Science Brief

ECOSYSTEM AND PUBLIC HEALTH RISKS FROM NEARSHORE AND OFFSHORE FINFISH AQUACULTURE

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EXECUTIVE SUMMARY

Aquaculture is a dynamic and expanding global industry that produced 73.8 million tons of fish, crustaceans, and shellfish in 2014. One type of aquaculture is characterized by fish farming in coastal or open waters of oceans or large lakes, called nearshore or offshore finfish production. Production occurs in net pens or cages with free exchange of water with the surrounding environment. In the United States (U.S.), there is currently one company raising salmon in nearshore net pens in Maine and Washington, a second company raising caged yellowtail in Hawaii, and smaller net pen or cage research sites in other states. Some stakeholders would like to expand finfish aquaculture into U.S. federal waters (3 to 200 nautical miles away from the shore). The National Oceanic and Atmospheric Administration (NOAA) and other federal agencies established a regulatory system in 2016 to permit up to 20 offshore operations in the federal waters of the Gulf of Mexico. No permits have been issued to date, and there is a pending legal case challenging the regulations. Supporters of the near- and offshore finfish industry often focus on recent advances in production methods and describe the industry as an environmentally sound and economically sustainable approach to reduce the seafood trade deficit in the U.S.

The purpose of this report is to assess whether an expanded industry in the U.S. would be environmentally sound and safe based on current production practices. To perform our assessment, we examined recent peer-reviewed studies, focusing on fish escapes, disease pressures and treatments, fish waste, and occupational health and safety.

The current scientific literature reveals significant, ongoing ecological and public health risks from near- and offshore finfish aquaculture. Importantly, these risks do not apply equally to all net pen or cage finfish aquaculture operations. The major issues that we identified are: large numbers of recent farmed fish escapes, infectious disease outbreaks on farms, development of drug resistant parasites and bacteria, persistence of veterinary drugs in the environment, fish waste causing local and regional ecosystem impacts, and dangers that could cause elevated rates of injury and death among workers. Some of these issues can be minimized or addressed with improved regulation and/or monitoring, and others, such as fish escapes and release of fish waste, are inevitable outcomes of fish farming in open water systems as currently practiced.

The tendency to rely upon the application of existing laws, instead of creating a new regulatory system specifically for aquaculture, has led to regulatory gaps. These gaps mean that many risks described in this report are not adequately monitored and/or addressed under current law. We conclude that expanding the nearshore finfish industry or beginning an offshore industry in the U.S. carries significant risks for aquatic ecosystems and public health. Without a robust, comprehensive regulatory system in place, no new near- or offshore operations should be permitted, and regulations allowing offshore finfish operations in federal waters should not be issued in other regions of the U.S.

INTRODUCTION

Aquaculture is a diverse and growing food production sector that includes farming of fish, crustaceans, shellfish and aquatic plants in ponds, lakes, rivers, bays, estuaries and oceans. More than half of seafood consumed globally is now farmed, and aquaculture has surpassed global beef production in recent years.

The United States (U.S.) is a net importer of seafood. In 2016, the U.S. imported edible seafood products valued at \$19.5 billion, and exported \$5 billion, leaving a \$14.5 billion seafood trade deficit [1]. Domestic seafood production in the U.S. is skewed heavily toward wild-caught seafood. In 2013, the value of edible U.S. seafood production was \$5.29 billion for wild-caught commercial landings and \$1.15 billion for farmed products [2, 3]. Wild-caught seafood production is not expected to expand due to natural resource constraints, but there is growth potential for the aquaculture industry in the U.S. and abroad.

There is interest among some aquaculture industry stakeholders and U.S. regulators in developing a near- and offshore finfish aquaculture (NOFA) industry in U.S. state and federal waters. This form of aquaculture involves raising large numbers of finfish in net pens or cages near the water surface or in the water column. Farms could be located in the Atlantic or Pacific Oceans including Pacific Islands, the Gulf of Mexico, or the Great Lakes. These operations can be sited in open water similar to an oil rig or wind farm. In this document we summarize recent peer-reviewed scientific articles and reports that reflect the current state of commercial NOFA production in developed countries and impacts on aquatic ecosystems and humans. It is important for stakeholders to consider the environmental and public health implications when developing NOFA policies and regulations, and when investing in aquaculture operations.



CURRENT NEAR- AND OFFSHORE FINFISH PRODUCTION IN THE U.S.

Commercial production of finfish in near-shore settings is limited in the U.S. to farmed Atlantic salmon in coastal Maine and Washington and farmed yellowtail in Hawaii. There are fewer than ten farm sites in Maine and Washington combined, all owned by Cooke Aquaculture, a vertically-integrated global aquaculture corporation. Cooke Aquaculture is the 5th largest salmon producer in the world [4]. Over the years, Cooke Aquaculture has consolidated the farmed salmon industry in the U.S. by purchasing their competitors, True North Salmon in Maine and Icicle Seafood in Washington [5]. Maine and Washington are important for Cooke Aquaculture; these states represent roughly one fifth of their production (19,500 tons) valued at \$77 million in 2015 [6], but Maine and Washington are minor contributors (< 1%) to global farmed salmon production [7]. In Hawaii, a single company, Blue Ocean Mariculture, operates a net

pen farm. In 2014, the company produced 450 tons of yellowtail in six net pens and planned to scale up to 1,100 tons in eight net pens by 2017 [8]. There has been some discussion of a net pen industry in the Great Lakes and state agencies have commissioned reports to explore this issue [9].

There is no commercial offshore finfish production in U.S. federal waters, however, the National Oceanic and Atmospheric Administration (NOAA) and the Gulf of Mexico Fisheries Management Council approved a permitting system for offshore finfish aquaculture in the region in 2016 [10]. More information about the regulatory approach regarding offshore finfish production in U.S. federal waters is on page 12.

ECOSYSTEM AND PUBLIC HEALTH ISSUES

This report compiles literature relevant to four key ecosystem and public health impacts of NOFA: 1) fish escapes, 2) disease pressures and treatments, 3) fish waste, and 4) occupational health and safety. There is variation in production practices and impacts from NOFA by operation, producer, and country. Many operators have made progress toward reducing environmental impacts over the past three decades. Therefore, this report focuses on current challenges described in recent peer-reviewed literature from developed countries to maximize relevance to NOFA in the U.S. Key references are indicated in bold, and a short summary of each key reference is provided in the bibliography on pages 14-28. References that are not bold provide additional, important context.

FISH ESCAPES

Farmed finfish are selectively bred over multiple generations to increase desirable traits like larger size, faster growth rates, or adaptation to captivity or breeding [11]. Escapes of farmed fish remain a perennial issue for NOFA across multiple continents. Globally, several million fish escape net pen farms each year. In Europe, over a three year period in the late 2000s, 242 incidents of escapes were recorded totaling over eight million escaped fish **[12]**. In Canada, hundreds of thousands of fish escape net pen operations annually [13]. In August 2017, approximately 160,000 farmed Atlantic salmon escaped from net pens in Washington State [14]. In this case, some research suggests there is low risk to wild salmon populations native to the Pacific coast, because recaptured fish were found to not be eating and were free of disease. However, fishers



A damaged nearshore salmon net pen near Cypress Island, Washington, U.S. Approximately 160,000 farmed Atlantic salmon escaped from the net pen in August 2017.

Attribution: Washington State Department of Natural Resources

and environmentalists remain concerned about escapes [15]. Researchers have sampled water bodies looking for evidence of farmed fish. In one study, a team snorkeled in 41 wild salmon supporting rivers in Vancouver Island, Canada, and detected escaped farmed Atlantic salmon in over a third of those rivers [16]. Other studies use long-lines to catch farmed fish in the wild. Once fish escape farms, the success rate of catching them and returning them to the farm are very low; averaging 8% across multiple studies [17].

Studies indicate there are both short-term and long-term ecological risks from escapes related to selective breeding and low genetic variability of farmed finfish. In the short-term, farmed fish can exert competitive pressure on native wild fish, as has been found with salmon [16]. Scientists have studied the feeding habits of wild salmon and escaped farmed salmon in the North Atlantic by inspecting the stomach contents of caught fish. They found diets consumed by wild and escaped farmed fish were similar, suggesting that escaped farmed fish were well adapted to the wild [18]. Studies exploring longterm risks focus on genetic pollution and establishment of farmed fish populations in the wild. For example, farmed salmon populations exist in the wild in Chile and trace their ancestry to farmed broodstock from the U.S. and Canada [19]. Farmed Atlantic cod escapees were also found to reproduce in the wild [20]. Established populations of farmed fish could provide an economic benefit to fishermen [21], but these benefits must be weighed against the ecological risks caused by escaped fish and the large economic loss caused by escapes [12].

Researchers modeled the potential genetic impact of fish escapes from Gulf of Mexico net pen operations on wild cobia populations over 50 years. They found that more escapes and use of genetically different source populations increased the genetic impacts on wild species [22]. Proponents of NOFA argue that U.S. laws and regulations effectively address most of the potential environmental effects of NOFA [23], but accidental fish escapes similar to the recent escape in Washington are difficult to protect against and are likely to occur where NOFA sites operate.

DISEASE PRESSURES AND TREATMENTS

The burden of infectious diseases, subsequent treatment, and the consequences of long-term treatment must be considered for all food animal operations, including aquaculture. To reduce the risk of disease overall, aquaculture producers must consider juvenile fish health, stocking density, biosecurity protocols, and comprehensive operations management. Below, we summarize current trends in disease burden and therapeutant use in salmon production in Canada and the U.S. as an illustrative case study, instead of summarizing disease pressures for all of NOFA. Farmed salmon production has been extensively studied and significant resources have been invested in disease prevention and treatment. Although fish species and specific pathogens vary by region, current disease burdens affecting the salmon industry in these two countries reveal ongoing challenges that are relevant to disease burdens the industry may encounter in other regions of the U.S. In addition to significant economic losses related to disease treatments and culling of sick or dead fish, disease outbreaks in NOFA operations can spread to wild fish populations and therapeutants and/ or their breakdown products can impact aquatic ecosystems [24, 25].

Parasites

Sea lice, a type of parasite that attaches to salmonids and feeds on tissue and blood, is one of the most significant diseases of salmon aquaculture around the world. Sea lice do not directly cause death in infected salmon, instead the deep erosions they create result in loss of tissue for human consumption, chronic stress (which leads to loss of growth), and vulnerability to other pathogens that can cause illness and death [26]. One study estimated that sea lice cost the salmon industry hundreds of millions of dollars annually [27]. Antiparasitics used to treat sea lice have been linked to reduced populations of wild aquatic animals, especially crabs, lobsters, and other crustaceans that are biologically similar to sea lice. Emamectin benzoate (EB, trade-name SLICE®) is currently the only product in the U.S. labeled for treatment of sea lice infestation, and there is documented evidence of lice that are resistant to this treatment [28-30]. Vaccine development efforts have shown some progress, but no sea lice vaccines are currently available for commercial use [31]. Even with vaccination, other chemotherapeutic agents may be required, which can contribute to pollution and toxicity [24]. This is a serious public health concern because EB is a neurotoxin that is toxic to humans in high concentrations [32]. If fish are at risk for sea lice, EB is typically provided to young fish and in months with warm weather. Residues of EB in edible tissue of farmed fish are not expected to be a food safety concern if drug withdrawal periods (60 days) are followed. Concentrations of EB in treated fish increase for two weeks before dropping, and variation in EB plasma levels in treated fish have been found,



A scientist removes sea lice from a wild-caught salmon in Scotland. Diseases can be passed between wild and farmed fish, and sea lice treatments have been shown to impact other aquatic organisms and lead to sea lice developing resistance to treatment.

Attribution: Photo by Colin McPherson/Corbis via Getty Images

indicating uneven dosing in net pens [33, 34]. Therefore, adherence to regulatory withdrawal times for EB is critical. EB and another antiparasitic compound, deltamethrin, were found to degrade very slowly or not at all in microcosm studies, which could lead to a build-up of these compounds in marine sediments under farms leading to potential impacts on crustaceans and other organisms [35]. The use of antiparasitics in the U.S. should be closely monitored by regulators and representative samples of fish treated with antiparastics should be tested by federal seafood inspectors.

Bacteria

Aquatic animals, including salmon, can become infected by a variety of bacteria. The bacteria described here are endemic to Canada, including Vibrio, Mycobacterium, Streptococcus, Listonella, Moritella, and Photobacterium [36-38]. The impact of Aeromonas salmonicida, which causes furunculosis, has been significantly reduced through vaccination [39]. Two bacterial diseases that could cause significant problems in U.S. NOFA are Bacterial Kidney Disease (BKD), caused by Renibacterium salmoninarum, and stomatitis/winter ulcers/salmon ulcerative tenacibaculosisis, caused by Tenacibaculum maritimum [37]. BKD, a chronic, progressive disease, has been estimated to have a 3% prevalence in Canadian salmon aquaculture and can cause significant losses of market-size fish [40]. T. maritimum is an emerging pathogen in the Western Hemisphere and also causes significant loss in the salmon aquaculture industry in Canada. It requires a two to five day treatment of antibiotics [37].

Antibiotics are used to treat bacterial infections in all types of farmed animals, including salmon and other farmed finfish. Numerous studies have shown correlation between the use of antibiotics in animal production and development of antibiotic resistance in bacteria; antibiotic use in the aquaculture industry is no exception. Specifically, Vibrio, Mycobacterium, and Streptococcus species are bacteria known to infect humans, and infection with resistant strains of bacteria may result in an illness that is more difficult to treat. The World Health Organization (WHO) recognizes antibiotic resistance as a current crisis that "threatens...global public health" [41]. The three most common antibiotics used in the U.S. aquaculture industry are oxytetracycline, oxilinic acid, and florfenicol, and all three are identified by the WHO as belonging to drug classes that are important in human medicine [42].

Viruses

Viruses are also a type of pathogen that cause detrimental, highly contagious diseases in fish that result in significant illness and mortality. Infectious salmon anemia virus (ISAV) potentially poses the greatest threat to salmon aquaculture. Epidemics occur frequently in locations near the U.S.; in 2016 Canada had 17 known outbreaks of ISAV [43]. Some reports indicate up to 95% mortality, which could devastate the salmon industry and market as it did in Chile in the late 2000s [44].

Additional viruses of concern include infectious hematopoietic necrosis virus (IHNV), heart and skeletal muscle inflammation (HSMI), pancreatic necrosis virus, and salmonid alpha virus. IHNV is seen globally, but is especially prevalent in the U.S. and Canada. This disease causes significant mortality, up to 78%, and unvaccinated industries can face significant losses if fish become infected [37]. HSMI is a relatively new disease which is thought to be caused by piscine reovirus. HSMI mortality can reach 20% and

FISH WASTE

There is no mechanism to capture animal waste from NOFA, unlike terrestrial animal production where animal manure is ideally collected, composted, and used to build soil fertility. Fish waste instead deposits in sediment under cages and net pens or disperses into the water column and can travel outside the farm environment. Modelers have studied fish waste and estimated that in NOFA, every ton of fish produced results in an additional 69 kg of nitrogen and 10 kg of phosphorus released into the environment [48]. In 2010, NOFA production was estimated to be five million tons, resulting in an estimated 345 million kg of nitrogen and 50 million kg of phosphorus excreted in fish waste [48]. Over the past four decades, feed conversion ratios in finfish aquaculture have been reduced and less nitrogen and phosphorus are released per unit production, but industry growth projections indicate significant increases in the amount of fish raised and therefore larger amounts of waste that can lead to nutrient pollution and eutrophication [48]. High nutrient levels in aquatic environments can cause algal blooms, resulting in low oxygen levels and mortality among aquatic animals.

Several recent studies have been published about the impacts of uneaten fish feed and fish

can impact salmon growth and wellbeing [45]. HSMI has been recognized in Europe and recently in Canada, and could become an issue in U.S. aquaculture operations [46]. Pancreatic necrosis virus and salmonid alpha virus also pose risks to the industry, despite vaccine availability, because of the high cost of vaccination [47].

waste on the local environment and ecosystem, which adds to a growing body of literature on fish waste. Impacts can be separated into near-field impacts on sediments and the water column, and far-field impacts on the ecosystem [49]. Studies find a gradient of impacts with greater nutrients and waste proximate to the farm and diluted further from the farm. The distance waste travels varies based on animal stocking density, feeding rates, and siting issues such as water depth and water velocity or currents. Price et al. 2015 reviewed the impacts of marine cage culture on water quality and primary production of local biota (non-farm animals). The authors found nutrient enrichment in the water column within 100 meters of the farms (near-field effects) but not at greater distances, and these nutrients were consumed by local biota which agrees with other research [50]. The local nutrient impacts sometimes modifies the trophic structure of local biota, but the degree to which these impacts resulted in positive or negative outcomes was not reported [51].

Far-field ecological effects can occur in intensively farmed regions over time. Impacts are variable and depend on farm siting, density of farms, and the strength of local regulations. Sarà et al. 2011 studied far-field effects of marine aquaculture by examining historic nitrogen and phosphorus loading. They found nutrient and chlorophyll-a concentrations steadily increased in a Sicilian bay after marine finfish aquaculture operations were introduced and were at higher concentrations than water outside of the bay [52]. In Norway, the risk of organic loading and eutrophication outside of the production area of the farm was considered low [53]. Ongoing monitoring of production areas is needed to ensure that near-field and far-field impacts are not damaging ecosystems and aquatic organisms.

Integrated multi-trophic aquaculture (IMTA) is an emerging type of aquaculture that combines production of aquatic species that are fed (e.g., finfish, shrimp) and species that filter nutrients and particulates from the water column (e.g., bivalves, seaweed, sea cucumbers). The two primary benefits of the IMTA production model are reducing overall nutrient load in the area around a net pen or cage operation and diversifying income for aquaculture farmers [54]. There are challenges with this production model that are relevant to human health and food safety because the filter feeding animals and/or plants may also absorb pesticides, veterinary drugs, heavy metals and other harmful substances often used to control fish disease outbreaks or algal growth on net pens or cages. Some initial research has been conducted on this topic, and researchers found elevated levels of heavy metals in seaweed grown alongside farmed salmon [55], but more work is needed on this topic.

OCCUPATIONAL HEALTH AND SAFETY

NOFA combines elements of agriculture, commercial fishing, and commercial diving, and all of these occupations have high rates of injury, illness, and death [56, 57]. Studies have identified numerous occupational risks for aquaculture workers, including electrical shock, drowning, slips, trips, falls, sprains and strains, accidents with machines, exposure to chemicals, night work, fires, explosions, and exposure to infectious pathogens and therapeutants [56, 57]. Research focused on salmon net pen production in developed countries describes the work as particularly dangerous with additional hazards including exposure to extreme temperatures, decompression illness and other diving risks, falls from boats and cages, and needlestick injuries and complications [58, 59].

Net pen salmon production was identified as a highly hazardous working environment more than twenty years ago [60]. Nonetheless, it is

common for countries to rely on existing laws instead of passing new regulations specifically designed to regulate NOFA and protect worker health and safety [61]. The U.S. has followed this model, and there is a significant gap in the current regulatory approach regarding offshore aquaculture worker protection. A policy analysis conducted in 2014 found that the federal Occupational Safety and Health Act may not apply to aquaculture operations in federal waters due to jurisdictional limitations and exemptions for agricultural operations of a certain size [62]. Researchers who have studied risks to aquaculture workers strongly recommend systematic hazard identification, education, training and prevention, increased transparency, and robust tracking and reporting of injuries, illnesses, and deaths [58, 59, 61]. It is not clear how these critical activities would be accomplished in the U.S. under the current regulatory approach for aquaculture in federal waters.



A diver returns from inspecting broken netting in a salmon net pen in Australia. Diving is one of many occupations related to near- and offshore finfish aquaculture associated with health and safety risks. Attribution: Carla Gottgens/Bloomberg via Getty Images

CURRENT STATE AND FEDERAL POLICY

Nearshore operations in state waters are primarily regulated by the state agency in charge of implementing the National Pollutant Discharge Elimination System (NPDES) permits in the state (e.g., in Maine, it is the Department of Environmental Protection). NPDES permits are issued and managed to comply with the federal Clean Water Act, under authority granted by the Environmental Protection Agency. In general, state agencies issue location-based permits and collect information from producers on fish biomass, volumes of feed, use of therapeutants, and escapes. Additional agencies are involved, and the level of transparency regarding producer data and resources devoted to regulating nearshore finfish aquaculture varies by state.

NOAA is the lead federal agency in the U.S. developing and implementing regional permitting systems to allow NOFA in federal waters. The fishery management plan for offshore aquaculture in the Gulf of Mexico provides the first location where regulations and best management plans have been created and permits will be accepted for offshore aquaculture. NOAA developed the regulatory structure for finfish production in the Gulf of Mexico based on the authority given to NOAA via the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The MSA is the primary federal law regulating wild capture fisheries, and NOAA determined that finfish aquaculture in federal waters can be managed under the MSA. There is a pending legal action challenging inclusion of finfish aquaculture under the authority granted by the MSA [63]. NOAA has coordinated with the Environmental Protection Agency, U.S. Army Corp of Engineers, U.S. Coast Guard, Bureau of

Ocean Energy Management, and the Bureau of Safety and Environmental Enforcement to develop a permitting system in the Gulf of Mexico for offshore finfish production based on existing regulations [64]. Despite the involvement of these agencies, significant regulatory gaps remain at the state and federal levels, in part due to application of existing laws instead of development of a new regulatory system for NOFA. For example, in addition to the gaps regarding occupational health and safety described above, offshore operations may have an adverse impact on the aquatic ecosystem that is not subject to monitoring (i.e., does not result in higher mortality of a managed fish species), and therefore does not result in requirements to modify or stop production.

In addition to leading policy formulation and regulation of aquaculture in federal waters, NOAA, as an agency within the Department of Commerce, has an explicit goal to promote and grow the U.S. aquaculture industry. This is similar to the U.S. Department of Agriculture, which regulates and promotes agriculture. To reduce the potential for a conflict of interest, NOAA should consider separating the roles of policy/regulatory development from industry promotion. The current situation could lead to decisions regarding stringency of regulations and required levels of transparency that favor industry growth and profitability at the expense of protections for ecosystems and public health. A similar situation exists in Canada; an independent commission concluded that the Canadian Department of Fisheries and Oceans should not be responsible for regulating and promoting the farmed salmon industry [65].

CONCLUSION AND POLICY RECOMMENDATIONS

In this report, we summarize recent peer-reviewed literature relevant to potential impacts from NOFA in the U.S. Trade-offs between profitability and impacts to ecosystems and public health are a hallmark of many industries [66]. A robust, comprehensive regulatory system is necessary to ensure a potentially harmful indus-

- Increase requirements for monitoring and reporting at offshore aquaculture sites to include monthly reports of disease outbreaks, therapeutant use, mortalities, escapes, and current feed use and fish biomass. All information should be posted by regulatory agencies on a website accessible to researchers and the public.
- Implement active environmental monitoring systems that test for therapeutants and breakdown products in fish tissue and sediment samples, fish pathogens, escaped farmed fish, nutrient loading, and antibiotic resistant bacteria in sediments. The monitoring system should be fulfilled by trained agency staff, not industry staff.
- Develop a robust set of requirements to protect and monitor the health and safety of NOFA workers. Data on injuries, illnesses, and deaths should be reported to the Occupational Safety and Health Administration. Information specific to each NOFA operation should be posted on a website accessible to researchers and the public.

try consistently operates in a manner that minimizes risks, but the current regulatory structure for NOFA in the U.S. is inadequate. Due to the ongoing challenges associated with NOFA summarized above, current regulatory gaps, and potential impacts on public health and aquatic ecosystems, we recommend the following:

- Separate federal and state policy/ regulatory efforts from NOFA industry promotion to reduce potential conflicts of interest.
- Until the above recommendations are fully implemented, do not approve operations in the Gulf of Mexico and do not implement new permitting systems in other regions of the U.S.

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> This article reports the extent, size and causes of marine fish escapes in Europe from 2007 to 2009. The authors collected 242 incidents of escape, which totaled over 8 million fish. The most common fish to escape were sea bream, Atlantic salmon, sea bass, and cod. The cost due to lost sales of these escapes was 47.5 million Euros per year, mainly affecting Mediterranean fish farms.

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> The researchers snorkeled-sampled 41 wild Pacific-salmon supporting rivers in Vancouver Island, Canada and detected farmed Atlantic salmon in over 1/3rd of streams, detected over three years. After accounting for the imperfect detection (by snorkeling) they estimated that half of the streams contained farmed Atlantic salmon. Farmed salmon were more likely to live in streams that had high native Pacific salmon diversity. They suggest that farmed salmon can exert competitive pressure on native salmon, and policy decisions about farming must consider the impact of escaped farmed salmon.

[17] T. Dempster, P. Arechavala-Lopez, L. T. Barrett, I. A. Fleming, P. Sanchez-Jerez, and I. Uglem, "Recapturing escaped fish from marine aquaculture is largely unsuccessful: alternatives to reduce the number of escapees in the wild," Rev. Aquac., Jun. 2016.

> This review of the literature focuses on fish escapes, the behavior of fish after escaping, and recapture methods. Successful recapture programs need to start within 24 hours of an escape, however, recapture rates were low (8%) among the studies they reviewed. During recapture there may be high bycatch rates, which is a negative side effect and should be considered. The authors have several recommendations for ways to improve recapture programs and reduce escapes.

[18] J. Jacobsen, "Feeding habits of wild and escaped farmed Atlantic salmon, Salmo salar L., in the Northeast Atlantic," ICES J. Mar. Sci., vol. 58, no. 4, pp. 916–933, 2001.

> The authors studied the feeding habits of wild and escaped farmed Atlantic salmon in the Northeast Atlantic. The fish were caught on floating long lines and the stomach contents of n=2,992 wild and n=863 farmed fish were analyzed for species consumed. The authors found that diets consumed by wild and escaped farmed fish were similar, and concluded that escaped farmed fish were well adapted to the wild.

[19] C. Y. Di Prinzio, C. R. Rossi, J. Ciancio, J. C. Garza, and R. Casaux, "Disentangling the contributions of ocean ranching and net-pen aquaculture in the successful establishment of Chinook salmon in a Patagonian basin," Environ. Biol. Fishes, vol. 98, no. 9, pp. 1987–1997, 2015.

> Using molecular methods to identify genetic lineage, the authors studied escaped salmon populations in Chile. They determined that fish in one tributary originally came from a salmon ranching project in the 1970s and 1980s and the population was supplemented with escapes from net pen operations. The scientists also identified the source of broodstock for the salmon ranging and net pen operations as being from the U.S. and Canada.

[20] K. E. Jorstad et al., "Genetic marking of farmed Atlantic cod (Gadus morhua l.) and detection of escapes from a commercial cod farm," ICES J. Mar. Sci., vol. 71, no. 3, pp. 574–584, Apr. 2014.

> The researchers tracked genetically-marked farmed Atlantic cod escapees to identify if farmed and wild cod interbreed. Escaped cod demonstrated long term survival in the farm region and in a neighboring region, including some escaped cod that had reproduced. The researchers were unable to determine-- due to methods limitations-- whether interbreeding between wild and escaped farmed cod occurred.

[21] D. Izquierdo-Gomez, J. T. Bayle-Sempere, F. ArreguÃn-SÃ;nchez, and P. SÃ;nchez-Jerez, "Modeling population dynamics and small-scale fisheries yields of fish farming escapes in Mediterranean coastal areas," Ecol. Modell., vol. 331, pp. 56–67, 2016.

> The authors modeled temporal trends in biomass and yield of escapes from aquaculture in the Mediterranean Sea. The authors conclude that fishing fleets benefit from escapes in terms of yield, but gains must be compared to whether fish escapes positively or negatively affect the value of the catch.

[22] T. L. Darden, J. D. Robinson, A. E. Strand, and M. R. Denson, "Forecasting the Genetic Impacts of Net Pen Failures on Gulf of Mexico Cobia Populations Using Individual-based Model Simulations," J. World Aquac. Soc., vol. 48, no. 1, pp. 20–34, 2017.

> This article describes modeling of the genetic impact of fish escapes from net pen operations in the Gulf of Mexico on wild cobia populations over 50 years. More escapes and use of non-native species increased the genetic impacts on wild species. The authors recommend that the industry consider the source of broodstock when supplying fish farms.

[23] M. B. Rust et al., "Environmental Performance of Marine Net-Pen Aquaculture in the United States," Fisheries, vol. 39, no. 11, pp. 508–524, 2014. [24] O. Torrissen et al., "Salmon lice - impact on wild salmonids and salmon aquaculture,"J. Fish Dis., vol. 36, no. 3, pp. 171–194, Mar. 2013.

This article focuses on salmon sea lice, including farmed and wild salmon populations. The authors explore trends of sea lice reporting in producers of salmon globally, and take into consideration the effects of sea lice. Although treated populations of salmon perform better than untreated populations, sea lice are showing continually increasing rates of resistance. The authors explore options to treat sea lice as opposed to tradition methods (i.e. emamectin benzoate) such as vaccines, cleaner fish (wrasse), and novel drugs.

- [25] M. Holmer, "Environmental issues of fish farming in offshore waters: Perspectives, concerns and research needs," Aquaculture Environment Interactions. 2010.
- [26] P. Woo and D. Bruno, Eds., Diseases and disorders of finfish in cage culture. Wallingford: CABI, 2014.

This report summarizes the diseases and disorders of finfish, including parasitic, viral, and bacterial diseases in a variety finfish species. The chapter on Sea Lice focuses on the pathology and treatment of sea lice species.

[27] M. J. Costello, "The global economic cost of sea lice to the salmonid farming industry," J. Fish Dis., vol. 32, no. 1, pp. 115–118, Jan. 2009. [28] F. Lees, M. Baillie, G. Gettinby, and C. W. Revie, "The efficacy of emamectin benzoate against infestations of Lepeophtheirus salmonis on Farmed Atlantic Salmon (Salmo salar L) in Scotland, 2002-2006," PLoS One, vol. 3, no. 2, pp. 2002–2006, 2008.

> This study focuses on the known treatment of sea lice, Emamectin Benzoate (SLICE) on Lepeophtherius salmonis (a species of sea lice) over the years 2002-2006 in Scotland. The study shows that treatments of Lepophtheirus salmonis with SLICE was not always effective and the authors have indicated that there was reduced efficacy of SLICE over time.

[29] S. M. Aaen, K. O. Helgesen, M. J. Bakke, K. Kaur, and T. E. Horsberg, "Drug resistance in sea lice: a threat to salmonid aquaculture," Trends Parasitol., vol. 31, no. 2, pp. 72–81, Feb. 2015.

> This study describes compounds used to treat sea lice and the species of sea lice that are significant within the aquaculture industry. The study shows side-byside layouts of treatment options and the mechanisms of action. The authors also show trends of resistance within sea lice populations and discuss available treatment options.

[30] A. W. Bateman et al., "Recent failure to control sea louse outbreaks on salmon in the Broughton Archipelago, British Columbia," Can. J. Fish. Aquat. Sci., vol. 73, no. 8, pp. 1164–1172, Aug. 2016.

> This study describes increasing populations of sea lice following largely successful control efforts over the previous decade. Resistance to treatment regimens was noted within juvenile pink and chum salmon in the Broughton Archipelago in British Columbia. The authors believe that the outbreak of resistant sea lice may be due to the following reasons: 1. Poor timing of treatment 2. Evolution of resistance 3. "anomalous environmental conditions" that propagated sea lice growth or 4. High number of wild pink salmon returns.

 [31] Y. Carpio et al., "Novel gene isolated from Caligus rogercresseyi: A promising target for vaccine development against sea lice," Vaccine, vol. 29, no. 15, pp. 2810–2820, Mar. 2011.

> The authors indicate promising development of a novel vaccine for sea lice infestation in finfish. The researchers indicate that a recombinant my32 protein that led to immunization of salmon when challenged with Caligus rogercresseyi sea lice species. Researchers claim that this could be a vaccine that ends sea lice infestation, especially in Chile, where this species of sea lice is particularly burdensome.

[32] National Institute of Health (NIH), "Emamectin benzoate | C56H81NO15 - Pub-Chem." Available: <u>https://pubchem.ncbi.</u> <u>nlm.nih.gov/compound/22833503#section=Safety-and-Hazards</u>

> This resource is a summary of several health hazards that can result from contact with emamectin benzoate. The summary is provided by the National Center for Biotechnology Information, which is part of the National Institutes of Health. Health hazards include toxicity to humans and aquatic life. Human health risks include acute toxicity and damage to organs, eyes, and skin.

[33] A. G. T. Berg and T. E. Horsberg, "Plasma concentrations of emamectin benzoate after Slice treatments of Atlantic salmon (Salmo salar): Differences between fish, cages, sites and seasons," Aquaculture, vol. 288, no. 1–2, pp. 22–26, 2009.

> The primary focus of this research was to investigate the emamectin benzoate practices of two aquaculture farms in Norway during 2005 and 2006. The authors took note of emamectin benzoate administration, dosage, and residue in treated fish. The authors discovered highly variable residue concentrations, ranging from 6 ng/ml to 440 ng/ml, which may be contributing to the rise in resistance to treatments.

[34] P. A. Olsvik et al., "Pharmacokinetics and transcriptional effects of the anti-salmon lice drug emamectin benzoate in Atlantic salmon (Salmo salar L.)," BMC Pharmacol., vol. 8, no. 1, p. 16, 2008.

> The authors investigated the pharmacokinetic effects of emamectin benzoate on fish tissue, specifically the liver, the skin, and the muscle. The liver showed small transcriptional effects that indicated increased levels of glutathione-S-transferase. This shows that emamectin benzoate leads to some oxidative stress within salmon, that may "affect protein stability and folding, followed by a secondary inflammatory response."

[35] J. P. Benskin, M. G. Ikonomou, B. D. Surridge, C. Dubetz, and E. Klaassen, "Biodegradation potential of aquaculture chemotherapeutants in marine sediments," Aquac. Res., vol. 47, no. 2, pp. 482–497, Feb. 2016.

> The authors studied the degradation of chemotherapeutants (SLICE and Alpha-Max) and their active ingredients (emamectin benzoate (EB) and deltamethrin) in marine sediments maintained at 4 deg F and 10 deg F in biotic and abiotic conditions over 135 days, and found that degradation of the drugs and active ingredients does not occur (SLICE / EB) or occurs very slowly (for AlphaMax / delatmethrin).

[36] P. Bridson, "Atlantic Salmon, British Columbia, Canada," Monterey Bay Aquarium Seafood Watch Program, 2017. Available: <u>https://www.seafoodwatch.org/-/m/sfw/</u> <u>pdf/reports/s/mba_seafoodwatch_farmedbcsalmon_report.pdf</u>

> Monterey Bay Aquarium produced a document evaluating net pen aquaculture production practices in British Columbia for Atlantic salmon. Monterey Bay Aquarium rates operations based on ten criteria, including effluents, chemical use, feed, escapes, and disease. An informative summary of infectious diseases impacting the farmed salmon industry is on pages 56-84.

 [37] K. D. Lafferty et al., "Infectious Diseases Affect Marine Fisheries and Aquaculture Economics," Ann. Rev. Mar. Sci., vol. 7, no. 1, pp. 471–496, Jan. 2015.

> This review characterizes 67 infectious diseases that affect marine fish aquaculture. They discuss the transfer of diseases from wild to farmed populations and visa-versa. The authors focus specifically on sea lice, which increase farmed salmon costs by US \$0.15–0.30/kg with a global annual cost of US \$400 million. Lafferty identified baseline monitoring of wild salmon and a better understanding of the dynamics and risks of transmission and survival times as key research needs.

[38] S. H. S. Chatterjee, "Vibrio Related Diseases in Aquaculture and Development of Rapid and Accurate Identification Methods," J. Mar. Sci. Res. Dev., vol. s1, 2012.

> This study characterizes vibrio-related diseases in fish aquaculture via PCR, 16s rRNA and housekeeping genes, colony hybridization, fluorescence, ribotyping, RFLP, AFLP, and RAPD. The authors conclude that using new nucleic acid targeting methods are important to diagnose bacteria and help in treating these infections, which contribute to billions of dollars of losses annually.

[39] D. B. Morrison and S. Saksida, "Trends in antimicrobial use in Marine Harvest Canada farmed salmon production in British Columbia (2003-2011).," Can. Vet. J. = La Rev. Vet. Can., vol. 54, no. 12, pp. 1160–3, Dec. 2013.

> The authors explore the trends of antibiotic use from Marine Harvest Canada, a dominant salmon aquaculture producer, between the years 2003 and 2011. The study indicates that British Columbia has highly reduced its dependence on antibiotics, although the authors still call for vaccines for infections like stomatitis and bacterial kidney disease, since a large amount of antibiotics are used to fight these infections.

[40] S. K. Balfry and L. L. Brown, "Evaluation of Bacterial Kidney Disease (BKD) Impacts on the Canadian Salmon Aquaculture," 2006.

> This report describes Renibacterium salmoninarum, the causative agent of bacterial kidney disease (BKD). The authors indicate that BKD costs Canada's salmon industry a large amount of money via losses and expenditures on prevention and treatment. The prevalence of BKD is upwards of 5% in some Canadian aquaculture operations.

[41] World Health Organization (WHO), "Global Action Plan on Antimicrobial Resistance," Geneva, Switzerland, 2015. Available: <u>http://www.wpro.who.int/entity/ drug_resistance/resources/global_action_ plan_eng.pdf</u>

> The Global Action Plan on Antimicrobial Resistance is a document that describes the growing concern among health professionals regarding increased prevalence of antimicrobial resistance world-wide. This document, created by WHO personnel, provides action plans for slowing and reversing antibiotic resistance trends.

[42] H. Y. Done, A. K. Venkatesan, and R. U. Halden, "Does the Recent Growth of Aquaculture Create Antibiotic Resistance Threats Different from those Associated with Land Animal Production in Agriculture?," AAPS J., vol. 17, no. 3, pp. 513–524, May 2015.

> This study aims to determine if aquaculture contributes to the antimicrobial resistance trends that are seen elsewhere in the food animal agriculture industry. The authors indicate that aquaculture does add to the burden of antimicrobial resistance for three main reasons: 1. The large number of antibiotics (51) shared in aquaculture/agriculture industries and human medicine, 2. Bacteria isolates on seafood showed resistance to multiple antibiotics, and 3. The same mechanisms of resistance are seen in aquaculture and agriculture.

[43] Canadian Food Inspection Agency, "Locations infected with infectious salmon anaemia in 2016 - Animals - Canadian Food Inspection Agency," British Columbia, 2016.

> This document shows the recorded number of reported outbreaks of infectious salmon anemia in Canada over 2016. There were two locations that added up to a total of 14 distinct outbreaks of infectious salmon anemia.

[44] F. Asche, H. Hansen, R. Tveteras, and S. Tveteras, "The Salmon Disease Crisis in Chile," Mar. Resour. Econ., Dec. 2009.

[45] E. Biering and Å. H. Garseth, "ICES Identification Leaflets for Diseases Parasites of Fish and Shellfish," Copenhagen, 2012.

> The authors reviewed the pathology and significance of Heart and Skeletal Muscle Inflammation in fish. The document highlights clinical signs, susceptible species, and methods of control.

[46] E. Di Cicco et al., Heart and skeletal muscle inflammation (HSMI) disease diagnosed on a British Columbia salmon farm through a longitudinal farm study, vol. 12, no. 2. 2017.

> This study sampled salmon from a farm in British Columbia and collected clinical data and mortality from operations. Diagnostics such as immunohistochemistry were performed to detect for heart and skeletal muscle inflammation. The authors concluded that piscine orthoreovirus is highly associated with heart and muscle inflammation in salmon, and that Canada is the third country to discover this connection within its aquaculture population.

[47] M. F. McLoughlin and D. a Graham, "Alphavirus infections in salmonids--a review.," J. Fish Dis., vol. 30, pp. 511–531, 2007.

> This is a review of the literature on alphavirus infections in salmon populations. The authors reflect on the types of infections that are caused by alphaviruses and where they occur in terms of country location. The authors delve into the pathology and pathogenicity of the alphavirus diseases, diagnosis, prophylaxis, and control.

[48] A. F. Bouwman, A. H. W. Beusen, C. C. Overbeek, D. P. Bureau, M. Pawlowski, and P. M. Glibert, "Hindcasts and Future Projections of Global Inland and Coastal Nitrogen and Phosphorus Loads Due to Finfish Aquaculture," Rev. Fish. Sci., vol. 21, no. 2, pp. 112–156, Apr. 2013.

> This study modeled and predicted nitrogen (N) and phosphorus (P) loading due to finfish aquaculture. Total nutrient releases for aquaculture in 2010 were estimated to be 1.5 million tons of N and 0.15 million tons of P in marine and freshwater environments. The authors express concern about eutrophication caused by inputs of N and P from freshwater aquaculture, particularly in Asia.

[49] J. Day, T. Chopin, and J. A. Cooper, "Comparative study of the aquaculture environmental monitoring programs for marine finfish in Canada and other jurisdictions: time to go beyond sediment related impact monitoring and consider appropriate tools for water column and ecosystem related impact monitoring," Bull. Aquac. Assoc. Canada, pp. 34–52, 2015.

> The authors reviewed the impacts of marine finfish aquaculture and identified three major impacts: sediment related impacts, water column related impacts, and ecosystem related impacts. The authors reviewed finfish aquaculture monitoring tools in Canada, and made specific recommendations to improve the monitoring of sediments, the water column, and the ecosystem.

[50] M. Callier, S. Lefebvre, M. Dunagan, M. Bataille, J. Coughlan, and T. Crowe, "Shift in benthic assemblages and organisms' diet at salmon farms: community structure and stable isotope analyses," Mar. Ecol. Prog. Ser., vol. 483, pp. 153–167, May 2013.

> This study examined benthic communities living on the seafloor along a transect below two Irish salmon farms, and found (using stable isotope analysis) that fish waste was assimilated and became a food source for benthic organisms. The researchers call for more work to understand whether biota living near farms can completely process the nutrients from fish waste that are released into the water column and sediments, or whether these nutrients organically enrich the local environment.

[51] C. Price, K. Black, B. T. Hargrave, and J. A. Morris Jr, "Marine cage culture and the environment: effects on water quality and primary production," Aquac. Environ. Interact., vol. 6, pp. 151–174, 2015.

> This is a review of the impacts of marine cage culture on water quality and primary production. The authors found nutrient enrichment in the water column within 100 meters of farms (so called "near-field" effects) but not at greater distances, and these nutrients sometimes had secondary impacts such as modifying the trophic structure of local biota. They call for more work on the additive impacts of multiple farms and on the "far-field" ecological effects that occur over time and in regions that are intensively farmed.

[52] G. Sarà et al., "Impacts of marine aquaculture at large spatial scales: Evidences from N and P catchment loading and phytoplankton biomass," Mar. Environ. Res., vol. 71, no. 5, pp. 317–324, Jun. 2011.

> The authors studied far-field effects of marine aquaculture by examining historic nitrogen and phosphorus loading. They found nutrient and Chlorophyll-a concentrations steadily increased in a bay after aquaculture operations were introduced and were at higher concentrations than water outside of the bay.

[53] G. L. Taranger et al., "Risk assessment of the environmental impact of Norwegian Atlantic salmon farming," ICES J. Mar. Sci., vol. 72, no. 3, pp. 997–1021, Mar. 2015.

> The researchers performed a risk assessment of the environmental impacts of Norwegian salmon farming. The risk of organic loading and eutrophication outside of the production area of the farm was considered low. Risk of viral disease outbreaks and sea lice infections on farms and among wild fish were moderate to high in some locations. The risk of wild salmon with genetic introgression from farmed salmon was moderate to high in over 60% of wild salmon populations.

- [54] L. Granada, N. Sousa, S. Lopes, and M. F. L. Lemos, "Is integrated multitrophic aquaculture the solution to the sectors' major challenges? - a review," Rev. Aquac., vol. 8, no. 3, pp. 283–300, Sep. 2016.
- [55] J. J. Ratcliff et al., "Metal content of kelp (Laminaria digitata) co-cultivated with Atlantic salmon in an Integrated Multi-Trophic Aquaculture system," Aquaculture, vol. 450, pp. 234–243, Jan. 2016.

[56] M. L. Myers and H. P. Cole, "Simple solutions for reduced fish farm hazards.,"J. Agromedicine, vol. 14, no. 2, pp. 150–6, May 2009.

> The authors conducted interviews with U.S. and Canadian fish farm operators and other stakeholders to identify cases when worker injuries had occurred (or almost occurred) and cases of illnesses among employees. They identified the following risks at various types of aquaculture operations: electrical shock, drowning, slips, trips, falls, sprains and strains, machines, chemicals, night work, fires, and explosions. The authors noted that aquaculture combines occupational risks typical of agricultural work, which has high rates of morbidity and mortality, and working around water. Strategies were identified that could reduce risks, and additional risks for workers associated with offshore finfish farming were discussed.

 [57] D. W. Cole et al., "Aquaculture: Environmental, toxicological, and health issues," Int. J. Hyg. Environ. Health, vol. 212, no. 4, pp. 369–377, Jul. 2009.

> One section of this review article focused on occupational hazards in aquaculture, and the authors categorized them as physical work hazards, chemical and toxic exposures, and infectious disease. Decompression illness was identified as a risk for divers working on aquaculture operations. Exposure to chemicals, especially when used in combination, can be dangerous for workers. Warning labels on various chemicals usually do not address use of multiple chemicals together or in close proximity. Workers can also be exposed to infectious pathogens and chemicals used to prevent or treat fish diseases.

[58] D. T. R. Moreau and B. Neis, "Occupational health and safety hazards in Atlantic Canadian aquaculture: Laying the groundwork for prevention," Mar. Policy, vol. 33, no. 2, pp. 401–411, Mar. 2009.

> The authors conducted a literature review and policy analysis focused on occupational health and safety risks associated with marine aquaculture in Atlantic Canada. Marine aquaculture in Atlantic Canada was described as a hazardous and expanding industry with very little research and monitoring on morbidity and mortality among workers. The authors highlighted shared occupational risks with other industries, and pointed to characteristics of aquaculture that make it particularly risky for workers. The main categories of occupational risks were: work design hazards (e.g., musculoskeletal disorders caused by heavy lifting, prolonged standing, awkward postures and repetitive work), physical hazards (e.g., slips, trips, falls from height, transportation, machinery, electricity and fire safety, and exposure to heavy metals), exposure to extreme temperatures, SCUBA diving safety, excessive noise, confined spaces, chemical hazards, biological hazards, and psychosocial hazards. To minimize these risks, the authors call for systematic hazard identification, education, training and prevention, increased transparency, and robust tracking and reporting of injuries, illnesses, and deaths.

[59] M. L. Myers, "Review of Occupational Hazards Associated With Aquaculture," J. Agromedicine, vol. 15, no. 4, pp. 412– 426, Oct. 2010.

> A review of peer-reviewed studies and case reports relevant to occupational hazards experienced by aquaculture workers identified causes of mortality and morbidity, and separated them by aquaculture production method. Ten studies on nearshore salmon production were included; they were published in the 1990's and 2000's and focused on production in Canada, Norway, Ireland, and the United Kingdom. The occupational hazards specific to near-shore salmon production included falls from boats and cages, respirable dust from feed, leptospirosis, muscoloskeletal injuries from lifting nets, diving risks including decompression illness, pesticides, needlestick injuries and complications, self-injection of fish vaccine, and injuries from cages, diving, cranes, hoists, and sea-going workboats. The author concludes by calling for rigorous epidemiological research on risks facing aquaculture workers.

[60] J. D. Douglas, "Salmon farming: occupational health in a new rural industry.," Occup. Med. (Lond)., vol. 45, no. 2, pp. 89–92, Apr. 1995.

[61] A. Watterson, D. Little, J. A. Young, K. Boyd, E. Azim, and F. Murray, "Towards integration of environmental and health impact assessments for wild capture fishing and farmed fish with particular reference to public health and occupational health dimensions," Int. J. Environ. Res. Public Health, vol. 5, no. 4, pp. 258–77, Dec. 2008.

> In this review article, the authors argue for requiring robust, comprehensive health impact assessments that include occupational health and safety when a new fisheries or aquaculture venture is proposed. At the time, there was very little information on rates of morbidity and mortality in the aquaculture sector. The authors also note that most countries with aquaculture sectors do not have regulations specifically designed for aquaculture, instead relying on fisheries or agriculture regulations. The authors state that this situation may result in important regulatory gaps that could impact worker and community health, the environment, and food safety.

[62] J. Fry, D. Love, A. Shukla, and R. Lee, "Offshore Finfish Aquaculture in the United States: An Examination of Federal Laws That Could be Used to Address Environmental and Occupational Public Health Risks," Int. J. Environ. Res. Public Health, vol. 11, no. 11, pp. 11964–11985, Nov. 2014.

> The authors examined U.S. federal laws relevant to public health and offshore finfish production. Marine aquaculture production in the U.S. has so far taken place in state waters and been regulated primarily at the state level. A new, comprehensive set of regulations has not been passed to regulate offshore aquaculture in federal waters. Therefore, existing regulations must be applied to create the regulatory structure and this requires collaboration across multiple government agencies. Identifying relevant laws and potential regulatory gaps is important because aquaculture production can involve hazardous working conditions and the use of veterinary drugs and agrochemicals. The authors describe 11 federal laws that can be used for preventing, controlling, or monitoring potential environmental health risks and identified a potential regulatory gap regarding occupational health and safety in offshore settings.

[63] World Fishing & Aquaculture, "Lawsuit filed against NOAA's new aquaculture regulations," 23 Feb, 2016. Available: <u>http://</u> www.worldfishing.net/news101/fish-farming/lawsuit-filed-against-noaas-new-aquaculture-regulations

- [64] National Oceanic and Atmospheric Administration (NOAA), "A Guide to the Application Process for Offshore Aquaculture in U.S. Federal Waters of the Gulf of Mexico." Available: <u>http://sero.nmfs.noaa.gov/sustainable_fisheries/gulf_fisheries/aquaculture/documents/pdfs/permit_applicant_guide_2.pdf</u>
- [65] B. I. Cohen, "The Uncertain Future of Fraser River Sockeye," Adams River, 2012. Available: <u>http://publications.gc.ca/site/</u> eng/432516/publication.html
- [66] P. Benson and S. Kirsch, "Capitalism and the Politics of Resignation," Curr. Anthropol., vol. 51, no. 4, 2010.