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Making Fish Culture Sustainable

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Abstract

The challenges facing the population of fish throughout the world are critical. Overfishing, physical impediments, and the warming of the world oceans are threatening the population that includes small krill, tuna, trout, salmon, and whales. Some scientists predict that by 2050, the oceans could be fishless. Various solutions are being sought and some have been implemented that include conservation, the removal of dams on rivers, and aquaculture for ocean salmon and tuna. Aquaculture refers to the breeding, rearing, and harvesting of plants and animals in all types of water environments. Marine aquaculture refers to the culturing of species that live in the ocean. Herein, we explore the various threats to fish populations and efforts to mitigate them, especially in Japan.

INTRODUCTION

Since 1880, the National Oceanic and Atmospheric Administration's (NOAA) records show only one other instance when global temperature records were set three years in a row: in 1939, 1940 and 1941. In recent decades, however, that 1941 now ranks as the 37th-warmest year on record. The temperatures in 2016, far exceeded those of the previous two years, each setting a record for the highest world-wide in the respective year (Gillis, 2017: A8). The average temperature across global land and ocean surfaces was 1.69 Fahrenheit (.94 Centigrade) above the 20th century average. This was the highest among 137 years since records began in 1880 (Hotz, 2017: A3). The year 2014 was the warmest year on record and the past 20 years are the warmest on record. Stefan Rahmstorf, head of earth system analysis at the Potsdam Institute for Climate Impact Research in Germany, recently said "…the fact that the warmest years on record are 2014, 2010 and 2005 clearly indicates that global warming has not 'stopped in 1998,' as some like to falsely claim." And, 2015 "far eclipsed" 2014 as .29 Fahrenheit warmer and is the warmest year since records were recorded beginning in 1891. Further, eight of the world's 10 deadliest heat waves occurring since 1997 (Gillis, 2016).

The vast majority of those who study the climate say the earth is in a long-term warming trend that is profoundly threatening and caused almost entirely by human activity. They expect the heat to get much worse over coming decades, but already it is killing forests around the world, driving plants and animals to extinction, melting land ice and causing the seas to rise at an accelerating pace. The vast majority of those who study the climate say the earth is in a long-term warming trend that is profoundly threatening and caused almost entirely by human activity (Gillis, 2015).

In previous research, we have studied the role of water in sustainable development (Flynn, 2014a; 2012a), sustainable rice cultivation in Japan (Flynn, 2014b), and the role of dams in sustainable development (Flynn, 2012b). Dams and sustainable development are especially salient to the topic of sustainable fish (and other sea species) populations, i.e. sea fauna. Herein, we will focus on the bluefin tuna population in Japan, the Atlantic cod and salmon population in the United States, world fisheries in general, and the effect of dams on river and stream fisheries.

In particular, after centuries of unrestrained addiction by government officials to the pursuit of economic development through the construction of huge or super hydro-electric dams, indications are that humankind is waking up to the reality that the economic, political, social, cultural, ecological, moral and environmental costs of this technological choice seem to be consistently outstripping its benefits. To many people, big dams have instead become a nightmare. Nevertheless, more and more superior huge dams continue to be pushed by governments and financiers as the wise choice to development particularly in the poor regions of the world (Oweyegha–Afunaduula, 2000). One controversial example is the Belo Monte river dam project that is being vigorously opposed by indigenous Indian people in Brazil (Jelmayer, 2013). In particular, six indigenous groups from the Xingu, Tapajós and Teles Pires River basins are protesting the building of hydroelectric dams in their territories in the Amazon (Amazon Watch, 2013).

The Ecology of Dams

Rivers possess a delicate ecology that depends on a regular cycle of disturbance within certain tolerances. The plant and animal communities that inhabit the river and river margins have evolved to adapt to their river's own peculiar pattern of flood and drought, slow and fast current. Dams disrupt this ecology.

There are several types of dams. Check dams prevent flooding of small areas. Diversion dams divert river water to irrigate crops. Large dams may be built for flood control or electrical generation, or both. Flood control dams are often earth dams - made of huge mounds of clay, sand, gravel, and rock - but other dams are generally made of concrete. Hydroelectric dams are concrete marvels of engineering. This section will examine mostly the large dams: flood control and hydroelectric dams.

Interrupting Natural Cycles

The first effect of a dam is to alter the pattern of disturbances that the plants and animals of a river have evolved for. Many aquatic animals coordinate their reproductive cycles with annual flood seasons. Every flood is valuable in that it takes nutrients from the land and deposits them in the river, providing food for the stream's residents. Floods also provide shallow backwater areas on vegetated and shaded riversides; the young of many animals depend on these backwaters to protect them from large predators.

As an example, a fish on a certain river may only reproduce during April of every year so that its offspring will have abundant food and places to hide. If the flood never comes because a dam holds the river back (because people want the water for themselves), the offspring may be produced during a time when they cannot possibly survive. If the fish can wait until the next flood, which may be in July or may be in October, its young will be born during the wrong time of year, and will have to contend with the absence of their normal food supply and temperatures for which they are not prepared. Maintaining water flows adequate to sustain fish is a constant challenge in the American West. For example, Oregon’s Upper Deschutes River was the site of a seasonal dam release drawdown in mid-October of 2013, resulting in the death of nearly 3,000 fish (Santella, 2013:14).

Vegetation, too, depends upon these regular cycles of flood. Quite often, people will decide that they can spare no water at all and no flooding will occur. Or they may have built the dams specifically to stop flooding, so they can build houses in the floodplains. When this happens, riparian vegetation, the vegetation bordering the river, changes forever. An example of this may be found in much of the Southwest United States, where enormous floodplains of cottonwood and marsh have been replaced by dry, barren areas of tamarisk and grass.

Dams hold back not only sediment, but also debris. The life of organisms (including fish) downstream depends on the constant feeding of the river with debris. This debris includes leaves, twigs, branches, and whole trees, as well as the organic remains of dead animals. Debris not only provides food, it provides hiding places for all sizes of animals and surfaces for phytoplankton and microorganisms to grow. Without flooding and without a healthy riparian zone, this debris will be scarce. Adding to the problem, although debris might come from the river above the dam, it is instead trapped in the reservoir, and never appears downstream. The bottom level of the food web is removed. All in all, the loss of sediment and debris means the loss of both nutrients and habitat for most animals (chamisa.freeshell.org/dam.htm). Recently discovered, altering the complex biological machinery with dams and diversions, leads to the long-term decline of the ecosystem. Only recently, have scientists explored the comprehensive ecological blueprint of river dynamics (Robbins, 2016: D6). This ecological trauma has also been occurring in Malaysia on the Sungai Pahang River, the longest river on the Malaysian Peninsula where clear cutting of forests have clogged the river threatening the fish ecosystem (Boneo Post, 2016:A18).

Recently, it has been discovered that the removal of two dams on the Penobscot has resulted in more than 500 Atlantic Salmon, two million alewives, thousands of mature sea lamprey, many baby eels, dozens of white perch and brook trout. Similarly, in the Elwha River, on Washington's Olympic Peninsula engineers removed two dams from 2011 to 2014. Afterward, chinook, chum and sockeye, steelhead trout quickly moved upriver according to a research scientist at the Western Fisheries Research center of the United States Geological Survey (U.S.G.S) (Carpenter, 2016: D6).

Dams in China

Recently, the Chinese State Council has removed a crucial roadblock to building the Xiaoanhai Dam on the Yangtze River. In a little-noticed ruling made public on Dec. 14, 2011, the council approved changes to shrink the boundaries of a Yangtze River preserve that is home to many of the river's rare and endangered fish species. The decision is likely to clear the way for construction of the Xiaonanhai Dam, a $3.8 billion project that environmental experts say will flood much of the preserve and probably wipe out many species. Chinese environmental groups and the Nature Conservancy have waged a long battle against the Xiaonanhai Dam, one of 19 dams proposed or under construction on the upper reaches of the Yangtze. The dams will turn the river from a swift-running stream that drops from its source in Qinghai Province, three miles high, into a series of large, slow-moving lakes.

The projects are part of a frenetic and much-criticized rush into hydroelectric power by the Chinese government, which, with 26,000 such dams, already has more than any nation in the world. At 1,760 megawatts, the Xiaonanhai project is comparatively small by Yangtze standards, but still three-quarters the size of the Hoover Dam, Scientific American reported in 2009. Critics say the project makes little economic sense except as a temporary job creator. The reservoir will flood 18 square miles of prime farmland and displace 400,000 people, driving the cost of every kilowatt of generating capacity to $2,144 — triple that of the Three Gorges dam, according to Fan Xiao a geologist who has fought the project for years. The national reserve that critics say will be destroyed by the dam was, in fact, established to address concerns that the Three Gorges dam would endanger the fish population. Of the

Yangtze's 338 freshwater fish species, 189 live in the reserve — and many of those are found in no other river basin in China (Wines, 2011: A8).

Arguably, the Three Gorges Dam has also had some deleterious effects on the environment. As discussed previously (Flynn, 2010), a nearly blind white dolphin in China, the baiji, that survived 20 million years has been declared possibly extinct according to Robert Pitman and August Pfluger (New York Times, 2006) who completed a six week search for any surviving baiji. The expedition began on the Yangtze River from the Three Gorges damn and ended in Shanghai. However, recently, a videotape from the Yangtze River in central Anhui Province providing slim hope for the baiji's survival (New York Times, 2007a). The last sighting of this huge sturgeon was in 2003. It has been concluded that sonar that blocks the dolphins ability to find food, pollution, and over-fishing has "functionally" caused the baiji's extinction (or near). Also, importantly, the Three Gorges damn has stopped the dolphin from returning to its breeding ground in the upper Yangtze deep into the Tibetan plateau (Winchester, 1996). Further, in the upper Yangtze River, forest coverage has dropped from 30-40% in 1950 to 10% in 1998. Also, in 2002, 48.5% (approx.) of the southern Yangtze River was unsuitable for human contact (Economy, 2005). A report in China Daily cited that 370 miles and 30 percent of the Yangtze tributaries are seriously, and perhaps irreversibly, polluted. Also, the reservoir created by the Three Gorges Dam was also seriously polluted (New York Times, 2007c).

Sea Life Threatened Worldwide

"We may be sitting on a precipice of a major extinction event," according to Douglas J. McCauley, an ecologist at the University of California, Santa Barbara. He however believes that we are able to avert catastrophe - compared to continents, the oceans are mostly intact, still wild enough to bounce back to ecological health (Zimmer, 2015: A1). Some scientists, however, dourly predict that by 2050, the oceans could be fishless. There is some hope however in the planting and harvesting of sea kelp as has recently been undertaken by Bren Smith off of Stony Creek, Connecticut (Goodyear, 2015: 42-43).

Some of the challenges facing scientists include the vastness of the ocean and the difficulty of studying the well being of a species over the thousands of miles. Also, changes that scientists observe in a particular ecosystem, may not reflect trends across the planet. According to an article in Science, Dr. Pinsky and McCauley and their colleagues sought a clearer picture of the oceans' health by pulling together data from a range of sources, from discoveries in the fossil record to statistics on modern container shipping, fish catches and seabed mining. There are clear signs that humans are harming the oceans to a remarkable degree. Some oceans are overharvested, as discussed below for the cod population in the northeast United States, but even greater damage results from large-scale habitat loss. Mining operations, in particular, are poised to transform the oceans where contracts for seabed mining now cover 460,000 miles underwater. Seabed mining has the potential to tear up unique ecosystems and introduce pollution into the deep sea. Restricting industrialization of the oceans to some regions could allow threatened species to recover in other regions of the sea (Zimmer, 2015: A1 & A3). Recently, Repsol SA, a Spanish oil company, stopped its drilling 3000 meters below sea level off the coast of the Canary Islands. Even though the project was opposed by local officials and environmental groups, the Spanish courts allowed the project. However, the project was scrapped because of the lack of necessary volume and quality oil reserves (Bjork, 2015) (please see Figure # I).

Coral reefs have declined by 40 percent worldwide, partly as a result of warming as a result of climate change. Attempts have been made to restore coral reefs are being implemented as one can see in the transplanted coral reefs off of Java Island, Indonesia. Changing temperatures of the oceans are forcing fish species to migrate to cooler waters as evident by black sea bass migrating from the waters off of Virginia to New Jersey (Zimmer, 2015).

In November of 2014, regulators from the National Oceanic and Atmospheric Administration (NOAA) shut down the recreational and commercial cod fishing in the Gulf of Maine. Recent surveys revealed that cod populations are at record lows, despite decades of regulations to restore them.

As early as the 1850s, fisherman from Maine requested that the government do something about the declining stocks. Yet annual cod landings have declined from about 70,000 metric tons in 1861 to about 54,000 in 1880, to about 20,000 tons in the 1920s, to just a few thousand metric tons in recent years.

In July of 1914, the *New York Times*, ran a story "Extermination Threatens American Sea Fishes – Cost to Consumer Has Risen between 10 and 600 Per Cent Because of Decrease in Supply." Fisherman confronting declining catches developed gear that fished more intensively, taking a larger percentage of the declining population. In 1954, a fisheries economist from Boston charged fishing interests with continuing "to exploit recklessly the limited self-renewing stocks of these species." That was just before the first factory-equipped freezer-trawler arrived at he prime fishing waters around the Grand Banks of Newfoundland from Europe. Such a strategy was clearly not sustainable. Meanwhile, fisherman continued to earn enough to make fishing worthwhile however discouraging their sons to pursue other professions. The Gulf of Maine cod stocks today are probably only of fraction of 1 percent of what they were during George Washington's time.

The recent ban on cod fishing in the Gulf of Maine was an important step toward restoration, though clearly marine systems are very complex and subject to many variables. Considering that ban in light of history, however, is crucial. Historical perspectives provide a vital sense of scale for the sobering restoration challenges we face. Recently, however, a new study says that the quotas were set too high because the effect of an increasingly warming ocean was not taken into account and cod stocks have not recovered. From 2004 to 2014, the temperature of the waters in the Gulf of Maine rose faster than 99.9 percent of the global ocean. Some scientists argue that the decline on cod stocks has occurred because the building of dams has reduced the availability of prey and the disappearance of traditional spawning sites from overfishing in those areas (Goode, 2015). Another important agreement has been made in July of 2015 by the five nations (Norway, Canada, Denmark (on the behalf or its territory of Greenland), Russia and the United States that border the Arctic Ocean pledged to prohibit commercial fishing in the international waters of the Artic until more scientific research could be done on how warming seas and melting ice are affecting fish stocks (Myers, 2015: A6).

The fisheries story, however, also provides a heading into the future, revealing as it does the tragic consequences of decision makers' unwillingness to steer a precautionary course in the face of environmental uncertainties. At every step of the way, decisions could have been made to exploit fish stocks more sustainably (Bolster, 2015) (please see Figure # II).

Another Atlantic fish, the salmon, has received some encouraging news with the approval of genetically engineered salmon by AquaBounty Technologies in Panama. However, at present, the facility has the capacity to produce 100 tons of salmon a year, far below the 200,000 tons of Atlantic salmon imported each year. There are plans to open other facilities in Canada and the United States. The so-called AquAdvantage salmon "contains a growth hormone gene from the Chinook salmon and a genetic switch from the ocean pout, an eel-like creature , that keeps the transplanted gene continuously active, whereas the slamon's own growth hormone is active only parts of the year. The company has said the fish can grow to market weight in 18 to 20 months, compared to 28-36 months for conventionally farmed salmon." (Pollack, 2015: A3).

Fish Culture in Japan

Tokyo's first fish market began life a few miles north of Tsukiji about 400 years ago on a spot next to the original Edo castle (long since razed), and close to Nihonbashi Bridge in today's business district. Fish not consumed by the castle were sold on the streets here, and this is where Edomae-style sushi, now beloved around the world, first evolved. Several Tsukiji companies can trace their histories to this original market, which was lost to the Great Kanto earthquake of 1923. Tsukiji replaced it, opening in 1935.

More than 2,000 tons of seafood pass through Tsukiji's 80-year-old halls every day (Booth, 2014).

The world's biggest wholesale fish and seafood market, Tsukiji, located in central Tokyo, is to move to a new location in two years (please see Figure # III). The 431 billion yen ($4 billion) transfer to more current facilities will free up valuable Tokyo seaside real estate and allow a modernization plan for the site. Among those reportedly eyeing the real estate, after the wholesale fish market is torn down, are resort builders and casino operators who want to build up the spot in time for the 2020 Tokyo Olympics.

Tsukiji, owned by the Tokyo Metropolitan Government, is currently sandwiched between the Sumida River and the expensive Ginza shopping district. Truckloads of fresh products from all over the world arrive as early as 3 in the morning, within easy reach of wholesalers, food processing firms and large retail chains. The market handles hundreds of varieties of seafood from sea urchin to caviar to baby sardines, all weighing some 700,000 metric tons a year. About $20 million worth of seafood and other produce is traded in the market on an average day. Among the daily highlights is the auction of the prized, sashimi-grade tuna whose prices hit a new peak each January. Last year a single bluefin tuna sold for a record $1.7 million. The buyer of the 222 kg (489 lbs.) fish was Kiyoshi Kimura, owner of a Tokyo-based sushi restaurant chain.

The market which has occupied prime real estate in its current site in the heart of Tokyo for eight decades is slated to move to Toyosu, a mile-and-a-half away. Construction of the new set of buildings was to be completed by March 2016. The new space will be nearly twice as big, a more sanitary facility with temperature-controlled buildings, cold chain and processing infrastructure and ample parking for transport vehicles. It will have expressway access. The move has been slowed due to environmental concerns at the former site of a gas plant. It may even affect the plan for a new highway to be built through the original location (Obe, 2016).

Yet, it is a controversial move for more reasons than one. The move has run into trouble. The new location across the river is a parcel of reclaimed land which used to house a gas plant and is said to be heavily polluted, requiring a major cleanup. That is expected to further inflate relocation costs.

Some of Tsukiji's unionized traders have organized protests and are fighting what they call a move to satisfy the greed of real estate developers. A string of lawsuits also questions the move to a site containing toxic materials. Besides, the traders will also have to pay higher rents at the new site.

But the Tokyo government calls the move a 'market need' and lists one main reason: most of the buildings are past their durability period. The market was built to suit railway transportation but since the commodities arrive mainly by trucks, the parking space and traffic congestion are serious problems. The open structure of the market does not lend itself to modern storage facilities. Acknowledging that the transition may be less than smooth, the government said in a written note that the opening of the new Toyosu market will be fixed after discussions with all the "people concerned" (Forbes, 2014).

Japan's Tuna Crisis

A shortage of tuna, discussed in more detail earlier (Flynn, 2015), is forcing Japanese chefs to start using substitutes in sushi and sashimi — cheaper fish, even avocado rolls. The real issue is not the deprivation of Japanese taste buds but the decline of the tuna population. Along with sharks and other ocean-dwelling species, tuna have been in free fall for decades, in part from rapacious overfishing by big industrial fleets, of which Japan's is by far the most aggressive.

Obviously, rising consumption is also to blame. And the Japanese — whose per capita fish consumption is the largest among industrialized nations — are right to point out that the appetite for sushi and sashimi has rocketed in the United States and in increasingly affluent countries like Russia and China.

The primary answer is a system of global discipline. With that in mind, an international commission representing dozens of fishing nations, agreed last year to a 20 percent reduction in annual tuna catches in the eastern Atlantic and the Mediterranean. This only made the Japanese more nervous, though in fact they, should be asking for stricter measures.

Ellen Pikitch, director of the Pew Institute for Ocean Science, and other experts believe that the new limits may not be tough enough to prevent commercial extinction of the much-prized Atlantic bluefin tuna. Ms. Pikitch also points out that in any case illegal and unreported fishing will push actual catches well above those levels causing one-third of the world's fish stock were overexploited. Recently, Secretary of State, John Kerry, said that the biggest challenge to protecting the world's oceans is enforcement, although declaring off-limits to commercial activity may also help. Chile has recently announced their intention to cordon off more than 200,000 square miles of the Pacific Ocean near Easter Island from commercial fishing and oil exploration (Urbina, 2015: A7).

Recognized close to ten years ago, Japan's sushi crisis may be just the wake-up call for both the consuming public and the regulators (New York Times, 2007b).

Japan's Scientists Respond to the Crisis

At least two large-scale scientific attempts at raising bluefin tuna in controlled environments are presently in process at the Seikai National Fisheries Research Institute (Nagano, 2013) and Osaka's Kinki University (Hayashi, 2014). The material that is discussed below was gleaned largely from these two sources, unless otherwise noted.

Tokihiko Okada, a researcher at Osaka's Kinki University, received an urgent call from a Tokyo department store that needed sashimi. Instead of needing to go fishing, he relayed the message to a diver who plunged into a round pen with an electric harpoon and stunned an 88-pound Pacific bluefin tuna, raised from birth in captivity. It was pulled out and slaughtered immediately on the boat.

With a decades long global consumption boom depleting natural fish populations of all kinds, demand is increasingly being met by farm-grown seafood. In 2012, farmed fish accounted for a record 42.2% of global output, compared with 13.4% in 1990 and 25.7% in 2000. A full 56% of global shrimp consumption now comes from farms, mostly in Southeast Asia and China. Oysters are started in hatcheries and then seeded in ocean beds. Atlantic salmon farming, which only started in earnest in the mid-1980s, now accounts for 99% of world-wide production—so much so that it has drawn criticism for polluting local water systems and spreading diseases to wild fish.

Until recently, the Pacific bluefin tuna defied this sort of domestication. The bluefin can weigh as much as 900 pounds and barrels through the seas at up to 30 miles an hour. Over a month, it may roam thousands of miles of the Pacific. The massive creature is also moody, easily disturbed by light, noise or subtle changes in the water temperature. It hurtles through the water in a straight line, making it prone to fatal collisions in captivity.

The Japanese treasure the fish's rich red meat so much that they call it "hon-maguro" or "true tuna." At an auction in Tokyo, a single bluefin once sold for $1.5 million, or $3,000 a pound. All this has put the wild Pacific bluefin tuna in a perilous state. Stocks today are less than one-fifth of their peak in the early 1960s, around the time Japanese industrial freezer ships began prowling the oceans, according to an estimate by an international governmental committee monitoring tuna fishing in the Pacific. The wild population is now estimated by that committee at 44,848 tons, or roughly nine million fish, down nearly 50% in the past decade.

The decline has been exacerbated by earlier efforts to cultivate tuna. Fishermen often catch juvenile fish in the wild that are then raised to adulthood in pens. The practice cuts short the breeding cycle by removing much of the next generation from the seas.
Net pens, originally developed by Teruo Hara in the 1950s. The pens improved the efficiency of fish farming dramatically compared with the preceding era, when fish were kept in much larger spaces in the bay created by simple partitions.

Scientists at Kinki University decided to take a different approach. Kinki began studying aquaculture after World War II in an effort to ease food shortages. Under the motto "Till the Ocean," researchers built expertise in breeding fish popular in the Japanese diet such as flounder and amberjack.

In 1969, long before the world started craving fresh slices of fatty tuna, Kinki embarked on a quest to tame the bluefin. It sought to complete the reproduction cycle, with Pacific bluefin tuna eggs, babies, juveniles and adults all in the farming system.

Two scientists from Kinki went out to sea with local fishermen, seeking to capture juvenile tuna for raising in captivity. "We researchers always wanted to raise bluefin because it's big and fast. It's so special," said one of the scientists, Hidemi Kumai, now 79 years old. "We knew from the beginning it was going to be a huge challenge"(Hidemi Kumai, an emeritus professor at Kinki University and former head of the bluefin tuna farming department) (Hayashi, 2014).

It took nearly 10 years for fish caught in the wild to lay eggs at Kinki's research pens. Then, in 1983, they stopped laying eggs, and for 11 years, researchers couldn't figure out the problem. The Kinki scientists now attribute the hiatus to intraday drops in water temperature, a lesson learned only after successful breeding at a separate facility in southern Japan.

In the summer of 1994, the fish finally produced eggs again. The researchers celebrated and put nearly 2,000 baby fish in an offshore pen. The next morning, most of them were dead with their neck bones broken. The cause was a mystery until a clue came weeks later. Some of the babies in the lab panicked when the lights came on after a temporary blackout and killed themselves. Mr. Kumai and colleagues realized that sudden bright light from a car, fireworks or lightning caused the fish to panic and bump into each other or into the walls. The solution was to keep the lights on at all times.

At last, in 2002, the Kinki team became the first in the world to breed captive bluefin from parents that were themselves born in captivity. The circle was complete. But the survival rate remained low. While farmed Atlantic salmon had developed into a multibillion-dollar business, it seemed doubtful for years that the tuna undertaking could be commercially viable.

Kinki University had funded its project with proceeds from the sale of more common fish raised at its research facilities. That kept the tuna farming alive even after other academic and commercial organizations gave up. One early supporter, however, was a young employee of Toyota Tsusho Corp., a trading company affiliated with the auto maker. Taizou Fukuta was working at a desk job in the company's finance department in Nagoya when he saw a documentary about the tuna project. He was inspired to propose a tuna farming business in a Toyota in-house venture contest and won, according to Mr. Fukuta.

With $1 million in seed money, Mr. Fukuta, now 39, visited Kinki's Mr. Okada, the university's head of tuna research, many times until the academic agreed to team up with Toyota in 2009. Toyota payed the bill for larger facilities where baby fish hatched at the university's labs could be raised in large numbers for about four months. At that point, the juvenile fish are stable enough to be sold to commercial tuna ranches, where they are fattened in round pens around 100 feet in diameter and 30 feet deep for three to four years before being sold for slaughter.

After shipping an average of 20,000 juvenile fish a year over the past three years, Toyota's production is expected to rise to 40,000. That complements Kinki's own capacity for about the same number of fish. Together, they could supply nearly 20% of the demand for juvenile fish at Japanese tuna farms, taking pressure off the wild stock. Tin 2014, Mr. Fukuta says the venture he proposed five years ago is likely to break even for the first time.

Today around one or two in 100 of the baby tuna hatching from eggs at Kinki survive to adulthood, up from one in several hundred a few years ago. By contrast, only about one in 30 million babies hatched from eggs in the wild survive to adulthood. Specifically, a large female Pacific bluefin produces tens of millions of eggs but on average, even in a protected farm environment, only 0.2 percent to 0.3 percent of fertilized eggs will survive the first three months to grow into 30-centimeter fish; and fewer than 0.1 percent will survive to full adulthood. If high-technology methods can significantly raise the survival rate, the commercial consequences will be considerable. By strictly controlling the pool environment, they hope to maximize egg production and survival. The pool water is kept in a constant temperature range, between a maximum of 30 degrees Celsius, or 86 degrees Fahrenheit, in summer and a minimum of 13 degrees Celsius, or 55 degrees Fahrenheit, in winter.

Demand is certainly rising for the farmed tuna from gourmet stores and sushi restaurants in Japan. The university itself runs two restaurants in Tokyo's Ginza district and Osaka, both of them booked months in advance, it says. In Nagasaki prefecture, one of the main areas for domestic tuna farming, shipments of farmed bluefin rose to 3,000 tons in 2013, nearly five times the amount five years earlier.

At Kinki University's restaurant in Tokyo's Ginza district, the most popular lunchtime dish is a sashimi rice bowl. The slices of red meat on the left side are bluefin tuna raised in captivity at one of Kinki's labs (Hayashi, 2014).

Environmental concerns remain. Bluefin tuna require 15 pounds of feed fish to produce 1 pound of meat, prompting the Kinki team and others to look for artificial feed. Benefits of artificial feed include less pollution. With real fish, a large part is left uneaten and sinks to the bottom of the ocean, polluting the water. Artificial pellets are easier to eat so there are fewer leftovers. The team has been able to replace up to 30% of the ingredients with vegetable protein but going further stunts the fish's growth.

With global environmental protection treaties such as the Convention on International Trade in Endangered Species leaning toward listing Pacific bluefin tuna as an endangered species, finding a better way to farm the fish has become of national importance. The farming of Pacific bluefin is not new. Japan has 140 established farms, including 60 in the Nagasaki area alone, growing the fish from age three months to adulthood.

The Nagasaki research center, and a sister facility on Amami-Oshima Island in Kagoshima Prefecture — which has been working on Pacific bluefin research since 1995 - aims to develop improved strains of fish, using classic breeding techniques, rather than genetic modification, to produce fast-maturing, disease-free fish with high survival rates. The goal is to develop a method capable of producing as many as 100,000 three-month-old fish a year to stock the nation's fish farms, Mr. Mushiake said (Nagano, 2013).

CONCLUSION

It has been argued that intervention is necessary in order to provide a healthy sustainable future through aquaculture. Aquaculture refers to the breeding, rearing, and harvesting of plants and animals in all types of water environments. Marine aquaculture refers to the culturing of species that live in the ocean. U.S. marine aquaculture primarily produces oysters, clams, mussels, shrimp, and salmon as well as lesser amounts of cod, moi, yellowtail, barramundi, seabass, and seabream. Marine aquaculture can take place in the ocean (that is, in cages, on the seafloor, or suspended in the water column) or in on-land, manmade systems such as ponds or tanks. Recirculating aquaculture systems that reduce, reuse, and recycle water and waste can support some marine species (NOAA). As mentioned earlier, the planting and harvesting of sea kelp offers some promise in providing sustainable zero carbon emissions. Dulse, a pinkish-red seaweed, also referred to as red kale, has also been grown in bubbling seawater inside of warehouses at the Hatfield Marine Science Center, Oregon State University, in Newport, Oregon (hmsc.oregonstate.edu). The Bay Foundation has also been working to reforest the giant kelp in Santa Monica where three-quarters of the forest has vanished since 1950 (Goodyear, 2015).

For the streams and rivers, we need to restore the natural habitat for fish to migrate without the impediment of dams. Further, efforts are necessary to provide the restoration of rivers and streams as they have become obstructed with sediment and other obstacles.

It is also necessary to moderate our fishing behavior so that fishing stocks can be restored. In some cases, as with cod, this may take decades (Goode, 2015). Dredging and long line fishing must be curtailed and in some cases, banned. As recently reported on National Public Radio (NPR) most of the seafood Americans eat comes from abroad. And a lot of that is caught illegally by vessels that ignore catch limits, or that fish in areas off-limits to fishing. No one knows how much of it is illegal, because the oceans are too big to patrol. Or at least, they were.

Now environmental groups have harnessed satellite technology to watch pirate fishing vessels from space — and they've already caught some of them.

John Amos is one of the pioneers. He runs a small organization in West Virginia called SkyTruth. He started out collecting satellite images of oil spills in the ocean. In 2011, he learned about the automatic identification system, or AIS, which ships use to prevent collisions at sea.

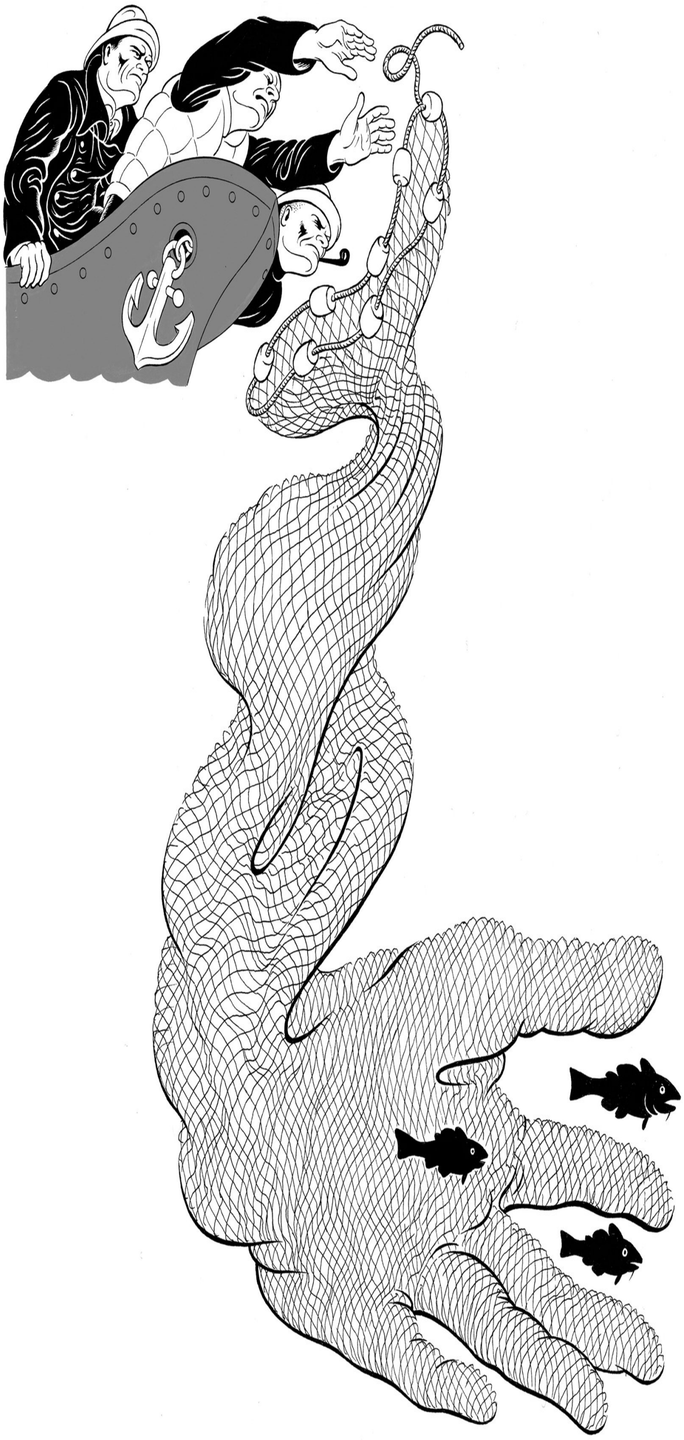
"Those AIS communication broadcasts can be picked up by orbiting satellites," Amos explains. Large ships carry electronic devices that constantly broadcast the ship's location and heading. This signal includes the boat's name and where it's from. Working with Google, Amos developed software that uses AIS signals to track up to 150,000 vessels all over the world. And he's also collaborating with the Pew Charitable Trusts, a nonprofit that's trying to curb illegal fishing with a program called Eyes on the Seas.

Amos learned how to recognize the kind of movement displayed on a map of the ocean that indicates a boat is fishing. "It's kind of a slow back and forth movement that would indicate they've put fishing gear, like long lines with baited hooks, into the water," he says.

Finally, it is worth noting that the Milford Laboratory in Milford, Connecticut has been selectively breeding bay scallops in aquaculture tanks with water pumped in from Long Island Sound. The bay scallop population has been dwindling over the past 50 years when in 1962, 1,433 metric tons of bay scallops were wild-caught. In 2013, 100.4 metric tons were caught (De Avila, 2015:A15).

Figure : I
“No to petroleum drilling, yes to renewables” (Bjork, 2015).

Figure : II



Overfishing is tragically depleting the cod habitat in the North Atlantic (Bolster, 2015*).*

Figure : III

Frozen tuna at the Tsukiji wholesale market in central Tokyo (Booth, 2014).

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