that you are not able to face current day problems and complexities. I can't say "I will not do euthanasia." Well, it's very easy to say it, but then who will suffer more? The animal, not me! So it's easy to say that, but if you aren't able to go there and do that you won't develop these capabilities. And the big problem is that, with time, the mentality of the veterinarian profession is changing. And this is not good [for the animals].

As this veterinarian pointed out, as part of their caregiving responsibilities, zoo and aquarium veterinarians must decide upon, execute, and deal with the consequences of the very real death of the animals under their care. For this reason, he is concerned that animal rights sentiments might hinder veterinary work.

**Endpoint: Fluid Futures.** This article is an initial attempt to sketch a portrait of the modern aquarium through the eyes of its veterinarians, a small but rapidly growing, and quite influential, professional cohort. Their feet in several worlds, aquarium veterinarians must balance their medical training and animal welfare sensibilities with the specific nature of the marine animals under their care, as well as with the understanding of their increasingly important role in ocean conservation. For these professionals, the rights-welfare-conservation approaches to animal care are not abstract ideas but real-life situations that dictate their actual modes of practice in caring for marine animals. As the anonymous veterinarian told me: “these animals pay a price to be here. The price is [that] they don’t have freedom. And what we must give them in return are the best conditions possible, which they wouldn’t get in the wild, like medicine, surgery, et cetera.”

Considering the ethics of taking fish from the wild and inflicting pain on them, the article reflected upon the relationship between zoo and aquarium veterinarians and the role of the latter in light of the changing role of public aquariums. Finally, I discussed how euthanasia is practiced and secured through the standardization and regulation of the fine details of veterinary operations. The hyperlegal apparatus that has emerged around what is typically seen as the profession’s most difficult decision reveals the challenges facing the contemporary work of zoo and aquarium veterinarians and the importance of law in the medical practice of caring for animals. Arguably, the work of aquarium veterinarians ought to become its own topic of study as part of a broader contemplation of how we must care for captive marine animals and for our blue planet.

### Works Cited

Aguirre, Alonso A. et al. *Conservation Medicine: Ecological Health in Practice*. Oxford UP, 2002.

“Aquarium.” *Encyclopedia Britannica*. n.d. Accessed 24 June 2019. Online.

“AVMA Guidelines for the Euthanasia of Animals.” 2013. Accessed 24 June 2019. Online.

Bakal, Robert. Director, Animal Health and Welfare, National Aquarium, Baltimore. In-person interview, September 27, 2018, Baltimore, MD.

Balcombe, Jonathan. *What a Fish Knows: The Inner Lives of Our Underwater Cousins*. Scientific American, 2016.

Baylina, Núria, Curator and Head of Conservation, Oceanário de Lisboa. Telephone interview, November 12, 2018.

Bernardino, Rui. Zoo veterinarian, Lisbon Zoo. In-person interview, July 9, 2018. Lisbon, Portugal.

Bourke, Joanna. *The Story of Pain: From Prayer to Painkillers*. Oxford UP, 2014.

Braverman, Irus. "Captive for Life: Conserving Extinct Species through Ex Situ Breeding." *The Ethics of Captivity*. Lori Gruen, ed. Oxford UP, 2014. 193-212.

\_\_\_\_\_. "Corals in the City: Cultivating Ocean Life in the Anthropocene." *Contemporary Social Science: Journal of the Academy of Social Sciences* (Special Issue: Urban Animals: Cartographies of Radical Encounters) (forthcoming, 2019).

\_\_\_\_\_. "Saving Species, One Individual at a Time: Zoo Veterinarians Between Welfare and Conservation." *Humanimalia* 9.2 (2018): 1-27. Online.

\_\_\_\_\_. *Wild Life: The Institution of Nature*. Stanford UP, 2015.

\_\_\_\_\_. *Zooland: The Institution of Captivity*. Stanford UP, 2012.

"Caring for Fish." PETA. Accessed 24 June 2019. Online.

Clayton, Leigh. Vice President of Animal Care and Welfare, National Aquarium. In-person interview, September 27, 2018, Baltimore, MD.

Dror, Otniel E. "The Affect of Experiment: The Turn to Emotions in Anglo-American Physiology, 1900-1940." *Isis* 90.2 (1999): 205-37.

*FishBase*. 2018. Accessed 24 June 2019. Online.

Grassmann, Michael, McNeil, Bryan, and Jim Warton. "Chapter Four — Sharks in Captivity: The Role of Husbandry, Breeding, Education, and Citizen Science in Shark Conservation." *Advances in Marine Biology* 78 (2017): 89-119.



Gunther, Mark. 2018. "Fish Are Getting Their Animal Rights Moment." *Civil Eats* January 18, 2018. Accessed 24 June 2019. Online.

"The History of the Aquarium." *ZSL*. Accessed 24 June 2019. Online.

"Humane Endpoints and Euthanasia." *USDA. Animal Welfare Information Center*. n.d. Accessed 24 June 2019. Online.

"Humane Endpoints in Laboratory Animal Experimentation." *Humane Endpoints*, n.d. Accessed 24 June 2019. Online.

"Is There Really a Difference Between Wild-Caught and Aquacultured Marine Aquarium Livestock?" *Algae Barn*. Accessed 24 June 2019. Online.

Jones, Susan D. *Valuing Animals: Veterinarians and Their Patients in Modern America*. Johns Hopkins UP, 2003.

Jørgensen, Kasper. Team Leader, Animal Department, National Aquarium Denmark. In person. Copenhagen, Denmark. July 30, 2018.

Key, Brian. "Why Fish Do Not Feel Pain." *Animal Sentience* 2016.003. Accessed 24 June 2019. Online.

LePage, Véronique. Associate Veterinarian, Ripley's Aquarium of Canada. In-person interview, Toronto, Canada, November 22, 2018.

McFadden, David. 2018. "Marylanders Crabby Over PETA's Vegan Billboard in Baltimore." *WTHR*. August 25, 2018. Accessed 24 June 2019. Online.

Moscoco, Javier. *Pain: A Cultural History*, Palgrave Macmillan, 2012.

Neal, Leah, former Director of Husbandry, Ripley's Aquarium of Canada. Skype interview, January 16, 2018.

"Ocean Conservation." *AZA*. Accessed 24 June 2019. Online.

Parsons, Ed. Director of Husbandry, Ripley's Aquarium of Canada. In-person interview, November 22, 2018.

Pereira, Nuno Marques. Veterinarian, Oceanário de Lisboa. In-person interview, Lisbon, Portugal. July 10, 2018.

Perrin, Kathryn. Center for Zoo and Wild Animal Health, Copenhagen Zoo. In-person interview, July 30, 2018, Copenhagen, Denmark.

Ridgway, Sam H. "History of Veterinary Medicine and Marine Mammals: A Personal Perspective." *Aquatic Mammals* 34.4 (2008.): 471-513.

Ridgway, Sam H., Norris S. Kenneth, and Lanny H. Cornell. "Some Considerations for Those Wishing to Propagate Platanistoid Dolphins." *Biology and Conservation of River Dolphins*. Robert Brownell, W.F. Perrin, Kaiya Zhou and Jiankang Liu, eds. IUCN Species Survival Commission Occasional Papers (no. 3.), 1989. 159-167.

Rose, J. D., Arlinghaus, R., Cooke, S. J., Diggles, B. K., Sawynok, W., Stevens, E. D., & Wynne, C. "Can fish really feel pain?" *Fish and Fisheries* 15.1 (2014): 97-133.

Safina, Carl. "Are We Wrong to Assume Fish Can't Feel Pain?" *The Guardian*, October 30, 2018. Accessed 24 June 2019. Online.

Shmuelly, Shira. "Law and the Laboratory: The British Vivisection Inspectorate in the 1890s" (under review, cited with permission).

Stokstad, Eric. "New Hope for an Endangered Fish in Madagascar." *Science Magazine*. December 13, 2013. Accessed 24 June 2019. Online.

Schweig, Sarah H. "Finally: Aquarium Will No Longer Capture Dolphins and Whales from the Wild." *The Dodo*. 3 June 2016. Accessed 24 June 2019. Online.

Tlusty, Michael & Andy Rhyne. Director of Ocean Sustainability Science at the New England Aquarium and Research Scientist, New England Aquarium. In-person interview, May 11, 2016, Boston, MA.

Travis, Alexander J. "Domestic Dogs, Gene Repair, and the 'One Health' Approach." *Gene Editing, Law, and the Environment: Life Beyond the Human*. Irus Braverman, ed. Routledge, 2017. 153-168.

Wailoo, Keith. *Pain: A Political History*. Johns Hopkins UP, 2014.

Weber, Sam. "Why Can't Captive Breeding of Saltwater Aquarium Fish Catch On?" *PBS* February 15, 2015. Accessed 6 August 2019. Online.

Yanong, Roy PE et al. "Fish Slaughter, Killing, and Euthanasia: A Review of Major Published U.S. Guidance Documents and General Considerations of Methods." University of Florida IFAS, 2007.

The AVMA Guidelines for the Euthanasia of Animals can be accessed at <https://www.avma.org/KB/Policies/Documents/euthanasia.pdf>. Appendix 2: "Some of the acceptable agents and methods of euthanasia" appears on pp. 100-101, and Appendix 3: "Some of the unacceptable agents and methods of euthanasia" appears on p. 102. Both are copied below.

## Appendix 2

Some acceptable\* agents and methods of euthanasia.

Agent	Classification	Mode of action	Rapidity†	Ease of performance	Safety for personnel	Species suitability	Efficacy and comments	Conditions
Barbiturates	Hypoxia and cardiac arrest attributable to depression of the CNS	Depression of the CNS in descending order; loss of consciousness progressing to anesthesia, apnea, and cardiac arrest	Rapid onset of anesthesia	IV injection is necessary for best results and requires trained personnel; each animal must be appropriately restrained	Safe except human abuse potential; DEA-controlled substance	Most species, excluding aquatic invertebrates	Highly effective when appropriately administered; when an IV injection would be distressful, dangerous, or difficult due to small patient size, barbiturates may be administered intraperitoneal or intracelomic (pentobarbital combination products have only been approved for IV and intracardiac administration)	Apply to the use of non-IV routes (see text)
Benzocaine hydrochloride	Hypoxia attributable to depression of vital centers	Depression of CNS and heart	Rapid, depending on dose	Easily used	Safe	Smaller finfish and amphibians	Effective but expensive	
Carbon dioxide	Respiratory acidosis and produces a reversible anesthetic state followed by hypoxia attributable to depression of vital centers	Direct depression of cerebral cortex, subcortical structures, and vital centers; direct depression of heart muscle	Moderately rapid, depending on protocol	Easily with appropriate equipment, closed container, gas source, and once protocol are established	Minimal hazard with adequate ventilation	Most birds and mammals, excluding companion animals	Effective, but time required may be prolonged in immature and neonatal animals	May be used only with those species where aversion or distress can be minimized; gradual fill method must be used; must be supplied in a precisely regulated and purified form without contaminants or adulterants, typically from a commercially supplied cylinder or tank; an appropriate pressure-reducing regulator and flow meter or equivalent equipment must be used
Carbon monoxide	Hypoxemia	Combines with hemoglobin and blocks uptake of O <sub>2</sub>	Moderate onset time, but insidious so that most animal species are unaware of onset	Requires appropriately maintained equipment	Extremely hazardous, toxic, explosive in high concentrations, and difficult to detect	Most small species, excluding companion animals	Effective	Acceptable only when equipment is properly designed and operated
Cervical dislocation	Hypoxia	Direct depression of brain and cardiac fibrillation	Variable	Personnel must be skilled	Safe	Small birds, poultry, mice, immature rats (< 200 g), and rabbits	Variable	Must meet a performance standard of luxation of the cervical vertebrae without primary crushing of the vertebrae and spinal cord—inducing very rapid unconsciousness
Decapitation	Hypoxia due to disruption of vital centers	Direct depression of brain	Rapid	Requires training and skill	Guillotine poses potential employee-injury hazard	Laboratory rodents; small rabbits; poultry and birds; and some finfish, amphibians, and reptiles	Irreversible; violent muscle contraction can occur after decapitation	A commercially available guillotine should be used if available for the species and application. In lieu of this, a sharp knife and accurate placement are required.
Electrocution	Hypoxia	Direct depression of brain and cardiac fibrillation	Can be rapid	Not easily performed in all instances; requires specialist equipment and skilled application	May be hazardous to personnel	Used primarily in sheep, swine, ruminants, and other animals > 5 kg		Current must pass through the brain, and cardiac fibrillation must never occur before the animal is rendered unconscious; electroimmobilization is unacceptable; use of household electrical cords is unacceptable
Gunshot	Physical damage to brain	Direct concussion of brain tissue	Immediate	Requires skill and appropriate firearm	May be dangerous; aesthetically unpleasant for many	Large domestic and selected nondomestic species	Instant loss of consciousness, but motor activity may continue	Personnel must be trained in the use of firearms; only in jurisdictions that allow for legal firearm use; safety of personnel, the public, and other animals that are nearby should be considered

### Appendix 3

Some agents and methods that are unacceptable as primary methods of euthanasia.

Agent or method	Comments
Air embolism	Air embolism may be accompanied by convulsions, opisthotonos, and vocalization. If used, it should be done only in anesthetized animals.
Burning	Chemical or thermal burning of an animal is not an acceptable method of euthanasia.
Chloral hydrate	Unacceptable.
Chloroform	Chloroform is a known hepatotoxin and suspected carcinogen and, therefore, is extremely hazardous to personnel.
Cyanide	Cyanide poses an extreme danger to personnel and the manner of death is aesthetically objectionable.
Decompression (excluding low-atmospheric-pressure stunning when it can be demonstrated that it achieves euthanasia)	Decompression is unacceptable for euthanasia because of numerous disadvantages. (1) Many chambers are designed to produce decompression at a rate 15–60 times as fast as the recommended optimum for animals, resulting in pain and distress attributable to expanding gases trapped in body cavities. (2) Immature animals are tolerant of hypoxia, and longer periods of decompression are required before respiration ceases. (3) Accidental recompression, with recovery of injured animals, can occur. (4) Bleeding, vomiting, convulsions, urination, and defecation, which are aesthetically unpleasant, may develop in unconscious animals.
Diethyl ether	Diethyl ether is irritating, flammable, and explosive. Explosions have occurred when animals, euthanatized with ether, were placed in a non-explosion-proof refrigerator or freezer and when bagged animals were placed in an incinerator.
Drowning	Drowning is not a means of euthanasia and is inhumane.
Exsanguination	Because of the anxiety associated with extreme hypovolemia, exsanguination as a sole method of killing should be used only on unconscious animals.
Formaldehyde	Direct immersion of an animal into formalin, as a means of euthanasia, is inhumane with the exception of Porifera.
Household products and solvents	Acetone, cleaning agents, quaternary compounds (including CCl <sub>4</sub> ), laxatives, pesticides, dimethylketone, quaternary ammonium products, antacids, and other toxicants not specifically designed for therapeutic or euthanasia use are not acceptable.
Hypothermia	Hypothermia is not an appropriate method of euthanasia.
Magnesium sulfate, potassium chloride, and neuromuscular blocking agents	Unacceptable for use as euthanasia agents in conscious vertebrate animals.
Manually applied blunt force trauma to the head	Generally unacceptable for most species excluding piglets and small laboratory animals. Replace, as much as possible, manually applied blunt force trauma to the head with alternate methods.
Nonpenetrating captive bolt	Unacceptable excluding purpose-built pneumatic nonpenetrating captive bolt guns used on suckling pigs, neonatal ruminants, and turkeys.
Neuromuscular blocking agents (nicotine, magnesium sulfate, potassium chloride, and all curariform agents)	When used alone, these drugs all cause respiratory arrest before loss of consciousness, so the animal may perceive pain and distress after it is immobilized.
Rapid freezing	Rapid freezing as a sole means of euthanasia is not considered to be humane with the exception of reptiles and amphibians and < 5-day-old altricial rodents. In all other cases animals should be rendered dead or unconscious prior to freezing. (Rapid chilling of finfish is not considered to be rapid freezing.)
Smothering	Smothering of chicks or poults in bags or containers is not acceptable.
Strychnine	Strychnine causes violent convulsions and painful muscle contractions.
Thoracic compression	Not acceptable for use on a conscious animal.