

LEARNING HOW TO FARM FISH:
DEVELOPING SUSTAINABLE AQUACULTURE IN NORTH CAROLINA

by

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Abstract

As the world's population grows, there are greater demands placed on the natural environment to feed people – people whose dietary expectations have changed with globalization and a greater awareness of how other people live. With this increase in the consumption of animal protein, aquaculture has been portrayed as the latest technological panacea to save the environment, promote economic development, and strengthen food security. Aquaculture has also been vilified as depriving fishers of their way of life and causing damage to the marine and coastal environment. In the United States, while there are a number of structural impediments (especially a confusing array of regulatory bodies at the federal level), there are also social and state supports that allow for the development of aquaculture as a sustainable alternative to capture fisheries. Based on participant-observation fieldwork on North Carolina fish farmers in 2011-2012, this project will examine how elements in the culture of aquaculture can develop sustainable fish farming.

Problems in the sustainability of aquaculture have been traced to: a tight coupling to ecosystems and dependence on common-pool resources; poor farm management; weak governance, especially over the environment and market; and a lack of knowledge flow (scientific, technological, and economic) among farmers and between farmers, state agents, and consumers. Because the bulk of NC aquaculture is freshwater or in recirculating aquaculture systems, small-scale, and producing products largely for a niche market (for live fish or lesser-known species such as prawn), fish farmers and the state government in North Carolina are largely able to rely on information-based environmental governance to develop sustainable aquaculture enterprises. The connections between fish farmers, researchers, and state agents, as

seen in the emergence of new aquaculture cooperatives, provide support for the development of sustainable practices, especially as new aquaculturalists learn how to farm fish

Introduction

Food systems show the diversity of human social formations and cultural practices, since everybody must eat. The production, consumption, and exchange of food (however divorced individuals are from the actual making of food) is the most basic economic activity for families throughout the world and a shared social activity in all cultures. As a result, as an index of sustainability, food serves as a highly revealing lens through which to examine the triple bottom line or E³: Environmental conservation, Economic efficiency, and social Equity¹. As the world's population grows, there are greater demands placed on the natural environment to feed people – people whose dietary expectations have changed with globalization and a greater awareness of how other people live. With this increase in the consumption of animal protein, aquaculture has been portrayed as the latest technological panacea to save the environment, promote economic development (Sachs 2007), and strengthen food security (Godfray et.al. 2010). There is much to recommend sustainable aquaculture, especially when compared to other animal protein sources. Fish in general have a higher feed conversion ratio (the amount of feed necessary to produce one kilogram of meat) than beef, pork, or poultry (see Table 1 in the appendix; Steinfeld et.al. 2006; Hall et.al. 2011). Aquaculture has lower environmental costs when compared to other livestock production, whether in terms of land use and degradation, pollutant emissions, or fresh water and energy consumption (Hall et.al. 2011).

¹ The triple bottom line is also known in the business world as “people, planet, profit”; E³ is based on the Energy-Environment-Economy policy modeling conducted by the EU in preparation for Kyoto, but has been popularized in the corporate sustainability business literature as “ecology, economy, equity” (see Schumpeter 2011, Young and Tilley 2006).

The per-capita supply of fish for food is at an all-time high and the number of people employed in the fisheries sector has grown faster than both the overall population and employment in traditional agriculture (FAO 2010c:3-7); this growth in production and employment is happening because of the expansion of aquaculture. Farmed fish are also the fastest growing agricultural sector (between 1970 and 2008, see Table 2), outpacing population growth (FAO 2008:6), with the highest value in global trade (see Table 3). In 2008, aquaculture accounted for 45.7% of the global fish production for human consumption, with an estimated value of US\$ 98.4 billion (FAO 2010c: 18). The bulk of aquaculture production took place in developing countries, with China by far the largest producer (62.3%) of farmed fish (see Table 4). Not counting aquatic plants,

the bulk of aquaculture production (60%) takes place in freshwater, but seawater aquaculture (32%, either in ponds, coastal areas, or marine) provides many high value finfish, crustaceans, and molluscs (see Figure 1). Of these categories, crustacean aquaculture grew at the fastest rate between 1970 and 2008, largely due to white leg shrimp aquaculture in China (FAO 2010c:23).

Much of this growth in aquaculture, however, has been considered by many (Goldburg, Elliot, and Naylor 2001; Pauly 2002) to not be sustainable – meeting the needs of the present without compromising the ability of future generations to meet their own needs (as defined by

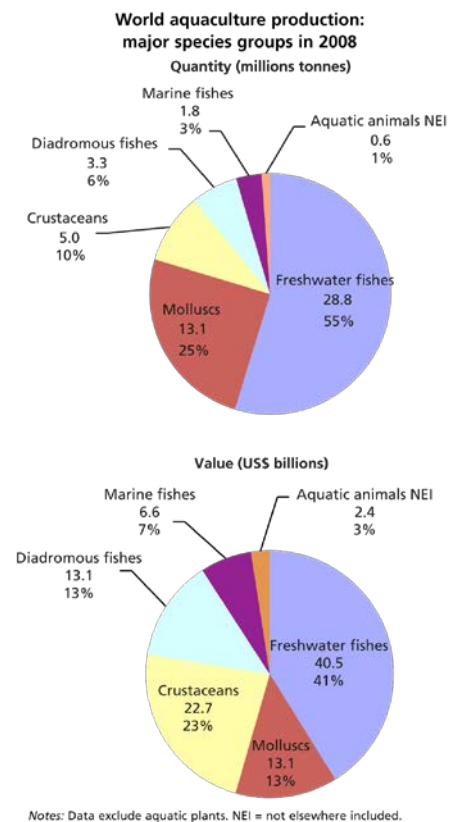


Figure 1 World Aquaculture Production 2008 (FAO 2010b:6)

the Brundtland Commission²). Sustainable development requires that three criteria be met to attain this goal: economic scale within an ecological system, equitable distribution of resources, and efficient allocation that accounts for natural capital (Costanza and Patten 1995:194).

Based on participation-observation fieldwork in 2011-2012, centered around participants in the North Carolina Aquaculture Development conference, this paper will explore how the social context and the resulting relationships established between scientists, farmers, and state agents have resulted in the development of an aquaculture industry in North Carolina that fits definitions of sustainability. While there are many documented examples of unsustainable aquaculture throughout the world, whether from over-intensive stocking of fish and the resulting concentration of wastes (FAO 2010a), overfishing of fish for feed and oil, or other ecological challenges due to problems in scale (Asche 2008), North Carolina aquaculture has been sustainably developed due in large part to appropriate management and education of fish farmers, as well as economic incentives that promote sustainable aquaculture. As opposed to other studies (Basurto 2005) where issues of state management and local, social impediments to access and use can be employed to prevent unsustainable practices, economic self-interest, coupled with strong knowledge flows among both producers and consumers, can promote sustainable aquaculture. The shift towards information-based environmental governance (Bullock 2012), where civil society organizations in partnership with governments establish and popularize sustainability ratings, can discipline business corporations towards sustainable practices in ways that neither the market nor government regulation alone can accomplish.

² The Brundtland Commission refers to the UN World Commission on Environment and Development chaired by then-Norway's Prime Minister Brundtland in 1982. They published the influential report "Our Common Future" in 1987, which contains the oft-cited definition of sustainability (see Kates et.al. 2005:10-12 for this history).

Aquaculture: History and Contemporary Context

Aquaculture is not a new phenomenon, but its explosive growth since the 1970s and domestication of new species makes it appear revolutionary. Documentary sources date the first treatise on aquaculture to 473 BCE in China with the publication of *The Classic of Fish Culture* (FAO 1988:8), but there are also references to tilapia farming even earlier (El-Sayed 2006; Nash 2011). Chinese aquaculture first started with the domestication of various types of carp (using wild fry transferred to ponds). By the fifteenth century, there was a peak in the domestication of aquatic animals throughout the world – fish ponds throughout Europe, the breeding and propagation of freshwater fish in Asia, Japanese shellfish management. By the eighteenth century, other mariculture-based species such as oysters, shrimp, and crabs were actively being farmed at larger-scales using dykes on reclaimed ocean land (Song 1999:10).

However, the Industrial Revolution and the mechanization of fishing fleets starting in the nineteenth century revitalized and expanded marine fishing capability, resulting in a decline in aquaculture. Nash argues that more distant offshore fishing sites, the use of machine-made ice, and the mechanization of fishing equipment led to this early turn away from aquaculture: “Industrialization of fishing brought about an explosion in uncontrolled harvesting of all continental shelves within two to three hundred miles, and all the fertile banks of the North American coastline and its neighboring seas were easy targets of overexploitation” (Nash 2011:46). So while aquaculture could be found throughout the world, it was at a small scale because of the limitations of scientific knowledge and the relative economic efficiency of capture fisheries.

Large scale aquaculture requires modern instruments that can measure oxygen and carbon dioxide solubility, buffering capacity, phytoplankton and zooplankton concentrations and

other critical factors necessary for efficient aquaculture production (Lucas and Southgate 2003:2). Prior to the twentieth century, the bulk of consumed seafood was obtained through capture fishery production (FAO 2008). Prior to 1950, fish and shellfish from capture fisheries were plentiful and cheap for those in the developed world. With the post-World War II emphasis on economic development and the establishment of international bodies like the United Nations Food and Agriculture

Organization, there was tremendous growth in aquaculture, especially in the developing world of Asia and Africa, while technological developments for a small number of highly-valued fish took place in the West (Nash 2011:150). By the 1980s and 1990s, these trends converged, leading to a greater scale of production and diversity of species, resulting in a global trade of fish that was managed scientifically using more intensive techniques. Aquaculture has increased sharply in the past decade, but still does not produce as much as capture fisheries. In 2006 the global capture production of seafood was 53% of a total of 110 million metric tons compared to 47% for global aquaculture (FAO 2008:3).

With declines in capture fisheries, aquaculture can have a crucial role in making future seafood production sustainable. Capture fisheries are depleting the stock of wild fish: 28% of stocks are either overexploited, depleted, or recovering from depletion; another 52% of stocks are categorized as fully-exploited (FAO 2008:7). Overfishing is not just a result of the application of industrialized production technologies to fishing; studies have shown that

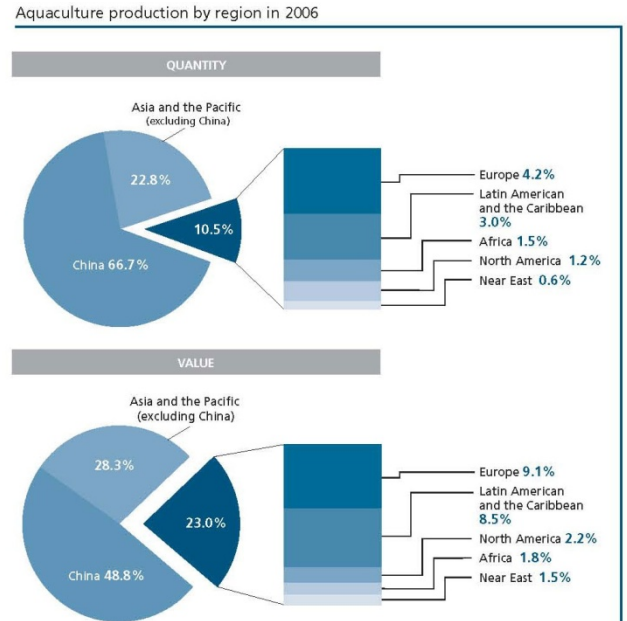


Figure 2: Aquaculture production by region, 2006 (FAO 2008:18)

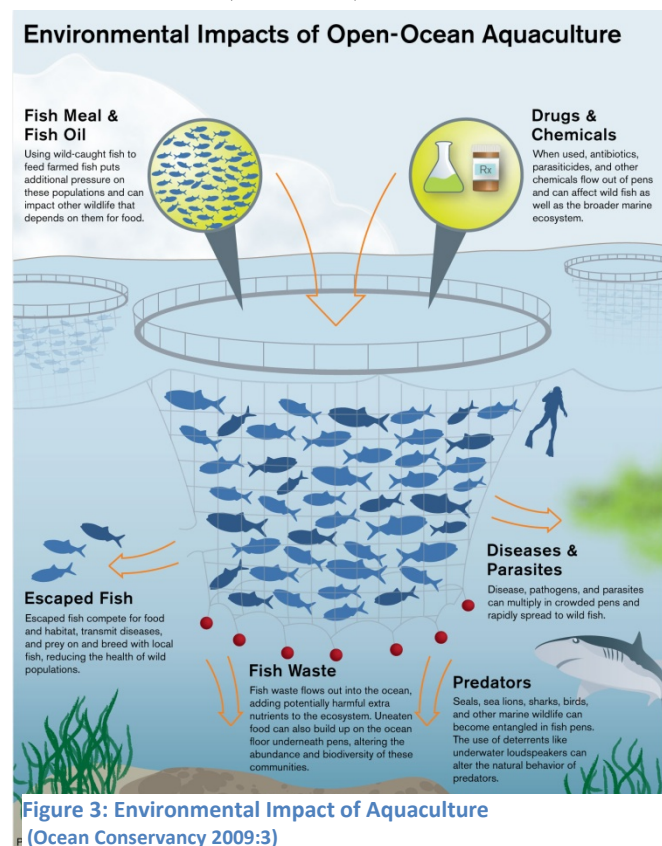
overfishing is a historical condition, predating more recent technologies such as bottom trawling and sonar. Jackson et.al. conclude:

Contrary to romantic notions of the oceans as the “last frontier” and of the supposedly superior ecological wisdom of non-Western and precolonial societies, our analysis demonstrates that overfishing fundamentally altered ... ecosystem structure and function ... as early as the late aboriginal and early colonial stages, although these pale in comparison with subsequent events. (2001:636)

Since these stock depletions have largely been in the more desirable, larger carnivorous species, capture fishing has shifted towards “fishing down the food web” – towards less valuable, smaller species at lower trophic levels (Naylor, Goldburg, et.al. 2000). As a result, Pauly, Christensen et.al. further argue that capture fisheries are inherently unsustainable, with a number of very rare and specific exceptions in undeveloped and remote communities (2002:689).

Aquaculture, however, faces numerous challenges in achieving sustainability. First, domesticated fish species require tremendous amounts of feed and fish oil for their managed growth: “much of what is described as aquaculture, at least in Europe, North America and other parts of the developed world, consists of feedlot operations in which carnivorous fish (mainly salmon, but also various sea bass and other species) are fattened on a diet rich in fish meal and oil” (Pauly, Christensen et.al. 2002:693). In fact,

many others argue (Smith, Asche, et.al. 2010; Goldburg, Elliot, and Naylor 2001; Naylor,



Goldburg et.al. 2000) that aquaculture is accelerating the “fishing down the food web” phenomenon, as less desirable fish are converted to feed for more desirable fish; for example, aquaculture production use fish feed at economic ratios of between 2.4 to 1.3 (feed to produced fish, Tacon 2005:46).³ It must be noted, however, that aquaculture consumes less than half of global fishmeal production (poultry, pigs, and other ruminants consume equivalent percentages; Tacon 2005:7); but aquaculture does consume over 80% of fish oil.⁴ Moreover, when compared to other industrialized livestock production (i.e., cattle, pork), aquaculture fairs better in environmental performance (Pelletier et.al. 2009:8735). Nonetheless, the greatest growth in global aquaculture is among large-scale operations growing high-value fish, and not among less-desirable, lower-trophic fish that could be used to “farm up the food web” because it is not economically profitable (Halweil 2008:20).

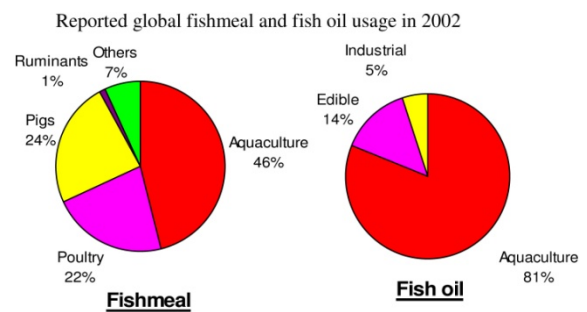


Figure 4: Fish Meal/Fish Oil Usage
(Tacon 2005:7)

Second, the creation and expansion of fish farms results in the loss of critical coastal and marine habitats. While the oceans seem vast, the areas suitable for mariculture (aquaculture in coastal and ocean waters) as currently practiced are limited. Naylor, Goldburg et.al. 2000 specifically point out the environmental problems created by conversions of mangroves and coastal wetlands into shrimp farms as especially damaging to the marine ecosystem as a whole (2000:1020). Third, wild fish stocks are further depleted as sources of seedstock for aquaculture.

³ Economic feed conversion ratios (FCR) are the total feed input divided by the total live fish output. According to Tacon (2005), FCR's have decreased since the 1980s, despite the increase lower trophic capture fishing production and leveling of fish feed production. Tacon's values differ from Goldburg, Elliot, and Naylor (2001), even through the dataset comes from Tacon; this comes from the difference between biological FCR (net amount of feed to produce one kg of fish) vs. economic FCR (all the feed used, taking into account feed losses and mortality).

⁴ Goldburg, Elliot, and Naylor (2001) note that for animal feed, fish meal and fish oil contained the highest levels of dioxins and PCB's (2001:12); this food safety issue for aquaculture needs more exploration than is possible here. Substitution of n-6 fatty acids in non-fish oils (with healthier n-3 fatty acids) may affect consumer demands for healthy protein sources (Naylor, Goldburg et.al. 2000:1022).

In the pursuit of seedstock, bycatch wastage can be as high as 85% (with only 15% of the catch comprising the desired seedstock; Naylor, Goldberg et.al. 2000:1021). Fourth, the mixing of domesticated and wild species, or the introduction of non-indigenous species through the expansion of aquacultural enterprises in various global locales, can not only disturb or transform local populations through habitat displacement and competition for food, but also introduce new diseases and parasites (Bondad-Reantaso, Arthur, and Subasinghe 2008:17).

In salmon mariculture for example, escaped fish are an especially acute problem; Food and Water Watch asserts that each year, two million “genetically-inferior, domesticated interlopers”⁵⁵ (Food and Water Watch 2007:3) escape into the North Atlantic, a number equivalent to the depleted population of wild Atlantic salmon. Lastly, intensive aquaculture, by concentrating fish populations in one place, creates effluent discharge toxic to local riverine and marine ecosystems. These discharges include excess feed, veterinary pharmaceuticals, and animal wastes, by aquaculture that take a “dilution as solution to pollution” approach to minimizing pollutant effects (Naylor, Eagle, and Smith 2003:31).

Sustainable aquaculture that minimizes these environmental challenges is possible, but needs proper management and economic accounting of the externalities that encourage “dilution as solution” approaches by aquacultural enterprises. Aquaculture production systems span a wide variety of ecological systems and scale; there clearly can be no “one size fits all” solution for both small-scale family pond production and industrialized mariculture in the myriad of local governmental regimes throughout the United States and internationally: “The diversity of production systems leads to an underlying paradox: aquaculture is a possible solution, but also a contributing factor, to the collapse of fisheries stocks worldwide. (Naylor, Goldberg, et.al.

⁵⁵ Naish et.al. 2007 conclude a more positive effect of hatcheries on wild salmon populations in the Pacific Northwest, suggesting that they aid in restoring endangered populations and that conflicts over domestic vs. wild salmon are largely social in nature.

2000:1017) Polyculture has been promoted as one way to reduce problems caused by effluent discharge and habitat degradation. Integrating production systems so that different species reuse or filter animal wastes, such as growing seaweed and mussels with salmon, reduces nutrient and

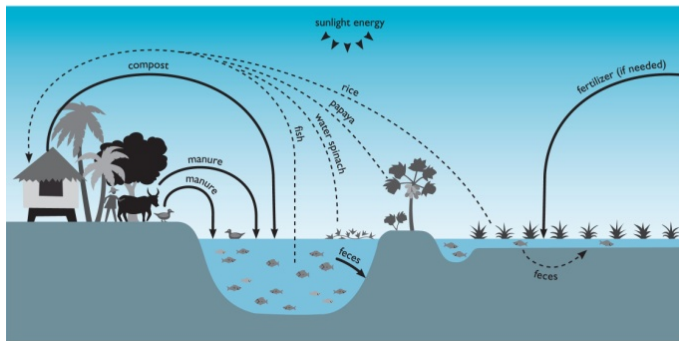
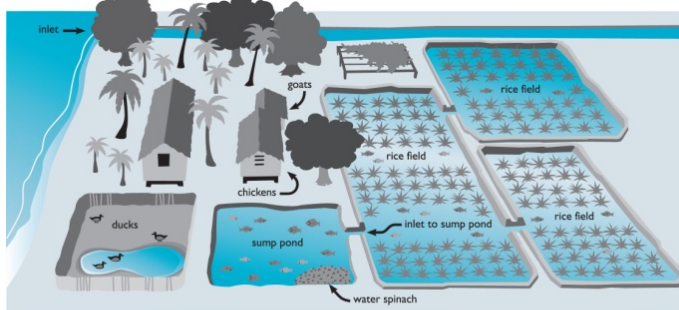


Figure 5: Traditional Integrated Aquaculture (White, O'Neill, and Tsankova 2004:10)

particulate loads while diversifying the aquacultural products produced (Naylor, Goldberg et.al. 2000:1022). Another promising approach for environmentally-sustainable aquaculture is the use of closed or recirculating systems, allowing for the separate treatment or repurposing of effluent discharge (White, O'Neill, and Tsankova 2004:12). Requiring the

building of tanks and other water transport infrastructure, these closed systems are more capital-intensive than marine farming using cage systems that allow the circulation of seawater (Lucas and Southgate 2003:309-314).

Regulatory Issues in Aquaculture

For capture fisheries, the Magnuson-Stevens Fishery Conservation and Management Act is the primary legal framework for regulating and managing the industry; the lead department is Commerce, through NMFS. Aquaculture, however, largely falls outside the jurisdiction of NMFS. For aquaculture, the National Aquaculture Act of 1980 is the primary legal framework, and positions the Department of Agriculture as the lead federal agency. The main purpose of this act was to promote and develop domestic aquaculture in order to increase fish production,

maintain food security, and reduce trade deficits. The act called for the development of a National Aquaculture Development Plan, the Joint Subcommittee on Aquaculture, and a National Aquaculture Information Center (Fletcher and Watson 1999:2). Other than adjustments to aquaculture because of changes to other laws (see Table 1), not much has changed in the regulatory environment since the passage of the National Aquaculture Act of 1980. Many of the impediments to the development of aquaculture identified by the Joint Subcommittee on Aquaculture in 1983 such as legal constraints due to overlapping jurisdictions and multiple-use conflicts continue to hold true in the 21st century (JSA 1983:28-30).

In the 2012 National Ocean Policy Draft Implementation Plan, the latest call for action from the federal government, the National Ocean Council again echoes the appeal from more than thirty years ago for greater development of the aquacultural sector to “create jobs, provide affordable and accessible food, and lower our trade deficit (currently 86-percent of seafood consumed in the United States is imported)” (National Ocean Council 2012:18). This latest federal push in aquacultural development specifically includes the call for a National Shellfish Initiative (to simultaneously reap ecosystem benefits and commercial value), greater streamlining of permitting processes (at the federal level and in the federal-state interaction), and use coastal and marine spatial planning to encourage greater participation from stakeholders.

Table 1: Federal Regulation of Aquaculture (modified from Goldberg, Elliot, and Naylor 2001:21)

<p>National Aquaculture Act (1980) Gives the US Department of Agriculture (USDA) lead authority in developing aquaculture, coordinating between Commerce, Interior, and other federal agencies.</p>	<p>Magnuson-Stevens Fishery Conservation and Management Act (1976, amended 1996 and 2006) Gives National Marine Fisheries Service (NMFS) authority over aquaculture operations in the Exclusive Economic Zone (EEZ).</p>
<p>Clean Water Act (1972, amended 1977 and 1987) Gives the EPA authority to control point-source discharge of effluent and Army Corps of Engineers permitting authority in conversion of water bodies for aquaculture.</p>	<p>Rivers and Harbors Act (1899) Gives the Army Corps of Engineers permitting authority for structures in navigable waters (including offshore aquaculture facilities).</p>
<p>Lacey Act (1900) Prohibits interstate trade of wildlife that have been illegally taken, transported, or sold. Prevents spread of potentially non-native species.</p>	<p>Endangered Species Act (1973) Gives US Fish and Wildlife Service (FWS) authority to manage aquaculture operations when it interferes with a covered species.</p>
<p>National Invasive Species Act (1990, amended 1996) Targets aquatic nuisance species.</p>	<p>The Migratory Bird Treaty Act (1918) Gives FWS authority to manage migratory bird predation of aquaculture fish.</p>
<p>Marine Mammal Protection Act (1972) Prohibits actions against marine mammal predation of coastal and open-ocean aquaculture fish.</p>	<p>Federal Insecticide, Fungicide, and Rodenticide Act (1910, amended 1947, 1988, and 1996) Grants authority to EPA to regulate aquaculture inputs.</p>
<p>Food, Drug, and Cosmetic Act (1938) Establishes the Food and Drug Administration (FDA) and its role in oversight of food safety issues.</p>	

In terms of direct regulation and management of aquaculture, there does not appear to be one functioning body responsible for permitting, evaluation, or enforcement; instead, the various federal agencies monitoring wider environmental, economic, transportation, and health issues together oversee the practices of aquacultural production. These bodies include the EPA, the Army Corps of Engineers, the US Fish and Wildlife Service, NMFS, and the FDA.⁶ The permitting process is further complicated because of the varied conditions required for different

⁶ In addition to the regulations listed in Table 1, there are many more acts which impact aquacultural production, include historical laws such as the Lacey Act “originally intended to combat hunting to supply commercial markets, the interstate shipment of unlawfully killed game, the killing of birds for the feather trade and the introduction of harmful invasive species” (Springsteen 2010:2).

species, requiring the intervention of state aquaculture coordinators to navigate through the myriad of regulatory regimes (Gegner 2006:4).

This myriad array of regulatory regimes leaves big holes in the net of aquacultural management, especially for mariculture. As is apparent in *United States Public Interest Group v. Atlantic Salmon of Maine, LLC*, 215 F. Supp. 2d 239 (D. Me. 2002), the failure of the EPA to create regulations that govern discharges from nearshore net pen aquaculture production and to provide clear definitions of what constitutes a concentrated aquatic animal production facility (CAAPF) resulted in environmentally-damaging violations of the Clean Water Act by an aquaculture operation. The court found Atlantic Salmon of Maine at fault even though it had applied for permit under the National Pollution Discharge Elimination System from the EPA in 1990. The EPA failed to respond (either positively or negatively) to the request by the time of the lawsuit, despite frequent attempts by the defendants to inquire about the status of their application. Price (2004) further concluded that the EPA's regulations allowed for discharges that violated the standards of the Endangered Species Act (at that time, the Atlantic salmon population was listed as endangered) as well as the Clean Water Act (a situation that was remedied by the court in their decision, Price 2004:720). Management via the court system, in lieu of clear guidelines from a regulatory body, is an inefficient way to build a sustainable aquacultural enterprise.⁷

While the selection of the Department of Agriculture as the lead agency for aquaculture makes sense because of its expertise and experience in commercial farming issues, the role of NMFS in aquaculture is less clear. Because of the longer history of freshwater aquaculture and shellfish coastal mariculture, regulatory mechanisms and permitting processes are relatively clear

⁷ Anderman-Hahn further concludes that the Atlantic Salmon of Maine case is evidence that the federal government is repeating lessons that should have been learned from agriculture in their irregular regulation of aquaculture (2006:1008).

in these operations, with state departments of agriculture, working with the USDA, managing day-to-day operations. However, the situation for coastal and off-shore finfish mariculture is less clear. Based on jurisdictional division, it appears that NMFS takes the lead for aquaculture operations place offshore, beyond state boundaries (open-ocean mariculture). The current process is managed through an Exempted Fishing Permit (EFP) issued by NOAA, a process which has only been used by five offshore operations and which NOAA has concluded is not viable for commercial aquaculture (Gulf FMC 2009:22). NOAA, with the support of Congress, attempted to resolve this issue in what was the National Offshore Aquaculture Act of 2007 (referred to committee, but never reported by committee to the House). In this legislation, NOAA hoped to have implemented a coordinated permitting process that incorporated a “programmatic environmental impact statement (EIS), regional mapping exercises to identify suitable and acceptable sites for offshore aquaculture, and interagency, state, and public consultations will be required as part of the regulatory design process” (NOAA 2007a:16).⁸ Without this legislation, the approval process for offshore aquaculture can be subjective, and greatly damaging to both the environment and fisheries. Moreover, NMFS’s expertise with marine species and the ecological interconnections between aquaculture and capture fisheries could remain untapped.

One of the benefits of aquaculture is the relief of pressure by fisheries on wild stocks; instead aquaculture has interfered with recovery, in part because the Magnuson-Stevens Act has not been fully applied to the industry as a whole, especially because of jurisdictional issues

⁸ Many in congress feel that aquaculture is not fishing; therefore NOAA does not have jurisdiction in this matter based on the Magnuson-Stevens Act. Various non-governmental organizations have attempted to revive this legislation, as seen in the National Sustainable Offshore Aquaculture Act of 2009 (Ocean Conservancy 2010).

between state and federal authorities.⁹ In addition to these direct interactions between aquaculture and capture fisheries, there is also a social dimension – the ongoing conflict between fishers and fish farmers, since fishers see themselves being economically displaced by fish farmers due to globalization and declining wild stock levels (Andreatta and Parlier 2010; Tango-Lowy and Robertson 2002; Ziegenhorn 2000).

What is needed at the federal level is clear policy on finfish coastal and off-shore mariculture (Devoe 1995), even though the current viability of off-shore mariculture remains questionable (Dempster and Sanchez-

Jerez 2008). The National Offshore Aquaculture

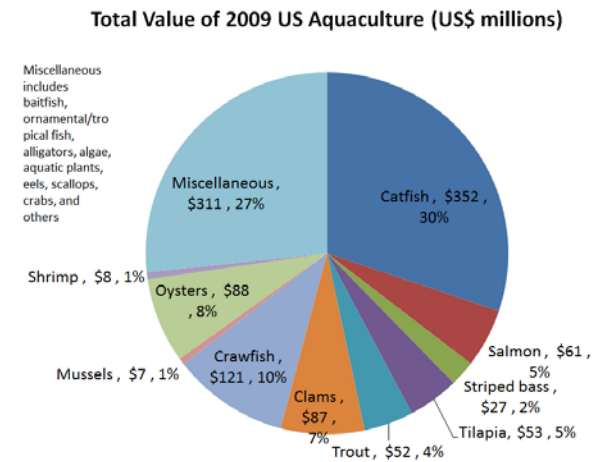


Figure 6: Data from NOAA 2011a:16

Act of 2007 (HR 2010), like the 2005 Senate version sponsored by Senator Ted Stevens, sought to standardize the regulatory structure over finfish coastal and off-shore mariculture. Opposition to this bill by environmental justice, consumer health advocates, and fishery advocacy groups was strong, and it did not make it out of committee. Davies argues that there are indeed structural problems (i.e., no acreage limit, no specific mechanism to balance the uses of the ocean by different stakeholders, see Davies 2007:117-119) in the National Offshore Aquaculture Act of 2007 that could be corrected through the implementation of marine zoning. Marine zoning, implemented by other countries such as Australia and New Zealand, would better account for the competing interests of different stakeholders and would allow for better management of

⁹ “Aquaculture facilities are placed directly in the oceans and coastal bays, allowing chemical and biological pollutants, including pesticides, antibiotics, uneaten fish feed, fish feces, and the fish themselves to escape into the water - thereby significantly altering ecological interactions. And yet, the primary federal law governing the protection of the nation’s fisheries and marine habitat, the Magnuson-Stevens Fishery Conservation and Management Act has minimally and inconsistently been applied to aquaculture” (Englebrecht 2002:1188).

environmental impacts through ecosystem based management (2007:102-104; see also Dempster and Sanchez-Jerez 2008).

None of this was made explicit in the final 2011 National Aquaculture Policy (NAP) released by the Department of Commerce in June 2011. While the policy again stated that the goal was to develop domestic aquaculture of all types so as to increase production in an environmentally and economically sustainable manner, there was no mention in the NAP about the use of marine zoning or clarifying the jurisdiction over mariculture. However, as part of the announcement of the NAP, NOAA also stressed that the National Shellfish Initiative and the Gulf of Mexico Fishery Management Plan for Aquaculture would be implemented; these two documents do specifically spell out the need for marine zoning, spatial planning, and ecosystem-based management. The 2012 National Ocean Policy Draft Implementation Plan makes most explicit the need for coastal and marine spatial planning in the permitting of coastal and offshore mariculture (National Ocean Council 2012:85-92).

North Carolina. The disconnections that take place at the federal level are not as evident at the state level, since jurisdictional lines are clearer because of the smaller scale and because of the absence of offshore mariculture in the EEZ near North Carolina. Within state ocean waters, the North Carolina Coastal Resources Commission and the Marine Fisheries Commission have shared jurisdiction over aquaculture; a permit is required from the Division of Marine Fisheries (DMF), and then a CAMA permit to build the facility. For mariculture in North Carolina, only flounder and shellfish (for either bottom or water column lease) are specified in NC DMF regulations. The bulk of aquaculture in North Carolina is either freshwater or recirculating water, and is managed by the North Carolina Department of Agriculture and Consumer Services (NCAgr). While the NC Wildlife Resource Commission (NCWRC) is responsible for the vitality

of freshwater and brackish water ecologies, and approves the farming of non-indigenous fish, NCAgr has the lead in working with potential fish farmers in navigating the licensing bureaucracy.

Following the National Aquaculture Act of 1980, the North Carolina General Assembly passed the Aquaculture Development Act (ADA) in 1989, which, like the national act, recognized aquaculture as a type of agriculture in North Carolina. This act established the authority of NCAgr as the permitting office and specified the species that could be farmed without special approval from the NCWRC (see Table 6 in the Appendix). Tilapia, one of the more popular farmed fish in North Carolina, is not on the list of native species, and requires additional oversight prior to a permit being issued. The NC ADA also created the Joint Legislative Commission on Seafood and Aquaculture, the legislative body which oversaw the development and management of aquaculture in North Carolina by state bodies such as NCAgr, the Division of Marine Fisheries, and developments at the federal level which pertain to North Carolina. The Joint Commission, however, was discontinued in June 2011 as part of a bill reducing the size of the North Carolina state government.

NCAgr issues three types of aquaculture licenses: Aquaculture Propagation and Production Facility License (production license, valid for five years), a Commercial Catchout Facility License (fee-fishing license, valid for five years), and a Holding Pond/Tank Permit (if neither of the two above licenses are held, valid for two years).

Aquaculture in North Carolina

Not including shellfish mariculture, the first documented commercial aquaculture operation began in 1950, with Rainbow Trout, followed by the seeding of oyster beds in

response to depletion of stocks by disease (MSX and Dermo, NC General Assembly 1991:3-4). By the 1980s, there were a number of different species with a production value between US\$ 9-12 million in North Carolina: rainbow trout, catfish, hybrid striped bass, and crawfish (NC General Assembly 1991:6-7). In 2003, the net total value of NC aquaculture had risen to US \$45 million, with the bulk of revenue coming from the fish production, hatcheries, and processing of rainbow trout, catfish, hybrid striped bass, tilapia, and shellfish (NC Aquaculture 2004). Despite the economic recession of 2008, in 2011, the net total value was \$52.9 million, with a significant increase in the value of hybrid striped bass and tilapia production and the addition of flounder, freshwater prawns and black sea bass (NC Aquaculture 2012).

Table 2: NC Aquaculture Production Value (US\$ million)

	1990	2003	2011
Trout	Unknown	19.2	16.5
Catfish	Unknown	18.2	19.6
Hybrid Striped Bass		5.8	9.9
Tilapia		2.1	3
Yellow Perch		0.05	0.04
Crawfish	Unknown	0.045	0.038
Shellfish	Unknown	0.8	0.5
Flounder			0.006
Prawns			0.25
Black Sea Bass			0.01
Blue Crab			2.1
Total Value	12	45	52.9

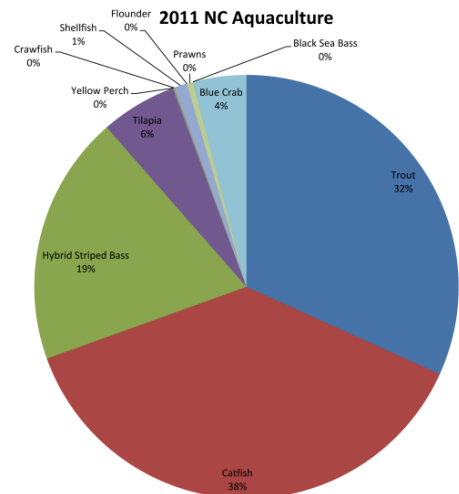


Figure 7: 2011 NC Aquaculture Production, by Fish

With mountains in the west and coastal plains in the east, North Carolina’s diverse natural environment has resulted in a diversity of species raised and production techniques. Aquaculture in the west is largely cold water flow-through tank production focusing on trout and more recently sturgeon (for meat and caviar), while in the piedmont recirculating tank production using tilapia is more common. The bulk of NC aquaculture lies in the coastal east, using warm water outdoor pond production of various fish and coastal mariculture of shellfish. Processing of

trout, catfish, and sturgeon have also become a more significant part of the aquaculture industry in North Carolina. As is evident in the relative paucity of mariculture, there is a large difference in the political ecology of aquaculture in North Carolina and other states where mariculture farmers have to negotiate a more complicated layer of federal management by NMFS.



Farmers, not Fishers: Hybrid Striped Bass.

While striped bass was abundant in the American east coast, the striped bass was introduced to California and the west coast by Dr. Livingston Stone in 1879; by 1897, striped bass was abundant in California waters, supporting a popular fishery (US Fish Commission 1900:187). The cultivation of striped bass was continued for environmental mitigation and re-stocking of wild fisheries because of its value to the sport fishing industry. With the development of the hybrid striped bass (a cross between striped bass *Morone saxatilis* and white bass *Morone chrysops*) in the early 1980s, commercial scale production began in the early-1980s in California (tank-raised) and North and South Carolina (pond-raised) (Carlberg et.al. 2000:26; Monterey Bay Aquarium 2005:4). The development of the hybrid striped bass resulted in a fish that had faster growth in its first two years, better survival, and greater resistance to disease (Kohler 2004:2). In 2005 (the last date for the USDA Census of Aquaculture), the hybrid striped bass foodsize production industry had sales valuing over US\$ 27 million, with North Carolina having the most number (27% of American farms) of hybrid striped bass farmers (USDA 2005:25).

As part of a group visiting farms as part of the NC Aquaculture development conference, I met one owner of a hybrid striped bass farm whom I will call Tim Dennis. This bass farm, located in Craven county in rural eastern North Carolina, is surrounded by other farms that grow various crops, poultry, and other agricultural products. The NC State extension agent who

organized the tour introduces Tim and his farm as a “mom and pop operation,” where Tim’s wife Betty has a full time job off the farm while Tim tends to the business that they started in 1991. Prior to starting their hybrid striped bass farm, Tim was a water quality engineer for a manufacturing company in the area, while Betty worked for another local manufacturing company. After establishing their farm, Tim and Betty were also active in establishing the first fish farmer’s cooperative¹⁰ in North Carolina in 2002. The cooperative serves as brokers and provides marketing information to its members.

In the chilly morning during the farm visit, Tim explained his philosophy as a trading quantity for quality by keeping his fish happy: “when the fish are feeling good, they’ll be feeding good.” While their goal of “getting meat on the bones,” as Tim put it, is similar to other hybrid striped bass farmers, because his farm is relatively small (with eight ponds), he can “baby the fish.” The trick he said is to keep a balance between the amount of feed used and maintaining water quality. Much of his management work is focused on maintaining pond water quality: keeping adequate levels of aeration, watching for toxic algae blooms, and other environmental factors that make the fish eat less. He takes special steps to reduce stress on the fish during harvest as well. For example, he does not use tractors to help with harvesting, after noticing that the fish swim hard away from the noise of the tractors; instead, he uses a net that is hand-cranked. While Tim employs a number of computerized sensors, he feels that the best diagnostic is to watch the fish.

¹⁰ Orbach asserts that cooperatives serve four functions for its members: they increase profitability, reduce costs, widen the range of goods and services available, and maintain or further social or political goals of its members (1980:48). He further describes cooperatives as democratically-controlled, sharing capital costs and profits by its members, and are registered as some kind of legal entity (1980:49).

The discourse used by Tim Dennis and the other fish farmers I talked with is strongly grounded in the discourses of agriculture and animal husbandry; they are mostly neighbors¹¹ with other farmers (with the notable exception of urban aquaculture, discussed later) and share the same attitudes, concerns, and approaches to solving problems; this culture is different than that described for fishers. In asserting the relevance of maritime anthropology as a field, James Acheson (1981) asserts that there is a shared culture among fishers in different societies throughout the world because of common social and ecological constraints. These commonalities exist largely because their production site is the marine environment: fishers work in dangerous seas, within the relatively confined spaces of fishing boats (sometimes for extended periods of time), and with less direct knowledge about the target of their fishing (Acheson 1981). Their work also is an exploitation of a public resource, which leads to unique conflicts very different from those engaged in work on private property. As a result, fishers have a strong commitment to fishing itself, outside of economic explanations, with a stress on cultural values such as independence and a lack of regimentation (Acheson 1981:296; Pollnac and Poggie 2006; Tango-Lowery and Robertson 2002; Walters 2007). While many problems arise from the fishers own interaction with the natural environment, there is also a shared distrust of ‘outsiders’ who are seen as exacerbating the situation, whether indirectly through economic manipulation or directly through concentrated exploitation of resources (McKay 1978).

The distinct cultures between fishers and fish farmers are clearly seen in mariculture where fishers and fish farmers are intertwined due to shared uses of maritime space. In his study of salmon farming and lobster fishery in the Bay of Fundy, Bradley Walters (2007) details the interaction between the two communities. While he notes the trend of conservatism among the

¹¹ The sample of aquaculturalists in this essay is clearly skewed towards inland operations because of my entry point through the NC Aquaculture Association; but the other works cited in this essay confirm the need to approach the culture of fish farmers from a different perspective than the culture of fishers.

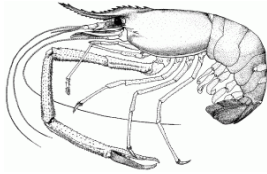
fishers, he asserts that fishers are not closed to working with fish farmers¹², and notes that there are more accepting attitudes towards fish farmers among younger fishers. Tango-Lowery and Robertson (2002) in particular examine predispositions among fishers that would lead them to switch over to farming, which they conclude is not merely a technological innovation but an occupational change for fishers. Tango-Lowery and Robertson essentially concluded that those fishers willing to change were less embedded in the culture of fishing – they had less commercial fishing experience, broader experience in different fisheries, and saw marine aquaculture as a more prestigious occupation (2002:249). Their conclusion corroborates the earlier observation by Acheson that fishers saw that “aquaculture is largely for the middle class” (1981:306).

What is most evident from the tone used by Tim in talking about hybrid striped bass farming is that aquaculture is clearly farming, and not fishing. The primary emphasis he placed in explaining to me and others how to be a successful fish farmer was on husbandry – taking care of the fish, so that they can take care of you via the marketplace. While both fish farmers and fishers rely on technology, there is a vast difference in approach because with its controlled environment, aquaculture is reliant on private resources.¹³ This alone does not ensure sustainability – there are many examples of unsustainable agriculture, as can be seen in neighboring industrialized chicken and pork farms. However, given the smaller scale of North Carolina fish farms and the tight interaction with extension agents and university researchers, small farmers like Tim can manage their fish in ways that minimize environmental impact – which also lessens his own cost in managing his property for long-term usage. When combined

¹² Walters’ study of course examines two species that are not in direct competition, since the fishers’ benthic lobsters can share the water column with the farmer’s salmon, but there are concerns by fishers because of issues of disease, pollution, and other potential

¹³ Participation in cooperatives clearly develops a common pool of resources, as will be discussed later, but the success of a particular enterprise within the cooperative is largely dependent upon the individual enterprises.

with other farms through their local cooperative for marketing and sales, however, Tim can also attain economic sustainability, making a living through aquaculture.



Working Together, Locally: Giant River Prawns.

The global shrimp aquaculture industry has grown tremendously in the past three decades, stimulating both the production and consumption of shrimp. From 2000 to 2008, crustacean aquaculture has increased on average 15 percent annually, due in large part to white leg shrimp production in China, Thailand, and Indonesia. Shrimp aquaculture is particularly suited for the global market because it is a relatively high-value commodity; in 1999, the value of shrimp from aquaculture from 1.1 million metric tons was US\$ 6.7 billion (World Bank et.al. 2002:1); in 2009, worldwide shrimp aquaculture grew to a production level of 5.3 million metric tons (FAO FishStat). As a result, shrimp farming is economically-viable for small-scale farmers with less than five hectares of land (World Bank et.al. 2002:1). While the shrimp fishery is a US\$10 million dollar industry (in 2010, according to NC DENR), at present there is no commercial shrimp farming in North Carolina.

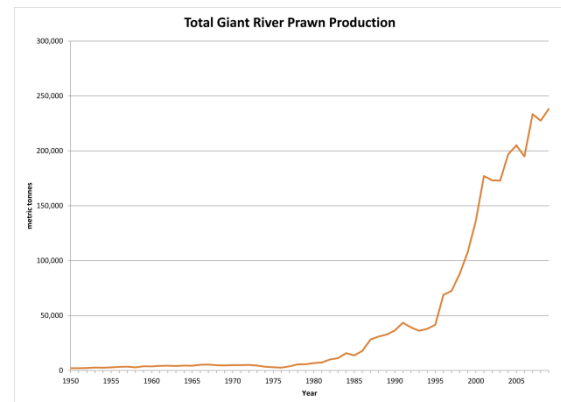


Figure 8: World Giant River Prawn Production (FAO FishStat)

There are, however, 10 active growers of giant river prawn (*Macrobrachium rosenbergii*) in North Carolina, which also serves as the home of the American Prawn Cooperative.

While shrimp and prawn aquaculture have a long history, modern shrimp farming started in Taiwan during Japanese colonization in the 1930s (Nash 2011:88). With the discovery of the need for salt water for the development of freshwater prawn larvae in 1961 by Ling Shao-wen in Malaysia (Fast and Leung 2003:246), prawn aquaculture took off in Asia once seed production

was possible. While freshwater prawns were a recognizable commodity in Asia, they were less recognizable in the West, and there is a noticeable difference in the taste and texture between freshwater prawns and marine shrimp. With its sizeable Asian-American population and a long history of aquaculture, however, fish farmers in Hawaii began cultivating prawns in the late 1960s (Fast and Leung 2003) and in the southern states in the US mainland by the 1970s (New 1990). In the United States, the target consumer continues to be Asian-American populations, where live or frozen whole “heads-on” prawns are preferred (as opposed to processed tail meat), although with the changing tastes of the wider American population, prawns are seen as an ideal product for maintaining a “domestic market image” that privileges local providers because of technological difficulties in transporting live or undamaged frozen whole prawns (New 1990). Overall, domestic prawn aquaculture is a small, niche market that produces less than 1% of the US consumption of shrimp and prawn, and the bulk of that is Pacific white shrimp (Monterey Bay 2009a).

I met with one prawn producer in eastern North Carolina, Dan Insmith (pseudonym) at a time when his ponds were empty in February, 2012. Freshwater prawns need 70 degree water for a 160 day grow-out, which takes place for Dan between May and October. Similar to the case for Tim and Betty discussed earlier, Dan and his wife also had full-time jobs outside of farming in the area. However, with federal support for farmers to shift away from tobacco, in 2005 they decided to use the land at his family farm that he inherited from his mother (and previously rented to tobacco farmers) to raise prawns. The first prawn farm in North Carolina was also established in 2002 by a farmer who previously grew tobacco; that farm continues to produce prawn and now provides seed for local farmers. Since then, Dan Insmith has expanded his prawn farming by including more sophisticated freezing and processing techniques. In our discussion of

his experience as a prawn farmer, Dan asserted that “it’s all about the marketing... much of my work involves educating people about my product,” which is why establishing a local cooperative was an early goal in his career as a prawn farmer.

He also said that he could not have accomplished what he did without the advice of the NC State extension agents. Dan states that prawns do not compete with shrimp fisheries in the local area; most of his customers are up north in New York and out west in California (areas with more significant Asian-American populations); he has run into problems with local buyers who are not familiar with prawns (i.e., unlike shrimp, thawed prawns cannot be refrozen – they turn into a pulpy mush). As a result, he believes in “less is more” – he primarily markets and sells his prawns to higher-end consumers who are willing to pay higher prices for high-quality, whole prawns. He is also interested in educating local consumers about prawns, and talked in detail about one harvest where he had a local chef give a cooking lesson in cooking with prawns.

With the help of the USDA, NC Department of Agriculture, and the NC State University Cooperative Extension, Dan was instrumental in establishing the American Prawn Cooperative (APC) in May of 2008 and is a former president, as one of the five original founding members. According to Charlotte Janeway (pseudonym), the current president of the APC (now with seven farms), their mission is to produce an all-natural wholesome product and to provide enhanced marketing services to producers of freshwater prawn. In describing the founding of this industry, Janeway said:

When we all got together and formed this coop, we basically sat down and had a meeting and we said hey, we're going to make this work, because we already know, my husband and I are all farmers, and have been for 30 years, so we basically know how farmers don't always work well together. But in this particular group we all have enough sense to realize it's in our best interest to work together because we are actually creating this industry, we are building this industry.

In addition to sharing marketing information and production expertise with each other, the cooperative provides a processing facility for the prawn farmers so that their product can get to the main buyers in New York and California. With support from the Tobacco Trust Fund Commission, the Rural Advancement Foundation International – USA, and the NC Rural Economic Development Center, the cooperative was able to purchase life haul tanks and trailers and build a processing facility in eastern North Carolina that provides a flash-freeze unit. With this equipment, the cooperative could take live prawns from their farms and individually quick freeze (IQF) the prawns, a step necessary for the majority of buyers who want to present prawns in the shell their diners. In 2012, the cooperative is also currently developing packaging that would individually-pack prawns (with claws) so the frozen prawns remain whole. APC also provides a nutritional label that certifies that the prawns are organic, identifying their prawns as a Monterey Bay Aquarium Seafood Watch “Best Choice” product. The cooperative also continues to explore new markets for their prawns.

As Janeway suggested above, the formation of a cooperative among independent-minded farmers (or fishers, see Poggie 1980) seems problematic, but she suggests that it is in all of their interest to collectively work together for success in their individual enterprises. In this sense, they differ from the Costa Rican fishermen described by Poggie (1980), where conflict can arise between successful and marginal fishers, because the prawn market is relatively new in the mainland United States. Moreover, the contemporary social and economic environment in which cooperatives may thrive (especially for marketing purposes) is different from the 1980s, where cooperatives were perceived by local fishers as an anachronism, or even “communist” (Orbach 1980).

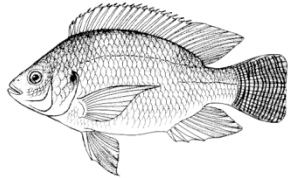
As globalization has penetrated to the most local of regions, however, cooperatives have seen a resurgence of popularity as a symbol of both local resistance to multinational corporations and as a branding mechanism for small enterprises and as a structure that provides an alternative network for producers to gain access to capital-intensive equipment and to expand consumer bases. This revalorization of the local can be seen in new social movements like the Slow Food Movement, the farm-to-table movements, or the locavore movement that have transformed food consumption into political statements. Ideas about sustainability have been coupled together with the strange bedfellow of food security in a way that makes farmers markets and local food products a highly-valued commodity.

In an analysis of Sardinian shepherd cooperatives, Vargas-Cetina (2011) argues that cooperatives serve as a moral bulwark against the visible amorality and social danger of transnational corporations (who are beholden to unseen shareholders, not customers). Paradoxically, however, globalization, with its neoliberal ideology, has also given new life to agricultural cooperatives, where they are essentially treated as small corporations:

Today, cooperatives are still treated as firms of different sizes, so the EU's and the Italian policies continue to apply to them in that general capacity. Agropastoral cooperatives now have to navigate the policies of the European Community, the price fluctuations that occur in the markets where they operate, the funds and projects for businesses and cooperatives promoted and implemented by the Italian government, and the always tighter regulations pertaining to food and food-processing quality enforced by the EU. (Vargas-Cetina 2011:S129)

In other words, cooperatives such as the American Prawn Cooperative can flourish precisely because of its focus on the local, where individual, smaller producers come together in order to survive the economic challenges of large-scale aquaculture enterprises from all over the world. Note that like the Italian cooperatives described by Vargas-Cetina, the American Prawn

Cooperative needed the support of the state, at both the federal and North Carolina levels, in order to develop the capital and technological capacity to sustainably produce their giant freshwater prawns.



Urban Aquaculture – Tilapia.

While the Van Camp Company patented the phrase “chicken of the sea” to brand their white albacore tuna in 1952, the true chicken of the sea (and rivers, lakes, and ponds) is tilapia. Tilapia¹⁴ is the second-most farmed fish in the world, due to their high tolerance for a wide range of environmental conditions, their omnivorous and flexible diet, and their ability to grow quickly in captivity. El-Sayed (2006) argues that there is undocumented evidence that tilapia were raised more than 4,000 years ago, but the first trials of modern tilapia culture were recorded in Kenya in the 1920s. He divides the history of tilapia aquaculture into three phases: prior to 1970, 1970-1990, and 1990-today (2006:1-3). Prior to 1970, tilapia culture was limited to seven countries that reported raising tilapia (including China, Egypt, Nigeria, Israel, and Thailand), but by 1990, seventy-eight countries were engaged in limited tilapia farming. Since 1990, tilapia culture grew tremendously, mostly because of the tremendous development of tilapia farming in China (see Figure 9). While production of tilapia in the United States pales in comparison to the top 10

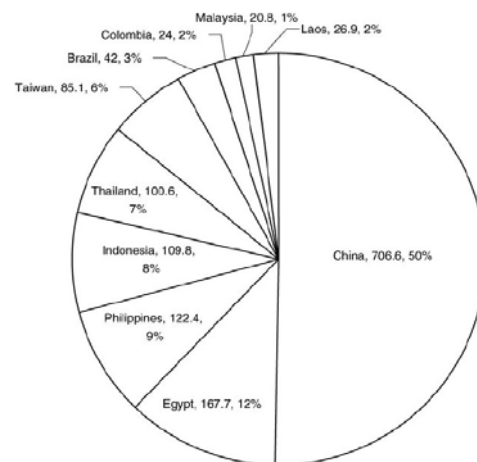


Figure 9: Top ten producers of farmed tilapia (El-Sayed 2006:6)

¹⁴ Tilapia is the commonly-used name for a wide variety of species within three genera; the most commonly farmed tilapia is *Oreochromis niloticus*, the Nile tilapia (Monterey Bay Aquarium 2009a).

producers of tilapia in the world, sustainable U.S. tilapia aquaculture is on the rise because of its use of recirculating systems (usually indoors), as opposed to the intensive pond culture used in other parts of the world, and the increased consumer attraction to local, sustainable products.

In North Carolina, tilapia aquaculture grew rapidly in the early 2000s, with one integrated (hatchery, grow-out, and processing), large-capacity (greater than 500,000 lbs of tilapia) facility and many smaller facilities. Tilapia growers attribute the growth of the industry in North Carolina to the NC State Fish Barn, a commercial-size research and demonstration facility located in Raleigh. The Fish Barn, which started its operation in 1989 with the passage of the NC ADA, has as its mission the “evaluation and development of recirculating technology for the intensive production of fish” (NCSU 2002) and the dissemination of the most economical and sustainable ways to operate an aquaculture facility. All commercial North Carolina tilapia culture uses closed recirculating systems (RAS), which makes adherence to the environmental restrictions on growing non-native species much easier for aquaculture farmers.¹⁵ As a result, in addition to the five-year aquaculture license granted by NCAgr, potential tilapia farmers must also apply to the North Carolina Wildlife Resource Commission for permission and are also inspected for proper installation of filtering equipment to ensure that domesticated tilapia do not escape into the environment and to maintain water quality for discharged water.

In 2011-2012, I met with two tilapia farmers in eastern North Carolina. Like the fish farmers mentioned above, these farmers had experience in other agricultural fields; one of the farms that I visited maintained a fish barn for tilapia on one side of the property, and commercial turkey houses in another part of the property. Another fish farmer, whom I will call Rick Easton, had a different background; he studied chemical engineering at NC State and is currently working full-time as a chemical engineer in a family-owned chemical company. His operation,

¹⁵ Tilapia is on the list of NC DENR’s potential aquaculture species not approved in NC statutes

however, was established in the middle of a major city, which resulted in a very different experience from the majority of his peers working in agricultural areas. When Rick started doing research on the possibilities of urban aquaculture, working with researchers from the NC State Fish Barn, he concluded that starting a tilapia farm in the city could be a challenging and profitable enterprise. He found an empty warehouse not far from the Charlotte airport that could be acquired fairly inexpensively, which eliminated the cost and time involved in building a new facility. The warehouse already had access roads and utilities, and was conveniently located near major arteries (as well as being relatively close to where he lived). Rick did note that there were a number of adaptations to the warehouse that he needed to complete to make it into a fish barn, including upgrading the power and water and cutting into the foundation to install pipes for the many tanks he incorporated into his design.

While the physical challenges were daunting enough, according to Rick the greatest challenges he faced were bureaucratic – how to establish intensive fish production in an urban environment, with municipal structures and people who were unfamiliar with the different requirements of commercial agriculture. For example, according to North Carolina G.S. 153A-340, farming is exempt from county zoning regulations¹⁶ – but it is not exempt from municipal zoning regulations. While the warehouse was already zoned for light industry, Rick discovered that the various zoning board experts did not know how to reclassify his urban aquaculture operation, because different parts of the operation had to be addressed by different codes. So overall, Rick’s warehouse was classified as “agricultural industry,” and the building was called a barn. However, that generated more delays because there were not any equine issues for the inspector who visited the site. Rick’s fish tanks were then classified as “swimming pools.” In the

¹⁶ As amended in NC G.S. 106, large-scale hog farms, however, are not exempt from county-zoning in order to manage lagoons and other environmental problems.

end, Rick had to convince Charlotte city planners that a fish barn was not a barn, which he was ultimately able to do with the intervention of NC State extension agents (who had already established a fish barn in Raleigh). To receive the permit, Rick had to generate a full building plan – but he still had to overcome the unfamiliarity of the local code inspector in examining his fish barn. Water was yet another issue for Rick – first, city water needed to be dechlorinated, so he decided to drill his own well. Discharged water was another potential problem, but it turned out that after the wastewater was filtered through Rick’s RAS system, Charlotte municipal resources could handle the volume. In the end, while pioneering an urban aquaculture operation in Charlotte was a bureaucratic nightmare, Rick was able to start farming tilapia in 2011.

Rick was motivated by the cultural push in the United States for sustainable, local food, where urban agriculture (along with community gardens and other participatory food production systems) has again become widespread in various US urban communities. Urban agriculture is “the growing, processing, and distribution of food and nonfood plant and tree crops and the raising of livestock, directly for the urban market, both within and on the fringe of an urban area” (Mougeot 2006: 4). In developing countries, urban agriculture has been promoted as a way to improve food security, reduce food-related transport, provide economic opportunities, and ease ecological problems (through the use of urban waste as nutrient supplies for agricultural products):

In the South, urban aquaculture is a well-established survival response to what has become a structurally-adjusted urban wilderness for many people. In the North, the imperative to grow one's own food seems less immediate, but the arguments in favour of urban agriculture on the grounds of community and health regeneration are compelling, particularly for those living on low incomes. (Garnett 1996: 300)

Garnett uses the term “South” to represent the developing world, but Lovell argues that urban agriculture can work in the North as well, especially among immigrants (Lovell 2010). Others

have specified the advantages of urban aquaculture in particular as ecologically-efficient sources of protein for human consumption, whether as small-scale aquaponics for hobbyists or commercial operations like Rick's, as models for modern ecological engineering (Costa-Pierce et.al. 2005, Lutz 2005).

In fact, Timmons (2005) asserts that operations like Rick's are particularly environmentally-sustainable. First, RAS systems reduce water consumption, using 90-99% less water than conventional pond aquaculture and provide for more environmentally-safe wastewater treatment and effectively eliminates the problem of escapees of domesticated fish (Timmons 2005:138). Second, because RAS systems are indoor climate controlled systems, they allow for economies of scale, resulting in higher production levels per unit of land or labor. Third, the control of conditions and tighter monitoring in RAS results in greater food safety. As a result, US-grown RAS tilapia have been certified by Seafood Watch as a "Best Choice" product (Monterey Bay Aquarium 2009b). With his eco-friendly, local tilapia, Rick was able to enter into a major contract with a local processing company that supplies a major, up-scale supermarket in the American south. In fact, Rick is currently exploring possibilities for achieving the holy grail of aquaponics, where he would use wastewater to feed a crop of vegetables. In the meanwhile, one local nursery and an experimental college farm is working with Rick to obtain his solid waste for composting.

Coming Together: NC Aquaculture Conference. The North Carolina Aquaculture Development Conference first met in 1988, coincident with the passage of the NC ADA in 1989. Unlike the problems in coordinating three departments (Agriculture, Commerce, and Interior) at the federal level, aquaculture in North Carolina has been primarily promoted by NCAgr due to the paucity of commercial mariculture in the state. Each year since 1988, NCAgr (along with

university-based extension agents and corporate partners) organizes an annual meeting that brings together experienced and novice fish farmers with university-based aquaculture researchers and corporations providing aquaculture equipment and supplies. I attended the 2011 meeting in Atlantic Beach and the 2012 meeting in New Bern, and much of what follows is based on my participation at those two meetings. The North Carolina Aquaculture Association, first established in 1991 and revived in 2007, is a private, non-profit corporation made up of aquaculture producers, NCAgr and other state government specialists, university and community college researchers and educators, also has an annual meeting at the same time as the Development Conference.

The primary goal of the NC Aquaculture conference is to “to bring together the general public, current and prospective fish farmers, scientists, and personnel from regulatory agencies to share information and ideas about the development of aquaculture in North Carolina” (NC Aquaculture 2012a). Information is shared in both formal settings (lectures, workshops, farm tours) and informal settings (meals, social events, and interactions with vendors at the trade show). There is great familiarity among many of the several hundred attendees, some of whom have been meeting with each other annually over the 24 year period and who also work with each other throughout the year. There are also many students in attendance as well: graduate and undergraduate students from the various NC universities, community college students, and even high school students interested in aquaculture through programs at their schools. While some, like the farmers mentioned above who attended the past two meetings, are established fish farmers, many attend the meeting to explore the possibility of diversifying or shifting their agricultural production. One father and daughter from Monroe, NC who attended the 2011 meeting, for example, already raise turkeys on their farm (in addition to his full-time job), but

they were thinking of building a fish barn to raise tilapia. Another 2011 attendee had just set up a summer flounder farm, and told me that she had left the hog industry because she was getting too old to deal with the physical demands of hog farming.

The conference starts off on a Thursday with a farm tour of featured fish farms, hatcheries, or university aquaculture operations located within easy driving-distance of the conference location. In 2011, the itinerary included a summer flounder farm, a hatchery/pond-stocking facility, and the UNC-Wilmington Aquaculture Research facility at Wrightsville Beach; in 2012, the farm tour featured a hybrid-striped bass farm, a tilapia farm, and a prawn farm. Extension agents who worked closely with these farmers introduced participants to the farmer, who then gave more extensive details about the various aspects of their operation. During the farm tour, there were active, detailed conversations about why the farmer chose a particular fish to cultivate or piece of equipment to use, with periodic comments made by the extension agents or other farm participants. The level of knowledge among participants of the farm tour varied, from novices who were completely unfamiliar with aquaculture to experienced farmers who were considering changing to a different species.

The first day of the actual conference was dedicated to a series of speakers who talked about a particular topic in aquaculture – marketing, biological or environmental research, or economics and policy. The first of these presentations, a state and national overview of the state of aquaculture, has always been delivered by Prof. Thomas Losordo from NC State University since its very beginning twenty-four years ago. Based on annual reports submitted by the farmers, his presentation each year consisted of a summary of the cumulative production and farm gate value of the different species raised in North Carolina, the various offices and services working to promote aquaculture in the state, and the educational programs and activities organized by

community colleges and K12 schools. Presentations would be delivered by invited speakers from all over the country, with different specialties, most of whom were university researchers, but also included journalists, industry representatives, and featured farmers. The business meeting of the NC Aquaculture Association was also conducted on this first day. The day would climax in the Aqua-Food Fest dinner, which featured many of the products raised by conference attendees, and prepared in a variety of culinary styles.

The second day of the conference mostly consisted of concurrent workshops on particular topics, where participants would select the workshops most relevant to their own interest. These workshops, like the farm tour, were more interactive than the lectures given on the first day, and consisted of more detailed discussions of the practicalities of topics such as the permitting process, maintaining water quality, pond construction, or managing disease. Many of the leaders of the workshops were extension agents, which gave potential fish farmers a chance to identify the relevant specialist whom they could contact later for more individual consultation. In addition to providing scientific information about particular species, workshop leaders placed an emphasis on the economics of starting and managing a fish farm; they provided spreadsheets that participants could use for planning and securing small business loans. While individual farmers were loathe to discuss financial details about their own operations, extension agents could talk about general information about market prices and profitability.

Slow and steady growth. With North Carolina's emphasis on the education of fish farmers, centering on the annual development conference and the everyday consultations by extension agents with individual farmers and local cooperatives, there has been a slow, steady, and sustainable growth of aquaculture in the state. One analyst from the John Locke Foundation

(a conservative North Carolina think-tank) has criticized the state managed efforts to develop sustainable aquaculture:

Yet, despite the impressive work the scientists and extension agents are doing, the state's fish farming industry remains fairly small — generating about \$52 million in revenues in 2010, about \$2 million less than the previous year. For comparison, the state's agriculture industry as a whole (aquaculture included) accounted for \$9.2 billion in 2009 (Cheston 2011).

This particular foundation¹⁷ seeks to limit state environmental management and allow the market to regulate agriculture; yet even this critical gaze at the productivity of the network of university researchers, state agents, and individual fish farmers found that these connections resulted in sustainable growth. Note the author also did not note that this slow but steady growth since 2008 took place within the context of a wider economic recession. Unfortunately, political forces in North Carolina have been seeking to reduce the state's role in environmental management and state regulation of industry. To this effect, one especially important forum has been removed – the NC State Fish Barn closed its demonstration facility for RAS aquaculture.

The sustainability of NC Aquaculture

The situation for aquaculture in North Carolina is very different from aquaculture in other areas of the United States and in the world because of the particularities of its biophysical context, economic conditions, and political ecology. Because NC aquaculture focuses mostly on freshwater species, with a significant proportion of closed, recirculating aquaculture systems, many of the negative environmental impacts associated with salmon farming (escapees, concentrated wastes, disease, and the sources of feed) or the loss of vital mangroves and

¹⁷ According to their website, the John Locke Foundation “envision[s] a North Carolina of responsible citizens, strong families, and successful communities committed to individual liberty and limited, constitutional government.”

wetlands for shrimp aquaculture, are not present. By avoiding the problems of mariculture, where policy is needed to streamline the relationships between different federal agencies, jurisdictional delineations at the state level are clear and allow for more efficient and effective management by state government. Lastly, with the relatively small-scale of individual fish farms, with products promoted as local, environmentally-friendly foods by cooperatives, NC aquaculture is focused on niche markets, encouraging farmers to follow more sustainable practices.

In a review of the sustainability of global aquaculture, Subasinghe et.al. (2009) assert that aquaculture as it is currently practiced in many parts of the world faces significant challenges to become a sustainable industry. What is most needed, they argue, is better management of aquaculture production by the producers themselves through a combination of good governance and self-regulation. Subsinghe et.al. then conclude that this combination can best be achieved by expanding the flow of information through formal networks of producer associations and other groups, similar to the efforts of NC Agr and the North Carolina Aquaculture Association described above. Pullin et.al. expand the stakeholders involved to include all the main actors in aquaculture: “policymakers, regulators, the private sector, communities, development donors, and individuals involved as producers and consumers of farmed fish” (2007:68).

This combination of good governance and industry self-regulation is necessary because of the unique context of aquaculture, as opposed to terrestrial agriculture. Smith et.al. 2010 assert that there are two characteristics of aquaculture that require special consideration: tight coupling to ecosystems and dependence on common-pool resources (2010:784). Aquaculture, despite its focus on controlling environmental fluctuations, can still be tightly linked to the wider ecosystem; this is especially true for mariculture, though less so for RAS aquaculture. The same division

holds for the problem of common-pool resources, especially if RAS aquaculture is conducted on private property. The recognition of this issue for aquaculture is why marine spatial planning was specifically addressed in aquaculture development in the National Ocean Policy Draft Implementation Plan, since the potential for conflict between various users of coastal and marine spaces is high (FAO 2010b). However, Smith et.al. 2010 conclude that policy changes are insufficient to create incentives for sustainable aquaculture, and that the jury is still out for the effect of private initiatives (such as third-party certification, eco-labeling, and direct sourcing) that are needed to reward sustainable producers since “natural resource prices fail to reflect the cost of sustainability” (Smith et.al. 2010:786).

What does this mean for North Carolina aquaculture? In summary, the challenges to the sustainability of aquaculture are the following:

- tight coupling to ecosystems and dependence on common-pool resources
- poor management of aquaculture operations
- Weak governance (environmental management, economic, etc.)
- Lack of knowledge flow (scientific, technological, economic) among farmers and between farmers, state, consumers; failure of “information-based management”

As demonstrated in the ethnographic case studies described above, fish farmers in North Carolina are able to avoid these pitfalls. First, there is a reduction in the first challenge, since the bulk of aquaculture in NC is in fully-controlled environments such as RAS or in small-scale pond systems that are maintained by the farmers. Second, through the intervention of extension agents, membership in cooperatives, and through other resources made available to fish farmers through the aquaculture network, management of individual farms is at a relatively high-level (and those that are not will not be economically viable, forcing their exit from the market). Third, despite recent constrictions of various state regulatory and educational departments (such as the Joint Commission on Seafood and Aquaculture and the NC State Fish Barn), state governance

over environmental management, economic facilitation, and scientific and technological education and research appears to still be fairly strong. Fourth, the flow of knowledge among researchers, state agents, producers, and consumers continues to be strong, as demonstrated by the vitality of the NC Aquaculture Development Conference, the NC Aquaculture Association, and most especially the local cooperatives that have been established by the fish farmers for their particular products. In addition to pooled marketing, these cooperatives are able to help individual farmers gain third-party certification from organizations such as the Monterey Bay Aquarium Seafood Watch, distinguishing their products from imported products that do not incur the cost of sustainable production. While their efforts individually are at a relatively small-scale of production, in total their combined production continues to grow; according to the last census of aquaculture conducted by the USDA in 2005, North Carolina ranks 6th in terms of farmed food fish produced (although it is only 10% of the number one producer of farmed fish, Mississippi). One of the reasons that aquaculture in North Carolina is sustainable is because of the absence of finfish mariculture. This clearly does not match the global trend, where high value aquaculture products such as salmon and shrimp are not in production in North Carolina.

Selling Sustainability. As mentioned above, one of the issues that makes NC aquaculture sustainable is the choice of products for niche markets, as was spelled out in more detail in the example of the giant river prawn farm. In that case, the cooperative was vital for establishing a “brand-name” that included a nutritional label. Washington and Ababouch (2011) note that eco-labeling, certification, and other private-party certification are thought by many to justify price premiums, thereby recognizing the cost of a producer following sustainable practices. One caveat, however, is that the connection between eco-labeling or certification does not ensure sustainability. One reason for this possible shortcoming is that price premiums are of

greatest benefit to retailers, and less so to producers or processors (Washington and Ababouch 2011:40). Furthermore, they also found that producers and processors often bear the cost of certification (especially for producers in the developing world. Moreover, consumers may feel “ethics confusion” – different certifying bodies may emphasize different issues, such as “fair trade” or “organic,” resulting in the development of many different ethical product differentiators (2011:46). However, they also found that the main beneficiaries of price premiums associated with labeling were small-scale producers selling to niche markets, such as the NC fish farmers described above. Even the urban aquaculture tilapia operation primarily targeted the “live fish” market, which gave Rick a competitive advantage over foreign tilapia producers because of his location.

This suggests that more work needs to be done to better understand the use of information-based environmental governance in promoting sustainable practices, especially in an age of long-supply chains and a reliance on large retailers as the primary source for food purchasing – these conditions further distance the consumer from making ethically-driven decisions about purchases, and further lessen the recouping of undervalued natural resources and the cost of sustainability. While this approach of participatory-governance, involving stakeholders in the establishment of labels and certification, is the FAO’s recommendation for making aquaculture sustainable at the policy level (FAO 2010c:85), the effectiveness of such approaches may be limited to certain consumers (early adopters, activists) and not the wider consuming public as a whole (Bullock 2011). Nonetheless, given the current cultural climate of food activism and the value in local food production, small-scale NC fish farmers are clearly making sound business decisions that, along with the symbolic and marketing support of their cooperatives, help them keep their aquaculture farms sustainable. In the end, it is the relations

that fish farmers build through the network of NC aquaculture that give them access to social capital that serves as a vital resource for learning how to farm fish sustainably. As Primavera (2005) argued, to be sustainable, aquaculture must not only focus on the environmental science, economics, and policy of farming fish, but should include a focus on the people involved.

Appendix

Table 1: Protein Content of Major Animal Foods and Feed Conversion Efficiencies for production (Hall et.al. 2011:45)

Commodity	Milk	Carp	Eggs	Chicken	Pork	Beef
Feed Conversion (kg of feed/kg live weight)	0.7	1.5	3.8	2.3	5.9	12.7
Feed Conversion (kg of feed/kg edible weight)	0.7	2.3	4.2	4.2	10.7	31.7
Protein Content (% of edible weight)	3.5	18	13	20	14	15
Protein Conversion Efficiency (%)	40	30	30	25	13	5

Table 2 Food production for major commodities (Hall et.al. 2011:8)

	Average annual production increase (1970–2008)	Average annual production increase (2004–2008)	2008 Production (tonnes x 1000)
Plant Food Commodities			
Cereals	2.1%	3.9%	2,525,107
Pulses	1.1%	0.6%	60,929
Roots and Tubers	0.9%	0.9%	729,583
Vegetables and Melons	3.4%	1.7%	916,102
Animal Food Commodities			
Beef and Buffalo	1.3%	1.6%	65,722
Eggs	3.2%	2.2%	65,586
Milk	1.5%	2.4%	693,707
Poultry	5.0%	3.9%	91,699
Sheep and Goats	1.8%	2.4%	13,174
Fish	8.4%	6.2%	52,568

Table 3: Export Value of Select Agricultural Commodities (Hall et.al. 2011:9)

	Trade Value US\$ billions 2007
Plant Commodities	
Fruit and Vegetables	150.89
Wheat	36.40
Tobacco	29.06
Sugar	18.58
Coffee	17.67
Rice	13.48
Pulses	4.82
Animal commodities	
Fish	92.80
Pigs	30.21
Cattle	28.99
Poultry	22.10
Sheep and Goats	4.35

Table 4: Top 15 Aquaculture Producers (FAO 2010c:10)

	2008 production (thousand tonnes)	Average rate of growth 1990-2008 (%)
China	32,736	9.4
India	3,479	7.1
Viet Nam	2,462	16.4
Indonesia	1,690	7.0
Thailand	1,374	9.0
Bangladesh	1,006	9.6
Norway	844	10.0
Chile	843	19.8
Philippines	741	3.8
Japan	732	-0.5
Egypt	694	14.4
Myanmar	675	28.8
United States of America	500	2.6
Republic of Korea	474	1.3
Taiwan	324	-0.2

Table 5: Value of 2009 US Aquaculture (US\$ millions); NOAA 2011a:16

Catfish	\$ 352
Salmon	\$ 61
Striped bass	\$ 27
Tilapia	\$ 53
Trout	\$ 52
Clams	\$ 87
Crawfish	\$ 121
Mussels	\$ 7
Oysters	\$ 88
Shrimp	\$ 8
Miscellaneous	\$ 311
Total	\$ 1,167

Misc: includes baitfish, ornamental/tropical fish, alligators, algae, aquatic plants, eels, scallops, crabs, and others.

Table 6: List of Potential Aquaculture Species not Approved in NC Statutes

COMMON NAME	SCIENTIFIC NAME
Arctic Charr	<i>Salvelinus alpinus</i>
Australian Red Claw Crayfish	<i>Cherax quadricarinatus</i>
Australian Marron	<i>Cherax tenuimanus</i>
Australian Yabbye	<i>Cherax albidus-destructor</i>
Barramundi / Asian Sea Bass	<i>Lates calcarifer</i>
Cobia	<i>Rachycentron canadum</i>
Flounder, Southern	<i>Paralichthys lethostigma</i>
Flounder, Summer	<i>Paralichthys dentatus</i>
Giant Malaysian Freshwater Prawn	<i>Macrobrachium rosenbergii</i>
Lake Trout	<i>Salvelinus namaycush</i>
Mosquito Fish	<i>Gambusia affinis</i>
Pompano	<i>Trachinotus carolinus</i>
Red Drum	<i>Sciaenops ocellatus</i>
Sauger	<i>Stizostedion canadense</i>
Shrimp, Gulf White	<i>Litopenaeus setiferus</i> (<i>Penaeus setiferus</i>)
Shrimp, Kuruma	<i>Marsupenaeus japonicus</i> (<i>Penaeus japonicus</i>)
Shrimp, Pacific Blue	<i>Litopenaeus stylirostris</i> (<i>Penaeus stylirostris</i>)
Shrimp, Pacific White	<i>Litopenaeus vannamei</i> (<i>Penaeus vannamei</i>)
Sturgeon, Atlantic	<i>Acipenser oxyrinchus</i>
Sturgeon, Gulf	<i>Acipenser desotoi</i>
Sturgeon, Lake	<i>Acipenser fulvescens</i>
Sturgeon, Russian	<i>Acipenser gueldenstaedti</i>
Sturgeon, Shortnose	<i>Acipenser brevirostrum</i>
Sturgeon, Siberian	<i>Acipenser baerii</i>
Sturgeon, White	<i>Acipenser transmontanus</i>
Threadfin shad	<i>Dorosoma petenense</i>
Tiger Prawn	<i>Penaeus monodon</i>
Tilapia (various species and hybrids)	Genus <i>Sarotherodon</i> or <i>Oreochromis</i>
Walleye	<i>Stizostedion vitreum</i>
Yellow Perch (west of I-77)	<i>Perca flavescens</i>

From NC WRC

(<http://www.ncwildlife.org/Portals/0/Conserving/documents/AquacultureSpeciesListNotApproved.pdf>)

References Cited

Acheson, James M.

1981 Anthropology of Fishing. *Annual Review of Anthropology* 10:275-316.

Anderman-Hahn, Jansen

2006 Net pens with adaptive management: how to manage the expansion of aquaculture using the Clean Water Act. *Vermont Law Review*. 30:1007-1043.

Andreatta, Susan and Anne Parlier

2010 The Political Ecology of Small-Scale Commercial Fishermen in Carteret County, North Carolina. *Human Organization*. 69(2):180-191.

Asche, Frank

2008 Farming the Sea. *Marine Resource Economics*. 23:527-547.

Basurto, Xavier

2005 How locally designed access and use controls can prevent the tragedy of the commons in a Mexican small-scale fishing community. *Society and Natural Resources*. 18:643-659.

Bondad-Reantaso, Melba G., James Richard Arthur, and Rohana P. Subasinghe

2008 Understand and applying risk analysis in aquaculture. *FAO Fisheries and Agriculture Technical Paper*, No. 519. <http://www.fao.org/docrep/011/i0490e/i0490e00.htm>, accessed 6 September 2010.

Bullock, Graham

2011 Green Grades: the popularity and effectiveness of information-based environmental governance strategies. Ph.D. dissertation, Department of Environmental Science, Policy, and Management, University of California, Berkeley.

Carlberg, James M., Jon Van Olst, and Michael J. Massingill

2000 Hybrid striped bass: an important fish in US aquaculture. *Aquaculture Magazine* 26(5):26-38.

Cheston, Duke

2011 Universities and businesses join in aquaculture. *Carolina Journal*. http://www.carolinajournal.com/issues/display_story.html?id=7549, accessed 20 March 2012.

Costanza, Robert and Bernard C. Patten

1995 Defining and predicting sustainability. *Ecological Economics* 15:193-196.

Costa-Pierce, Barry et.al., eds.

2005 Urban aquaculture. Oxfordshire: CABI Publishing.

Davies, Lynne D.

- 2007 Revising the National Offshore Aquaculture Act of 2007: Using State of Maine Aquaculture Laws, Regulations, and Policy Recommendations as a Prototype for the Proposed Framework. *Ocean and Coastal Law Journal*. 13(1):95-120.

Dempster, Tim and Pablo Sanchez-Jerez

- 2008 Aquaculture and Coastal Space Management in Europe: An Ecological Perspective. *In* M. Holmer et.al. eds., *Aquaculture in the Ecosystem*. Pp. 87-116. New York: Springer Science and Business Media.

DeVoe, M. Richard

- 1995 Marine Aquaculture Regulation in the United States: Environmental Policy and Management Issues. UJNR Technical Report no. 24. Texas A&M University Sea Grant College Program.

El-Sayed, Abdel-Fattah M.

- 2006 Tilapia culture. Oxfordshire: CABI Publishing

Englebrecht, Erin R.

- 2002 Can aquaculture continue to circumvent the regulatory net of the Magnuson-Stevens Fishery Conservation and Management Act? *Emory Law Journal* 51:1187-1245.

FAO Fisheries and Aquaculture Department

- 2010a World aquaculture 2010. <http://www.fao.org/docrep/014/ba0132e/ba0132e.pdf>, accessed 3 November 2011.
- 2010b Regional review on status and trends in aquaculture development in North America: Canada and the United States of America. <http://www.fao.org/docrep/014/i2163e/i2163e00.pdf>, accessed 6 March 2012.
- 2010c The state of the world fisheries and aquaculture 2010. Rome: FAO.
- 2008 The state of world fisheries and aquaculture 2008. Rome: FAO.
- 1988 History of Aquaculture. <http://www.fao.org/docrep/field/009/ag158e/AG158E02.htm>, accessed 15 November 2010.

Fast, Arlo W. and Ping Sun Leung

- 2003 Rise and fall of freshwater prawn (*macrobrachium rosenbergii*) culture in Hawaii: 1965-1999. *Reviews in fisheries science*. 11(3):243-290.

Fletcher, Kristen M. and Ginger Weston

- 1999 The Legal and Regulatory Environment: Offshore Aquaculture Permitting Process in the Gulf of Mexico. <http://aquanic.org/systems/cages/documents/00-029.pdf>, accessed 20 September 2010.

Food and Water Watch

- 2009 Fishy Farms Updates. <http://www.foodandwaterwatch.org/fish/report/fishy-farms-updates/>, accessed 20 September 2010.

- 2007 Fishy Farms: The Problems with Open Ocean Aquaculture.
<http://www.foodandwaterwatch.org/fish/fish-farming/fishy-farms/>, accessed 20 September 2010.
- Garnett, Tara
1996 Farming the city: The potential for urban agriculture. *The Ecologist* 26(6):299-307.
- Gegner, Lance
2006 Aquaculture Enterprises: Considerations and Strategies. The National Sustainable Agriculture Information Service, National Center for Appropriate Technology.
<http://attra.ncat.org/attra-pub/PDF/aquaculture.pdf>, accessed: 25 September 2010.
- Godfray, H. Charles, John R. Beddington, et.al.
2010 Food security: the challenge of feeding 9 billion people. *Science*. 327:812-818.
- Goldburg, Rebecca J., Matthew S. Elliott, and Rosamond L. Naylor.
2001 Marine aquaculture in the United States: environmental impacts and policy options. Pew Oceans Commission. http://aquanic.org/species/marine-fish/.../env_pew_oceans_aquaculture.pdf, accessed 16 October 2010.
- Gulf of Mexico Fishery Management Council
2009 Fishery Management Plan for Regulating Offshore Marine Aquaculture in the Gulf of Mexico.
<http://www.gulfcouncil.org/Beta/GMFMWeb/Aquaculture/Aquaculture%20FMP%20PEIS%20Final%202-24-09.pdf>, accessed 7 March 2012.
- Hall, S.J., A. Delaporte, M. J. Phillips, M. Beveridge and M. O'Keefe
2011 Blue frontiers: Managing the environmental costs of aquaculture. Penang: The World Fish Center.
- Halweil, Brian
2008 Farming fish for the future. Washington: Worldwatch Institute.
- Jackson, Jeremy B.C., et.al.
2001 Historical overfishing and the recent collapse of coastal ecosystems. *Science*. 293:629-638.
- Kates, Robert W., Thomas M. Parris, and Anthony A. Leiserowitz
2005 What is sustainable development? Goals, indicators, values, and practice. *Environment: science and policy for sustainable development*. 47(3):8-21.
- Kohler, Christopher C.
2004 A White Paper on the Status and Needs of Hybrid Striped Bass Aquaculture in the North Central Region. <http://www.ncrac.org/NR/rdonlyres/7527DD5E-F76B-4888-8E86-C97CDAB949E7/26689/HSBWhitePaper11404.pdf>, accessed 10 March 2012.

Lovell, Sarah Taylor

- 2010 Multifunctional urban agriculture for sustainable land use planning in the United States. *Sustainability*. 2:2499-2522.

Lucas, John S. and Paul C. Southgate

- 2003 *Aquaculture: farming aquatic animals and plants*. Oxford: Blackwell.

Lutz, Greg

- 2005 Viewing urban aquaculture as an agroindustry. In Barry Costa-Pierce, et.al., eds., *Urban aquaculture*. Pp. 15-24. Oxfordshire: CABI Publishing.

McKay, Bonnie

- 1978 Systems ecology, people ecology, and the anthropology of fishing communities. *Human Ecology*. 6(4):397-422.

Monterey Bay Aquarium

- 2009a Seafood Watch: U.S. Farmed Freshwater Prawn, *Macrobrachium rosenbergii*. http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_USFarmedFreshwaterPrawnReport.pdf, accessed 10 March 2012.
- 2009b Seafood Watch: Farmed Tilapia, *Oreochromis sarotherodon*, (2006, with 2009 appendices) http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedTilapiaReport.pdf , accessed 10 March 2012.
- 2005 Seafood Watch: U.S. Farmed Hybrid Striped Bass, *Morone chrysops X Morone saxatilis*. http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedAtlanticStripedBassReport.pdf, accessed 10 March 2012.

Mougeot, Luc J.A.

- 2006 *Growing Better Cities: Urban Agriculture for Sustainable Development*. Ottawa: International Development Research Centre.

Naish, Kerry A., et.al.

- 2007 An evaluation of the effects of conservation and fishery enhancement hatcheries on wild populations of salmon. *Advances in Marine Biology*. 53:61-194.

Nash, Colin E.

- 2011 *The history of aquaculture*. Ames: Blackwell Publishing.

National Ocean Council

2012. *Draft National Ocean Policy Implementation Plan*. http://www.whitehouse.gov/sites/default/files/microsites/ceq/national_ocean_policy_draft_implementation_plan_01-12-12.pdf, accessed 30 January 2012.

Naylor, Rosamond L., Josh Eagle, and Whitney L. Smith

2003. Salmon aquaculture in the Pacific Northwest: a global industry. *Environment*. 45(8):18-39.

Naylor, Rosamond L., Rebecca J. Goldberg, et.al.

2000 Effect of aquaculture on world fish supplies. *Nature*. 405:1017-1024.

New, Michael B.

1990 Freshwater prawn culture: a review. *Aquaculture*. 88(3):99-143.

NOAA

2011a Fisheries of the United States 2010.

http://www.st.nmfs.noaa.gov/st1/fus/fus10/FUS_2010.pdf, accessed 10 March 2012.

2011b National Shellfish Initiative.

http://www.nmfs.noaa.gov/ocs/mafacs/meetings/2011_10/docs/shellfish_initiative.pdf, accessed 7 March 2012.

2007a NOAA 10-year plan for marine aquaculture.

<http://aquaculture.noaa.gov/pdf/finalnoaa10yrrweb.pdf>, accessed 6 September 2010.

2007b U.S. Aquaculture: The National Offshore Aquaculture Act of 2007.

http://aquaculture.noaa.gov/pdf/02_bg_aq07act.pdf, accessed 20 September 2010.

North Carolina Aquaculture

2012a 2012 Annual Development Conference Homepage. <http://www.ncaquaculture.org>, accessed 23 February 2012.

2012b North Carolina Aquaculture Update 2011. Talk given by Thomas M. Losordo at the 2012 NC Aquaculture Development annual meeting in New Bern, 10 February 2012. http://www.ncaquaculture.org/pdfs/losordo_update_2011.pdf, accessed 23 February 2012.

2011 North Carolina State Operated Fish Barn.

http://www.ces.ncsu.edu/nreos/wild/aquaculture/fish_barns/index.html, accessed 8 February 2011.

2004 North Carolina Aquaculture Update 2003. Talk given by Thomas M. Losordo at the 2004 NC Aquaculture Development annual meeting in Atlantic Beach, 23 January 2004. <http://www.ncagr.com/Aquacult/PowerPoint/2003Update.pdf>, accessed 23 February 2012.

North Carolina Coastal Resources Commission

2009 Developing a Management Strategy for North Carolina's Coastal Ocean. Report of the Ocean Policy Steering Committee. <http://dcm2.enr.state.nc.us/opscreport.pdf>, accessed 6 March 2012.

North Carolina Department of Agriculture and Consumer Services

2002a Aquaculture in North Carolina: Hybrid Striped Bass – Inputs, Outputs, and Economics. <http://www.ncagr.gov/markets/aquaculture/Bass01.pdf>, accessed 23 February 2012.

2002b Aquaculture in North Carolina: Tilapia – Inputs, Outputs, and Economics.

<http://www.ncagr.gov/markets/aquaculture/tilapia01.pdf>, accessed 23 February 2012.

North Carolina General Assembly

- 2011 Session Law 2011-266, An Act Reducing State Government by Abolishing Certain State Boards, Commissions, and Committees.
<http://www.ncleg.net/Sessions/2011/Bills/Senate/PDF/S593v6.pdf>, accessed 6 March 2012.
- 1991 Joint Legislative Commission on Seafood and Aquaculture. Report to the 1991 General Assembly of North Carolina.
http://ia700309.us.archive.org/25/items/seafoodandaqu00nort/seafoodandaqu00nort_bw.pdf, accessed 6 March 2012.
- 1989 Aquaculture Development Act. (c. 752, s. 147),
http://www.ncga.state.nc.us/EnactedLegislation/Statutes/HTML/ByArticle/Chapter_106/Article_63.html, accessed 6 March 2012.

North Carolina State University

- 2002 The North Carolina State University Fish Barn.
www.ces.ncsu.edu/nreos/wild/pdf/aqua/fishbarn2.pdf, accessed 25 March 2012.

Ocean Conservancy

- 2010 A precautionary approach to U.S. open-ocean aquaculture.
<http://www.oceanconservancy.org/site/DocServer/federalMarineAquaculture7.pdf?docID=5941>, accessed 26 September 2010.
- 2009 The future of U.S. fish farming: Solid national vision or unsafe piecemeal approach.
http://www.oceanconservancy.org/site/DocServer/aquacultureFactSheet_final.pdf?docID=4681, accessed 26 September 2010.

Orbach, Michael K.

- 1980 Fishery cooperatives on the Chesapeake Bay: Advantage or Anachronism?
Anthropological Quarterly. 53(1):48-55.

Pauly, Daniel, Villy Christensen, et.al.

- 2002 Towards sustainability in world fisheries. *Nature*. 418:689-695.

Pelletier, Nathan, Peter Tyedmers, et.al.

- 2009 Not all salmon are created equal: life cycle assessment of global salmon farming systems. *Environmental Science and Technology Journal*. 43:8730-8736.

Pitcher, T. J., and M. E. Lam

- 2010 Fishful thinking: rhetoric, reality, and the sea before us. *Ecology and Society* 15(2):12.
<http://www.ecologyandsociety.org/vol15/iss2/art12/>, accessed 16 October 2010.

Poggie, John J.

- 1980 Small-scale fishermen's psychocultural characteristics and cooperative formation.
Anthropological Quarterly. 53(1):20-28.

Pollnac, Richard B. and John J. Poggie, Jr.

2006 Job satisfaction in the fishery in two southeast Alaska towns. *Human Organization*. 65(3):329-339.

Price, Brian R.

2004 Main aquaculture, Atlantic salmon, and inertia: what is the future for Maine's net pen salmon industry? *Boston College Environmental Affairs Law Review*. 31:683-721.

Primavera, Jurgenne H.

2005 Mangroves, fishponds, and the quest for sustainability. *Science*. 310:57-59.

Pullin, Roger, Rainier Froese, and Daniel Pauly

2007 Indicators for the sustainability of aquaculture. In Theresa M. Bert, ed., *Ecological and Genetic Implications of Aquaculture Activities*. Pp. 53-72. London: Springer.

Sachs, Jeffrey

2007 The promise of the blue revolution. *Scientific American* 297(July 2007):37-38.

Schumpeter, Joseph

2011 Green growth: some emerging-world companies are combining growth with greenery. *The Economist* (Sep 17 2011 print edition), <http://www.economist.com/node/21529015>, accessed 27 March 2012.

Smith, Martin, Cathy A. Roheim, et.al.

2010 Sustainability and global seafood. *Science*. 327:784-786.

Song Zhiwen

1999 Rural aquaculture in China. Bangkok: Regional Office for Asia and the Pacific, Food and Agriculture Organization of the United Nations. <ftp://ftp.fao.org/docrep/fao/003/x6945e/x6945e00.pdf>, accessed 25 November 2010.

Steinfeld, Henning, et.al.

2006 Livestock's long shadow: environmental issues and options. Rome: Food and Agriculture Organization.

Subasinghe, Rohana, Doris Soto, and Jiansan Jia

2009 Global aquaculture and its role in sustainable development. *Reviews in Aquaculture*. 1(2-9).

Springsteen, Elizabeth R.

2010 Aquaculture and the Lacey Act. http://www.nationalaglawcenter.org/assets/articles/springsteen_lacey.pdf, accessed 16 October 2010.

Tacon, Albert G.J.

2005. State of information on salmon aquaculture feed and the environment. http://aquaculture.noaa.gov/pdf/feeds_03tacon.pdf, accessed 6 October 2010.

Tango-Lowy, Torene and Robert Robertson

- 2002 Predisposition toward adoption of open ocean aquaculture by northern New England's inshore commercial fishermen. *Human Organization*. 61(3):240-251.

Timmons, Michael B.

- 2005 Competitive potential for USA urban aquaculture. *In* Barry Costa-Pierce, et.al., eds., *Urban aquaculture*. Pp. 137-157. Oxfordshire: CABI Publishing.

Todd, Ann

- 2011 Taking the plunge: American Prawn Co-op helping aquaculture take root in tobacco country. *Rural Cooperatives*. 78(4): 4-7.

U.S. Commission of Fish and Fisheries

- 1900 *A Manual of Fish Culture: Methods of the United States Commission of Fish and Fisheries*. Washington: Government Printing Office.

U.S. Department of Commerce

- 2011 National Aquaculture Policy. http://www.nmfs.noaa.gov/aquaculture/docs/policy/doc_aquaculture_policy_2011.pdf, accessed 7 March 2012.
- 1999 Aquaculture Policy. http://aquaculture.noaa.gov/pdf/18_docaqpolicy.pdf, accessed 6 September 2010.
- 1980 National Aquaculture Act of 1980. Public Law 96-362, 94 Stat. 1198, 16 USC 2801. http://www.nmfs.noaa.gov/sfa/sfweb/aqua_act.htm, accessed 5 March 2012.

U.S. House of Representatives.

- 2009 H.R. 4363: National sustainable offshore aquaculture act of 2009. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h4363ih.txt.pdf, accessed 16 October 2010.

U.S. Joint Subcommittee on Aquaculture

- 1983 National Aquaculture Development Plan. Federal Coordinating Council on Science, Engineering, and Technology. <http://ia600305.us.archive.org/20/items/nationalaquacult01fede/nationalaquacult01fede.pdf>, accessed 5 March 2012.

U.S. Senate

- 2010 S.3417: Research in aquaculture opportunity and responsibility act of 2010. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:s3417is.txt.pdf, accessed 16 October 2010.

Vargas-Cetina, Gabriela

- 2011 Corporations, cooperatives, and the state. *Current Anthropology* 52(S3): S127-S136.

Walters, Bradley B.

- 2007 Competing uses of marine space in a modernizing fishery: salmon farming meets lobster fishing on the Bay of Fundy. *The Canadian Geographer*. 51(2):139-159.

Washington, Sally and Lahsen Ababouch

- 2011 Private standards and certification in fisheries and aquaculture: Current practices and emerging issues. Rome: Food and Agriculture Organization of the United Nations.

White, Kathryn, Brendan O'Neill, and Zdravka Tzankova.

- 2004 At a crossroads: will aquaculture fulfill the promise of the blue revolution? http://www.seaweb.org/resources/documents/reports_crossroads.pdf, accessed 15 November 2010.

World Bank

- 2007 Changing the face of the waters: the promise and challenge of sustainable aquaculture. Washington: The International Bank for Reconstruction and Development.
- 2002 Shrimp farming and the environment: A World Bank, NACA, WWF, and FAO Consortium Program. Washington: The International Bank for Reconstruction and Development.

Yosef, Sivan

- 2009 Farming the Aquatic Chicken: Improved tilapia in the Philippines. *In* Daniel J. Spielman and Rajul Pandya-Lorch, eds., *Millions Fed: Proven Successes in Agricultural Development*. Pp. 125-130. Washington: International Food Policy Research Institute.

Young, William and Fiona Tilley

- 2006 Can businesses move beyond efficiency? The shift toward effectiveness and equity in the corporate sustainability debate. *Business Strategy and the Environment*. 15:402-415.

Ziegenhorn, Randy

- 2000 A river full of fish: industrial catfish production and the decline of commercial fishing on the upper Mississippi River. *Human Organization*. 59(2):162-168.