

Perspectives

Seafood in the Future: Bivalves Are Better

by Jennifer Jacquet, Jeff Sebo, and Max Elder



Photo by Jason Wishnow. Prepared by Chef Or'el Anbar

(Left to right): Kumamoto oysters, East Coast oyster (Riptide), Belon oyster, cockles, Topneck clam, East Coast oyster (Plymouth Rock), and PEI mussels.

The first animals we domesticated for food were sheep, around 9000 years ago, followed soon after by goats, cows, and pigs, and then, as recent as 2000 years ago, chickens. As human population expanded rapidly, these animals became part of a highly industrialized food system that destroys habitat, pollutes, and is unsustainable.

Now, humans are making similar mistakes in water that we made on land.

We are currently witnessing the fastest and most poorly thought out expansion of domesticated animals ever to occur—the expanding domestication of aquatic animals. Nearly 190 different countries now raise around 550 different aquatic animal species for human consumption.

Aquaculture—the farming of aquatic animals and plants for food—is the fastest growing food production system in the world. But it is growing in the wrong way. We are farming carnivores, like salmon,

that need us to catch additional fish to feed them, which is putting additional pressure on wild ecosystems. We are also completely ignoring welfare concerns.

If done correctly, aquaculture could provide sustenance for our growing planet as well as reduce overfishing. But if we want to avoid repeating the same mistakes, we need to make changes now, including changing our diets generally to include more plants and fewer animals, and eating more bivalves—oysters, mussels, and clams—instead of fish, shrimps, and octopus.

We argue here for an expanded evaluation of aquaculture that would consider the industry's broad range of ecological, social, and animal welfare impacts. If these issues were taken into consideration, we would make different decisions about whether or not we should domesticate and farm aquatic animals at all and, if we do, which species we should prioritize.

In 1974, farmed aquatic life only accounted for seven percent of the officially reported quantity of aquatic animals eaten each year. The remainder was caught in the wild. However, today, farmed aquatic animals represent roughly half of what we eat each year. That's over 60 million tons, excluding aquatic plants such as seaweed.

While 253 aquatic animal species were farmed in 1986, by 2014 that number had more than doubled to 543 aquatic animal species, almost two-thirds of which are fish, that is, vertebrates (Table 1).¹

Nearly 90 percent of aquaculture occurs in Asia (with China reporting over half of global production). A little more than two-thirds of aquaculture occurs in freshwater, while the remainder is farmed at sea (Table 1). The rates of domestication are occurring most rapidly for marine species.

For some species in some markets, farming, rather than fishing, now provides the vast majority of

Perspectives

Species Group	Number of species	Mariculture (million tons)	Freshwater (million tons)	Total (million tons)
Finfishes	362	6.30	43.56	49.86
Mollusks (including bivalves)	104	15.84	0.28	16.11
Crustaceans	62	4.17	2.74	6.92
Other invertebrates	9	0.37	0.52	0.89
Amphibians and reptiles	6			
Total	543	26.68	47.10	73.78

Source: The State of World Fisheries and Aquaculture 2016 (Food and Agriculture Organization of the United Nations, Rome, 2016).

Table 1. Number and tonnage of aquatic animal species under cultivation by species group (2014)

animals. Farmed Atlantic salmon, for instance, represents more than 99 percent of Atlantic salmon on the market (and two-thirds of all salmon), while farmed marine shrimps contribute to 55 percent of the total world market.

Domestication is “a long and endless process that is in its infancy for most farmed fish species.”² Society needs to take advantage of this infancy by seriously considering a wider range of criteria for aquaculture.

Ecology

The ecological concerns associated with intensified aquaculture have received the greatest amount of research and scrutiny.

Aquaculture as it currently exists adds to the exploitation of wild fish, as additional fish must be caught to feed many of the farmed animals.³

Farming carnivorous fish (e.g., salmon, seabream, and tuna), omnivorous fish (e.g., tilapia and catfish), and certain crustaceans (e.g., shrimp) requires catching more fish to use for feed and oils.

The aquaculture industry has tried to reduce the amount of wild fish and oils in feed, but the problem is far from solved.⁴ While about one-third of global fishmeal production in 2012 was obtained from the trimmings and other residues from seafood processing,⁵ the remainder has come from capture fisheries. An estimated 27 percent of the global marine fish catch each year goes to feeding farmed aquatic species.⁶ The ‘forage’ species (e.g., sardines, anchovies, and krill) that are caught for feed are not the only group affected—species that depend on these forage fish in the wild, such as seabirds, marine mammals, and larger finfish, are now competing with aquaculture for their food supply.^{7,8}

Scientists have been calling for aquaculture to focus on species lower on the food web that require little to no feed (e.g., freshwater carps, bivalves, and aquatic plants) for more than 35 years, and there is widespread scientific agreement that aquaculture, among other things, must reduce its reliance on capture fisheries for feed.^{4,9-11} In stark contrast

to widespread scientific agreement and recommendations, the percentage of fed farmed aquatic species has actually increased since the 1980s,¹² in part due to perverse market incentives, such as cheap feed. Aquaculture in the Mediterranean, for instance, has shifted toward higher trophic level species that require more, not less, fish feed.¹³ The trend is similar globally, with fed species accounting for an even greater percentage of production.⁵

The issue of the dependence of farmed aquatic species on wild aquatic food is just one of many ecological concerns. The Global Aquaculture Performance Index (GAPI) assesses finfish aquaculture across ten ecological criteria.¹⁴ In addition to the reliance on captured fish, other criteria include the sustainability of the feed, amount of energy farmed fish divert from marine ecosystems, antibiotics use, the use of chemicals, waste contamination (e.g., nitrogen, phosphorous; the pollution from finfish aquaculture in China has contributed to the poor state of coral reefs),¹⁵ farm escapees (which can



Photo by Jason Wishnow. Prepared by Chef Or'el Anbar

(Left to right): East Coast oyster (North Haven) with grape, Manzanilla sherry, and Fresno foam; East Coast oyster (Riptide) with stone ground mustard cocktail sauce; and Belon oyster with cucumber salad and celery chili mignonette.

interbreed, outcompete, or transfer parasites to native fish species),¹⁶ industrial energy demands, and an estimate of the pathogen rate on farms. The GAPI index is only for finfish, but there are also ecological concerns related to invertebrate farming, such as saltwater intrusion, sedimentation, pollution, disease outbreaks, and habitat loss. A recent study, for instance, compared satellite imagery from the mid-1970s to images from the present to estimate that commercial shrimp farming has led to a 28 percent decline in mangrove cover in Indonesia, Brazil, India, Bangladesh, China, Thailand, Vietnam, and Ecuador.¹⁷

This is by no means intended as a comprehensive list of the ecological impacts with aquaculture but does demonstrate the growing body of research and concern.

Food Security

In addition to the ecological impacts, aquaculture also raises social concerns, ranging from public health issues such as antimicrobial resistance

(especially common in shrimp cultivation) to human rights issues such as forced labor (also common in shrimp farming), particularly in developing countries.¹⁸ Some of these issues are dictated less by the species being farmed (although admittedly some species are more suitable for certain regions of the world) than by policy and governance. One social concern that has a strong relationship with the species under cultivation is food security.

Aquaculture is often touted as a solution to food insecurity, which is used as justification for continued growth and intensification in the sector. However, aquaculture's net effect on food security is unclear. The United Nations Food and Agriculture Organization (FAO), the international organization mandated to collect global statistics on food production, states that "at present little or no hard statistical information exists concerning the scale and extent of rural or small-scale aquaculture development within most developing countries."¹⁹

While aquaculture undoubtedly plays a role in food security in certain areas of the world, in some cases its food security benefits are greatly exaggerated. For example, the International Salmon Farmers Association released a 2015 report titled, "Salmon Farming: Sustaining Communities and Feeding the World." In reality, most salmon farmed in Scotland stays in UK markets.²⁰ Similarly, the British Columbia Salmon Farmers claim on their website that, "B.C. farm-raised salmon is the right choice for sustainability, food security, and our oceans." But salmon farmed in British Columbia is a luxury food destined mainly for the food-secure markets of the EU, Japan, and North America.²¹

Not only is farmed salmon sold to a food-secure market, but, due to its reliance on fish feed, farming salmon is also potentially exacerbating food insecurity by relying heavily on captured fish, which are often caught in developing countries (the largest fishery in the world is the Peruvian anchovy fishery, and most of the anchovies there are



Photo by Jason Wishnow. Prepared by Chef Or'el Anbar

(Clockwise from toast): Topneck clam shell; Kumamoto oyster with preserved lemon and shallot mignonette; Kumamoto oyster shell; East Coast oyster (North Haven) with stone ground mustard cocktail sauce; East Coast oyster (Riptide) with grape, Manzanilla sherry, and Fresno foam; Belon oyster with cucumber salad and celery chili mignonette; East Coast oyster (Plymouth Rock) shell; Topneck clam with white asparagus in yuzu kosho beurre fondu; East Coast oyster (Riptide) top shell; Cockles with white wine, tomatillo, and pearl tomato; East coast oyster (North Haven) shell; and PEI mussels with Gochujang Korean chili sauce and burnt Meyer lemon.

turned into fishmeal) and could instead be eaten by humans directly. The UN FAO Code of Conduct for Responsible Fisheries (Article II) advises that capture fisheries “promote the contribution of fisheries to food security and food quality, giving priority to the nutritional needs of local communities.”²² Under these FAO standards, the practice of feeding forage fish to farmed animals is clearly irresponsible.

Aquaculture production that truly considers food security would be concerned not only with the end use of the animals but also with the compromises to food security that occur when raising these species. As with environmental concerns, the conclusion is that we should not be farming species that rely on captured fish for feed.

Animal Welfare

Finally, aquaculture raises animal welfare concerns, which are commonly discussed in the case of terrestrial animal farming but almost never discussed in the case of aquaculture.

One important area of research is whether and to what degree fish and aquatic invertebrates experience pain and suffering. Over the past 15 years, scientific evidence has revealed that vertebrate species including fish do experience pain and suffering.²³ (Examining why so many people have assumed otherwise would require a much longer essay.) For example, many fish (e.g., trout, cod, carp, goldfish, and salmon) respond to harmful stimuli both behaviorally as well as physiologically, for instance, with increased heart rates, increased breathing rates, suppression of hunger, and a loss of focus on other aims, and there is strong reason to believe that these findings will generalize.²⁴ Granted, there are expected variations among fish species. Evidence for feeling pain is most robust for bony fish (and

thinner for cartilaginous fish). Fish are not the only vertebrate species under cultivation—soft-shell turtle farming, for instance, is also on the rise.¹² Still, at this point, we can be confident that most if not all of the farmed vertebrate aquatic species do experience pain and suffering as a general matter.

There is less certainty about invertebrate aquatic species since they are behaviorally, physiologically, and evolutionarily distinct from vertebrates. Many aquatic animals, vertebrates and invertebrates alike, react to helpful and harmful stimuli, exhibit withdrawal behavior, and suspension of normal behavior in favor of behavior that enhances protection and healing.²³ However, scientists have not yet identified pain receptors in groups such as crustaceans (e.g., shrimps) or even researched this question much at all in groups such as echinoderms (the farming of sea cucumbers, which are echinoderms, is also on the rise).¹²

Meanwhile, mollusks (a large phylum of invertebrates that includes cephalopods and bivalves) are a highly diverse group, members of which likely have highly diverse experiences. On one end of this spectrum, cephalopods (e.g., octopuses) perform exceptional behaviors and possess highly developed brains and nervous systems, to the extent that some people even refer to them as “honorary vertebrates.” In a review paper on pain in mollusks, for example, Crook and Walters state, “one must seriously consider the possibility that cephalopods can experience some form of pain.”²⁵ On the other end of this spectrum, bivalves (e.g., oysters, mussels, and clams) seem to be considerably less complex, though they do show some behavioral and physiological responses to harmful stimuli (e.g., escape swimming in scallops).

In addition to asking whether and to what degree aquatic animals are

likely to experience pain and suffering in general, another issue is whether and to what degree these species are likely to experience pain and suffering under cultivation in particular. As with terrestrial animal agriculture, we should raise animal welfare concerns at every step of the process, including but not limited to breeding, growth, rearing (especially related to species density and mobility), capture, handling, transport, and slaughter. The current scientific understanding is that the welfare concerns raised by these activities are likely to be much more acute for vertebrates and invertebrates such as cephalopods than for invertebrates such as bivalves, given that vertebrates and cephalopods have much more need for space and enrichment than bivalves do.²⁶ In addition, welfare concerns will be greater for motile, migratory animals like salmon than for sessile animals like mussels. This is not to say that no welfare concerns exist for bivalves or sessile animals. But it is to say that there are fewer welfare concerns about these species groups than about others, especially in conditions of captivity.

Any complete examination of aquaculture practices must take these considerations into account. Yet, the FAO Code of Conduct for Responsible Fisheries,²² which has a large section on aquaculture including a long list of ecological considerations, makes no mention of animal welfare. FAO does not publish the numbers of individual aquatic animals slaughtered annually, as they do with mammals and birds.⁵ Similarly, FAO hosts a participatory website dedicated to farmed animal welfare,²⁷ but aquatic species receive only marginal representation. Animal welfare should become a much bigger part of the aquaculture discussion, and FAO could be one of the many organizations to assist in facilitating this discussion.

The Solution?

Current industrial animal farming practices are designed to maximize economic benefits, with significant costs for the environment, food security, and animal welfare (among other negative impacts). Industrial aquaculture poses many of the same risks as terrestrial animal agriculture, yet because this industry is still in its early days, humans have an opportunity to chart a different, more responsible course.²⁸ It is imperative that we take advantage of this opportunity by questioning, right now, whether or not we should be farming aquatic animal species at all and, if so, which ones.

Based on the criteria we discussed here—environmental impacts, food security, and animal welfare—what would an ideal species group look like? Quite simply: plant species. Assuming, however, that we insist on farming aquatic animals, then the answer becomes species that are as plant-like as possible. It should be a species group that does not require fish feed, does not require conversion of habitat, does not contribute to pollution, and has very little potential to be invasive. It should consist of animals who are either not likely to experience pain and suffering at all, or not likely to experience significant pain and suffering in captivity in particular—animals whose health and well-being is at least somewhat compatible with industrial methods.

In general, non-fed invertebrates are likely better than fed invertebrates or any vertebrates. Of all the aquatic animal species groups that we eat as food, bivalves appear to be the most promising in terms of minimizing ecological harm (in some cases they may even be beneficial), minimizing food security harm (as highly nutritious organisms that do not rely on outside food sources), and minimizing animal welfare concerns related to captive rearing.

Bivalve farming is not free from ecological and welfare issues. Ecological impacts are already documented in some places (e.g., some bivalve species can become invasive). In terms of welfare, granting bivalves the ability to experience pain errs on the side of caution. However, even assuming they do experience pain, they are still likely to experience less pain in captivity than other, more active animals. Yet, despite bivalves being the species group with the most promise, and the fact that their absolute numbers keep increasing, they make up less and less of total aquaculture. Bivalves accounted for almost half of global aquaculture in the 1980s, but due to the explosion in finfish farming now account for only around 30 percent.^{5,12} This is precisely the wrong trend if we want animal aquaculture to lead to a more food secure, sustainable, and humane future. **S**

REFERENCES

- Mood, A & Brooke, P. Estimating the number of farmed fish killed in global aquaculture each year. Fishcount.org [online] (2012). <http://fishcount.org.uk/published/std/fishcountstudy2.pdf>.
- Teletchea, F & Fontaine, P. Levels of domestication in fish: implications for the sustainable future of aquaculture. *Fish and Fisheries* 15, 181–195 (2014).
- Naylor, RL et al. Effect of aquaculture on world fish supplies. *Nature* 405, 1017–1024 (2000).
- Naylor, RL et al. Feeding aquaculture in an era of finite resources. *Proceedings of the National Academy of Sciences* 106, 15103–15110 (2009).
- The State of World Fisheries and Aquaculture 2016. Food and Agriculture Organization of the United Nations [online] (2016). <http://www.fao.org/3/a-i5555e.pdf>.
- Alder, J, Campbell, B, Karpouzi, V, Kaschner, K & Pauly, D. Forage fish: from ecosystems to markets. *Annual Review of Environment and Resources* 33, 153–166 (2008).
- Cury, PM et al. Global seabird response to forage fish depletion—one-third for the birds. *Science* 334, 1703–1706 (2011).
- Piroddi, C, Bearzi, G & Christensen, V. Marine open cage aquaculture in the eastern Mediterranean Sea: a new trophic resource for bottlenose dolphins. *Marine Ecology Progress Series* 440, 255–266 (2011).
- Ackefors, H & Rosén, CG. Farming aquatic animals: the emergence of a world-wide industry with profound ecological consequences. *AMBIO* 8, 132–143 (1979).
- Diana, JS. Aquaculture production and biodiversity conservation. *BioScience* 59, 27–38 (2009).
- Duarte, CM et al. Will the oceans help feed humanity? *BioScience* 59, 967–976 (2009).
- The State of World Fisheries and Aquaculture 2012 (Food and Agriculture Organization of the United Nations, Rome, 2012). <http://www.fao.org/docrep/016/i2727e/i2727e00.htm>.
- Stergiou, KI, Tsikiliras, AC & Pauly, D. Farming up the Mediterranean food webs. *Conservation Biology* 23, 230–232 (2009).
- Volpe, JP et al. Global Aquaculture Performance Index (GAPI): The First Global Environmental Assessment of Marine Fish Farming. *Sustainability* 5, 3976–3991 (2013).
- Hughes, T, Huang, H & Young, MAL. The wicked problem of China's disappearing coral reefs. *Conservation Biology* 27, 261–269 (2012).
- Krkosek, M. Sea lice and salmon in Pacific Canada: ecology and policy. *FREE* 8, 201–209 (2010).
- Hamilton, S. Assessing the role of commercial aquaculture in displacing mangrove forest. *Bulletin of Marine Science* 89, 585–601 (2013).
- Tacon, AG. Climate change, food security and aquaculture. *Advancing the Aquaculture Agenda*, 109–119 (2010).
- Food and Agriculture Organization of the United Nations [online]. www.fao.org.
- Salmon Farming: Sustaining Communities and Feeding the World (International Salmon Farmers Association, Boston, 2015).
- BC Salmon Farmers Association [online]. www.bcsalmonfarmers.ca.
- Code of Conduct for Responsible Fisheries. Food and Agriculture Organization of the United Nations [online] (1995). <http://www.fao.org/docrep/005/v9878e/v9878e00.htm>.
- Sneddon, LU. Pain in aquatic animals. *The Journal of Experimental Biology* 218, 967–976 (2015).
- Braithwaite, VA. *Do Fish Feel Pain?* (Oxford University Press, Oxford, 2010).
- Crook, RJ & Walters, ET. Nociceptive behavior and physiology of molluscs: animal welfare implications. *ILAR J*, 52, 185–195 (2011).
- Bergqvist, J & Gunnarsson, S. Finfish aquaculture: Animal welfare, the environment, and ethical implications. *Journal of Agricultural and Environmental Ethics* 26, 75–99 (2013).
- Gateway to Farm Animal Welfare. FAO [online] (2016). http://www.fao.org/ag/aginfo/themes/animal-welfare/aw-awhome/en/?no_cache=1.
- McWilliams, J. *Just Food* (Little, Brown and Company, New York, 2009).