SOMETHING FISHY

Chile's Blue Revolution, Commodity Diseases, and the Problem of Sustainability

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At Marine Harvest, we are convinced that there are no real long-term conflicts between maximising value creation and operating in a sustainable way from a social or environmental perspective.

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Abstract: The United Nations describes aquaculture as the fastest-growing method of food production, and some industry boosters have heralded the coming of a sustainable blue revolution. This article interprets the meteoric rise and sudden collapse of Atlantic salmon aquaculture in southern Chile (1980–2010) by integrating concepts from commodity studies and comparative environmental history. I juxtapose salmon aquaculture to twentieth-century export banana production to reveal the similar dynamics that give rise to "commodity diseases"—events caused by the entanglement of biological, social, and political-economic processes that operate on local, regional, and transoceanic geographical scales. Unsurprisingly, the risks and burdens associated with commodity diseases are borne disproportionately by production workers and residents in localities where commodity disease events occur. Chile's blue revolution suggests that evaluating the sustainability of aquaculture in Latin America cannot be divorced from processes of accumulation.

In July 2007, employees of Marine Harvest, one of the world's largest aquaculture firms, detected an outbreak of infectious salmon anemia (ISA) in two Atlantic salmon sea pens in southern Chile (Godoy et al. 2008). Although industry spokespeople and Chilean government officials initially downplayed the risks of ISA, the highly contagious, influenza-like virus had been found at 105 farming sites by the end of 2008.[1] Aquaculture firms throughout the region began "harvesting out" Atlantic salmon, shutting down farms, and dismissing processing-plant workers. The Norway-based Marine Harvest, after posting net profits of 1.8 billion Norwegian kroner (approximately US$290 million) in 2006, reported losses of 2.8 billion kroner (US$560 million) in 2008; stock values tumbled, and the company dismissed 37 percent of its Chilean workforce (Marine Harvest 2006–2008).[2]

1. Severe anemia and hemorrhages in several organs characterize ISA. Outward signs include pale gills, protruding eyes, distended abdomen, and small hemorrhages in eye membranes (World Organization for Animal Health 2006).

2. The number of employees released by the 1,200 businesses of varying sizes that held contracts with companies like Marine Harvest is hard to determine but reportedly ran into the thousands (Gardner 2009; Zambrá 2009).

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A Marine Harvest company spokesperson called the disease "eye-opening," adding, "But as long as everybody has been making lots of money and it has been going very well, there has been no reason to take tough measures" (Barrionuevo 2008b, n.p.). By 2009, the number of reported ISA cases leveled off, but not before the virus dramatically busted—at least temporarily—one of Latin America's most profitable nontraditional export booms.

As recently as 1987, Chile registered no exports of Atlantic salmon (Phyne and Mansilla 2003). Twenty years later, the country had become the second-leading producer of farmed Atlantic salmon in the world and the primary supplier to the United States and Japan, exporting some 206,000 tons in 2007, the value of which ($1.434 billion) accounted for 62 percent of Chile's salmonid-derived export revenue, and 95 percent of the value of aquaculture exports to the United States (FishSite 2008). At the regional level, the fishing sector's contribution to the gross domestic product of the Los Lagos Region (formerly Region X) rose from 19.4 percent to 54.8 percent between 1991–1992 and 2002–2003 (Pinto 2007). Tens of thousands of people found employment in the *salmoneras*, which contributed to a dramatic decline in the percentage of people living in poverty, although income levels in the region remained among the lowest in Chile (Pinto and Kremerman 2005).

The meteoric rise of Chile's salmoneras is part of a much broader trend. The UN Food and Agriculture Organization (FAO) describes aquaculture as "the fastest growing food production system globally," expanding at an annual rate of 9 percent since 1985 (Food and Agricultural Organization 2009).[3] Of the leading twenty-four species of aquatic organisms harvested worldwide, fourteen are cultivated. Although aquaculture in China and other Asia-Pacific nations accounts for the vast majority of world output, aquaculture in Latin America has experienced the highest annual average rate of growth (22 percent) of any macroregion since 1970 (FAO 2009).[4] Most analysts anticipate that aquaculture production will continue to rise throughout the world as a result of two divergent trends: world fish consumption is estimated to have doubled since the early 1970s, and the annual global harvest from capture fisheries has leveled off between 80 million and 90 million metric tons.

The significance of the rapid expansion of aquaculture in Latin America and beyond is the subject of sharp debate among scholars, government agencies, aquaculture firms, trade unions, artisanal fishers, tourist operators, and conservationists. Advocates generally present aquaculture as a sustainable method of producing fish protein and creating jobs for a growing human population. For example, in a widely cited article, the *Economist* (2003, n.p.) anticipated that "[n]ew technologies, new breeds and newly domesticated species of fish offer great hope for the future. They promise a blue revolution in this century to match the green revolution of the last." More recently, an aquaculture industry group drew an

3. Much of this growth has taken place in China, where aquaculture has a long history; but even with China excluded, FAO statistics indicate that the volume of aquaculture products traded nearly doubled between 1999 and 2008. In addition to food, aquaculture by-products are used to make everything from biofuels to cosmetics.

4. Other Latin American nations with aquaculture industries include Colombia, Cuba, Costa Rica, El Salvador, Honduras, Mexico, Peru, and Uruguay.

explicit connection between aquaculture and the green revolution of the 1960s and 1970s when promoting its annual trade conference: "World Aquaculture 2009 will take place in Veracruz, Mexico, 40 years after [Norman] Borlaug's research program, giving us the opportunity to remember that our aquaculture industry offers a great opportunity to develop a new 'Blue Revolution' to feed the world" (World Aquaculture Society n.d., n.p.). Critics, often transnational networks of nongovernmental organizations, conservation foundations, and confederations of fisherfolk, have criticized the aquaculture industry for polluting waters, introducing exotic species, creating hazardous work conditions, and exacerbating pressures on overtaxed catch fisheries as a result of its consumption of large quantities of fish meal and fish oil (Pure Salmon Campaign 2010).

Scholars, primarily biologists and economists, have also intervened in the debates (see e.g., Muir 2005; Naylor and Burke 2005; Buschmann 2006; Ferguson et al. 2007). In a recent overview of aquaculture, the ecologist James Diana (2009, 27) echoes the discourses of industry boosters insofar as he begins his analysis by calling attention to human population growth: "A major challenge is not only to adequately feed the burgeoning population of the world, but also to improve the quality of life for those people living in poverty." Diana (2009) acknowledges potential ecological problems associated with some forms of aquaculture but points out that virtually all systems of food production generate wastes, require energy, and use water and/or soil resources. He argues that aquaculture should be compared with existing forms of agriculture, including slash-and-burn systems, to determine whether the former is a more sustainable means of producing food and income than the latter. Diana's use of world population growth as a framing device echoes an overview of aquaculture published thirty years earlier that began by declaring ominously, "optimistic forecasters of the world food supply in the year 2000 predict that serious regional food shortages will exist; pessimists warn of widespread famine as populations in many countries increase more rapidly than agricultural production" (Bardach 1968, 1098).

In this article, I take up Diana's call to compare agriculture and aquaculture systems by juxtaposing Atlantic salmon farming in southern Chile to the twentieth-century export banana industry in Latin America. However, I challenge the neo-Malthusian assumptions embedded in discussions of aquaculture as a system of food production designed to alleviate poverty and hunger, not because I dismiss the ecological significance of the 6.7 billion humans currently inhabiting the planet, but because world population growth is often viewed in isolation from other trends, including, but not limited to, rising income disparities and increased consumption of animal proteins. In addition, invocations of global population growth tend to obscure tremendous regional variations in population densities. In sparsely populated southern Chile, the development of salmon aquaculture has been propelled largely by state development policies, shifting tastes among affluent consumers in Japan and the United States, and investor desires for short-term profit (Barton 1997; Barton and Staniford 1998; Schurman 2003).[5] Producing

5. In 2002, the Los Lagos Region (forty-nine thousand square kilometers) had approximately 720,000 inhabitants.

inexpensive food for local populations has not been a driving motivation any more than it was so for the late nineteenth-century political elites and small-scale farmers in the Greater Caribbean who promoted the export banana trade.

My interpretation of Atlantic salmon farming in southern Chile combines insights from environmental history and studies of commodity flows to develop a model that integrates temporal depth and sensitivity to spatial relations (Mintz 1986; Kopytoff 1988; Cronon 1992; Marquardt 2001; Polanyi 2001; Foster 2006; Evans 2007; Molina de González 2009). The nascent field of Latin American environmental history has yielded rich case studies of regional-level ecological changes but little theorizing about broad patterns or divergences found among case studies. Furthermore, environmental historians have largely focused on people, events, and processes that unfold on terra firma. In contrast, scholars of commodity flows have developed some powerful theoretical frameworks that tend to privilege social relations over ecological ones (e.g., Mintz 1986; Appadurai 1988; Gereffi and Korzeniewicz 1994; Topik, Marichal, and Frank 2006).

This article begins to move beyond general declarations about the interaction of nature and culture—a fundamental insight of environmental history that nevertheless runs the risk of becoming both trite and totalizing— by placing the environmental histories of biocommodity flows into comparative perspective. To do so, I draw on the insights of Boyd, Prudham, and Schurman (2001, 556), who posit that "the physical properties of natural resources, the time required for biogeophysical (re)production processes to occur, and the fact that natural resources are extensive in space, found in particular locations and vary in quality, affect the capital accumulation process in unique and important ways." They argue that capitalistic firms in "biologically based industries" often attempt to substitute a logic of cultivation for a logic of extraction in order to overcome the "problem of nature" and turn potential constraints into opportunities for profit (Boyd et al. 2001, 567). For example, agribusinesses tend to change from extensive to intensive farming; timber firms transition from logging to silviculture; and fishing industries shift from capture fisheries to aquaculture.

I further refine Boyd and colleagues' (2001) category of biologically based industries to distinguish ingestible commodities from other kinds of biological ones. If true that food industries directly confront biogeophysical processes, so too do distributors, retailers, and consumers of food products, because ingestible commodities affect human bodies in a manner far more directly than fibers, timber, or minerals.[6] Food and drink are also closely tied to ideas about health and purity in ways that other commodities are not. Beliefs about what is good to eat—and where and when to eat those things—often influence production processes. As Mintz (1996) has noted, foodways are dynamic, yet paradoxically resistant to change. For example, many North Americans enjoy sushi to a degree that was unimaginable during World War II yet still find the Japanese taste for whale meat both unappetizing and unethical (Mintz 1996; Shoemaker 2005). Consequently, both cultural and biogeophysical processes can give rise to the "obstacles, oppor-

6. Research on salmon commodity chains has found more similarities to agroexport industries than to apparel production (Phyne and Mansilla 2003; Wilkinson 2006).

tunities, and surprises" that characterize the dynamics of industrial food production (Boyd et al. 2001, 560).

The particular "surprise" that provided the impetus for this article was the 2007 outbreak of the ISA virus in southern Chile, an event that drew international media coverage but that, more important, has had clear economic, social, and political impacts in Chile. One aspect of the ISA outbreak that neither journalists nor scholars have noticed is its similarity to historical outbreaks of diseases among biocommodity production systems. In fact, what piqued my interest in salmon farming in Chile was less the novel aspects of aquaculture than the apparent similarities between the ISA epidemic and epidemics of fungal pathogens that greatly influenced the twentieth-century export banana industry in Latin America and the Caribbean (Kepner 1936; Marquardt 2001; Soluri 2005).

Although few travelers would mistake a Central American banana plantation for a salmon farm in southern Chile, these ecologically distinct places of industrial food production have given rise to *commodity diseases*, a term I use to convey the importance of integrating the dynamic ecological relationships between host and pathogen, and the socially constructed meanings given to both *diseases* and *commodities*, meanings that in turn influence the scale and scope of the responses to diseases.[7] The ISA outbreak in southern Chile may have surprised some observers, but both biological and historical evidence demonstrates that commodity diseases are not random. The term *commodity disease* also serves as a reminder that the blue revolution that has washed over Chile has been directed by government policies and business strategies that see food production as a means of enabling accumulation—by corporate shareholders, small businesses, local governments, and wage earners. In this sense, Atlantic salmon farming hardly represents a revolutionary break from early twentieth-century banana farming. Assessments of the aquaculture industry's prospects for sustainability that fail to grasp the centrality of the profit-making imperative are unlikely to be accurate.[8]

INTRODUCING ATLANTIC SALMON

Scholarly analyses of Chile's salmon industry are often situated in a neoliberal moment that takes form during the dictatorship of Augusto Pinochet (Barton 1997; Phyne and Mansilla 2003; Schurman 2003). As I discuss here, this is an undeniably important context, but the history of salmon in southern Chile is considerably older and more complex. Atlantic salmon (*Salmo salar*) are native to the North Atlantic basin, where many populations evolved anadromous life cycles, migrating from their freshwater places of birth to the sea and back again to spawn and die.[9] Efforts to acclimatize Northern Hemisphere salmon to Chile began more than

7. I credit Stuart McCook for the term *commodity disease*.

8. The terms *aquaculture* and *agriculture* encompass a very diverse set of production systems that operate at different scales with varying levels of labor and material inputs. This article does not address Asian aquaculture systems that may serve both as an important source of low-cost protein for local people and as models of low-input production (Bardach 1968; Costa-Pierce 2002; Muir 2005; Diana 2009).

9. Populations of salmon exist that do not go to the sea, but anadromous populations have produced the largest and most economically important stock (Webb et al. 2007).

one hundred years ago.[10] In 1885, the Chilean consul in San Francisco, California, arranged for the transport of Pacific salmon eggs to Chile, an effort that failed on account of the poor condition in which the eggs arrived. One year later, the Chilean congress earmarked ten thousand pesos for the introduction of salmon to Chile and placed Julio Besnar, a French-born professor of veterinary science, in charge of the project. Besnar traveled to Europe, where he acquired technicians, equipment, and California salmon introduced to Paris via the French Society for Acclimatization. This effort also ended in failure, but it provides a glimpse of the transnational networks involved in moving fish around the world in the late nineteenth century. The Chilean government continued to contract foreign consultants in a vain effort to introduce salmon to the nation's waters. Elites' interest in creating fish hatcheries, the mix of private and state financing for such ventures, and the initial meager results bear noteworthy similarity to the late nineteenth-century United States, where "making fish" via hatcheries became the preferred approach for government agencies seeking to restore dwindling stocks of native salmon (Taylor 1999; Jenkins 2003).

The Chilean state's interest in salmon culture heightened in the early twentieth century, when imports of both canned salmon and theories of acclimatization were on the rise.[11] In 1905, the Chilean government erected a research station on the Blanco River in central Chile. That same year, after a thirty-eight-day journey, four hundred thousand fish eggs, including rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta fario*) from various locations in Germany, arrived at the research station. Two years later, the Blanco River staff reported the successful stocking of several rivers. In 1910, the Chilean state established a second salmon hatchery on Lake Llanquihue stocked with more than one million eggs that included Atlantic salmon and several types of trout. By midcentury, populations of brown and rainbow trout inhabited streams from central Chile to Tierra del Fuego, a range that stretched over 2,500 kilometers. Chilean hatcheries also supplied trout to Argentina, Bolivia, Colombia, Ecuador, and Peru. Atlantic salmon did not fare as well: after a brief period of high productivity (1928–1932), they began a rapid decline before disappearing completely from hatchery records in 1939. Explanations for why salmon did not acclimate to the region include high rates of freshwater mortality, possibly a result of predation by introduced trout; releases that were too widely dispersed geographically; and prevailing ocean currents that carried young salmon into waters from which they could not return (Joyner 1980; Basulto del Campo 2003).

The idea of introducing salmonids to Chile revived in the late 1960s, when public and private projects sought to introduce Pacific salmon. However, the major institutional force in Chile that advanced salmon aquaculture was Fundación Chile, a private foundation established in 1976 as part of an agreement between

10. Unless indicated otherwise, my summary of the history of salmon introductions to Chile is based on Basulto del Campo (2003).

11. Chilean writers often drew comparisons to New Zealand, where acclimatization societies' efforts to introduce salmon and trout in the early twentieth century led to the establishment of populations of chinook salmon (*Oncorhynchus tschawytscha;* Waugh 1980).

the government of Pinochet and the International Telephone and Telegraph Corporation (ITT), a U.S. multinational whose Chilean assets had been nationalized by the government of Salvador Allende following the company's covert efforts to undermine Allende's election in 1970 (Kornbluh 2003). In the early 1980s, under the direction of ex–ITT engineer Wayne Sandvig, Fundación Chile acquired a small aquaculture company operating on the island of Chiloé and formed a new company, Salmones Antártica, to raise Pacific salmon fry for release into the open sea for later capture (i.e., salmon ranching). The foundation also built two salmon-processing facilities and created two firms, Salmotec and Salmones Huillinco, dedicated to the production of Atlantic salmon juveniles. All these companies were subsequently sold to private investors (Fundación Chile n.d.).

Fundación Chile's leading role in promoting salmon farming in southern Chile merits further analysis in light of a recently published assessment of the foundation that completely ignores the historical contexts in which it emerged (Bell and Juma 2007). First, the Pinochet dictatorship—in collaboration with a U.S. multinational—nurtured Chile's aquaculture industry by making the initial investments and establishing the technical and social viability of production. The dictatorship also fomented the creation of a national fish meal industry that would become a major supplier to salmon firms (Délano and Lehmann 1993). Subsequently, the coalition of center-left political parties that ruled democratically from 1988 to 2008 continued to support the aquaculture industry by negotiating favorable trade agreements. The Chilean state also issued licenses granting permission to use a complete water column (i.e., surface to bottom) for aquaculture. The concessions, granted for indefinite periods of time, could be sold or leased to third parties. Once established, aquaculture firms in Chile have been subject to far fewer regulations than their counterparts in Norway (Bjorndal 2002). In other words, the famously neoliberal Chilean state, both during and after the Pinochet dictatorship, played an active—if not always direct—role in bringing about the free-market "miracle" in ways not dissimilar to Latin American states during nineteenth-century coffee and banana export booms (Kurtz 2001; Topik, Marichal, and Frank 2006).

But if the (iron) hand of the Chilean state could create start-up firms, it could not miraculously acclimate Atlantic salmon. The aquaculture projects of Fundación Chile took advantage of the work of Norwegian fish scientists who in the late 1960s began experimenting with raising Atlantic salmon in sea pens. Two different breeding programs developed five strains of Atlantic salmon derived from brood stock taken primarily from Norwegian rivers. Selection was initially based largely on body weight and survival. Later, after two years in the sea, salmon were selected on the basis of body weight and delayed maturity. Other traits selected for by Norwegian breeders included stress tolerance, disease resistance, flesh quality, and egg production. The fecundity of Atlantic salmon exceeds that of cattle, hogs, and fowl by several orders of magnitude, which enables high levels of selection to be applied over a brief period of time. However, an unexpected outcome of the intensive selection pressures has been a rapid decline in the genetic diversity of Norwegian farm strains of Atlantic salmon: the genetic contribution of the majority of the initial forty stocks was significantly reduced after just four generations (Ferguson et al. 2007). The Atlantic salmon that stocked the aquaculture industry in Chile, then, was itself a commodity molded by human thought and labor.

The story of the plant resources that formed the basis of the export banana industry is both similar to and different from that of Atlantic salmon. Varieties of bananas apparently had little difficulty establishing themselves in the American tropics, where smallholders and slaves widely cultivated them beginning in the sixteenth century (Carney and Rosomoff 2010). The emergence of mass markets for dessert bananas in the late nineteenth-century United States gave new importance to the Gros Michel banana variety that Caribbean-based cultivators first popularized in the mid-nineteenth century. Gros Michel represented an opportunity for industrializing production because it produced high yields of relatively thick-skinned, seedless fruit that made them popular among shippers and consumers in the United States. But the variety also presented obstacles to mass production because it was highly susceptible to fungal pathogens and wind damage when grown in monoculture. The absence of seeds, a trait for which generations of Southeast Asian or African cultivators presumably selected, played a critical role in the Gros Michel's life as a mass-produced commodity: on the one hand, the absence of seeds in the fruit increased consumer appeal; on the other hand, the difficulty in coaxing Gros Michel plants to bear seeded fruit stymied the powerful United Fruit Company's efforts to breed a disease-resistant, marketable variety throughout the twentieth century (Soluri 2005). The divergent biologies of Gros Michel bananas and Atlantic salmon posed different kinds of problems for those who sought to commodify them in Latin America, but both resulted from historical interplays of biological and cultural processes.

This sketch of the Atlantic salmon's long journey to southern Chile reveals that more than one hundred years of introductions have yet to result in the establishment of a self-reproducing population. The history of repeated failures raises several questions that scholars have only begun to explore (Camus and Jaksic 2009): Why did the idea to introduce salmon have such staying power among generations of Chilean elites? How did theories about the acclimatization of species travel around the globe, and how did local people hear and interpret such theories? What did Chileans think about native fish species? There is also a need for more attention to the history of Atlantic salmon breeding in Norway and elsewhere to understand how historical contexts influenced decisions about the breeding projects and who profited from the subsequent export of the Norwegian strains to Chile and elsewhere. As Boyd and colleagues (2001) point out, obstacles to accumulation posed by biological dynamics such as pathogens can be turned into opportunities by investors who have the knowledge to manipulate the reproductive processes—via genetics or otherwise—vital to the production of biocommodities.

MAKING SALMON, TAKING ADVANTAGE

Atlantic Salmon aquaculture in southern Chile mimics the life cycle of wild Atlantic salmon insofar as the juvenile fish are raised initially in freshwater before being transferred to sea pens.[12] The major Atlantic salmon hatcheries have been located on Lake Llanquihue, a large oligotrophic lake that in the past sustained several kinds of endemic fish.[13] Between 1995 and 2005, hatcheries on Llanquihue produced more than 270 million smolts, including 168 million Atlantic salmon (Arismendi et al. 2009). This represented more than one-third of total smolt production in Chile during that time period. Access to southern Chile's relatively clean, freshwater lakes meant that aquaculture firms did not have to invest in the enclosed recirculation systems commonly used in Norway to nurture juvenile salmonids—a classic comparative advantage (Bjorndal 2002).

However, a comparative advantage is a particular way of understanding a set of biophysical conditions that are subject to change. The export banana industry, along with other agroexport industries, sought to take advantage of the fecundity of tropical rain forests, whose productivity was proclaimed by Alexander von Humboldt, among others. But forests in the Greater Caribbean, along with the crop plants themselves, were historical outcomes of the Columbian exchange, a complex mixing of biological organisms that produced crosscutting effects in the Americas. The widespread decline in Native American populations linked to human disease epidemics and violence led to an expansion of forested landscapes from which nineteenth- and twentieth-century cultivators would extract forest rents: profits generated by making an advantage out of the soil, water, and fuel resources. But such rents were short-term and unevenly distributed, resulting in geographically extensive patterns of cultivation that quickly transformed forests and wetlands, thereby reducing the comparative advantage. By the 1930s, fruit companies increasingly relied an irrigation, fertilizers, chemical pesticides, and a large migrant labor force to produce bananas.

In the case of aquaculture in southern Chile, freshwater, not soil, serves as the medium in which the commodity first develops. Salmon smolts are "fertilized" with fishmeal and fish oils. The production system has altered lakes primarily via the unintentional release of smolts. Chilean law has not required hatcheries to report on fish escapes, but if we assume that freshwater escape rates were at least comparable to those measured in Norway and Scotland, then between 8 million and 14 million smolts may have entered Lake Llanquihue from 1995 to 2005.[14] To date, Atlantic salmon have not formed self-sustaining populations in Llanquihue; nevertheless, the probability of an exotic species establishing itself increases with repeated introductions, because fluctuating environmental conditions create windows of opportunity (Naylor et al. 2005). Furthermore, the limited reproductive success of Atlantic salmon in open waters does not preclude the possibility that escapees exert effects on other freshwater species. A recent study shows a

12. Aquaculture firms have worked to shorten the amount of time (ten to sixteen months) between hatching and harvesting. Among wild populations in the Northern Hemisphere, the freshwater phase lasts between one and two years at lower latitudes and three to six years at higher latitudes (Webb et al. 2007).

13. These include *Galaxias platei Steindachner, Percichthys trucha Valenciennes, Basilichthys australis Eigenmann,* and *Odontesthes mauleanum Steindachner* (Arismendi et al. 2009).

14. Studies in Norway and Scotland indicate a freshwater escape rate of between 3 percent and 5 percent (Arismendi et al. 2009).

negative correlation between the abundance of endemic fish species (characterized by small body mass) and introduced species (selected for large body size) in southern Chile's lakes, a tendency that is probably attributable to trout and salmon predation on native species (Soto et al. 2006).

The relationship between exotic species and the environments to which they are introduced is interactive: exotic species may reconfigure a biotic network and the network in turn alters the new species. For example, the millions of Atlantic salmon raised in Llanquihue have been exposed to the larvae of a freshwater parasite endemic to the region that can cause illness (Diphyllobothriasis) in people who eat infected fish. On at least one occasion, this previously local public health problem has been documented in patients in Brazil following their consumption of raw salmon imported from Puerto Montt (Cabello 2007). Here again is an example of a "surprise" associated with the mass production and long-distance shipment of a food commodity produced by local ecological change, rapid transport of perishable commodities via jet planes, and the globalization of sushi eating. The creation of transportation networks to move perishable commodities rapidly has increased opportunities for organisms of all types to move around the globe as commodity stowaways.

Since 2003, the salmon industry has started to convert to hatcheries that use enclosed systems, which, though costly to install, lower mortality, accelerate growth rates, and reduce (but do not eliminate) the risk of escapes into freshwater systems (Marine Harvest 2006–2008; Muñoz et al. 2007). Nevertheless, the overall expansion of production meant that the number of juveniles cultivated in lakes continued to rise through 2007. Aquaculture businesses in Chile, then, appear to have deferred the expenses of building recirculation systems in part because they bore no responsibility for endangering either endemic fish species or human health by introducing an exotic species to the region's freshwater ecosystems. More research is needed to trace the political origins of the comparative advantage offered by Lake Llanquihue and other lakes, but crucial contexts include both the neoliberal policies of the late twentieth-century and late nineteenth-century projects to acclimatize Northern Hemisphere trout and salmon to the region. Finally, the salmon industry was not operating in a pristine environment. As noted already, the Chilean government had established a hatchery on Lake Llanquihue as early as 1910. The subsequent formation of populations of introduced rainbow and brown trout helped give rise to tourism in southern Chile but presumably also had a major effect on endemic fish species (Muñoz et al. 2007; Arismendi et al. 2009). As Carey (2009) has argued, Latin American environmental historians need to look beyond industrial commodity production to tourism and the consumption of landscapes of leisure. The extent to which sport fishing acted as an agent of ecological change in southern Chile before the emergence of salmon aquaculture is a topic ripe for investigation.[15]

Atlantic salmon are transported from freshwater facilities to marine sea pens

15. Histories of work and leisure are not mutually exclusive, as the environmental history of Lake Yojoa, the largest lake in Honduras, reveals. Yojoa is home to several endemic species of fish whose

via trucks and/or well boats, where they spend between twelve and twenty-two months until they reach market weights (approximately 4.5–5.5 kilograms). The pens are located in places that combine adequate shelter from rough seas and sufficient circulation of water and oxygen. The dimensions of pens vary, but they are usually situated in water that is twenty to thirty meters deep. From an ecological standpoint, sea pens provide fish with both protection and "room service": in contrast to wild salmon populations, farmed salmon do not have to expend energy or dodge predators while foraging. This quickens the pace at which salmon grow to market sizes. These efficiencies notwithstanding, some researchers have likened the cultivation of carnivorous Atlantic salmon to raising "tigers of the sea" because they consume more fish by weight than they produce (Naylor and Burke 2005, 186). Manufactured feed for Atlantic salmon consists largely of fish meal (35–40 percent) and fish oil (25 percent). Feed represents between 40 percent and 50 percent of the direct costs of salmon cultivation. The fish meal and oil industry in Chile, also fostered by Fundación Chile, grew rapidly from the late 1980s through the mid-1990s, taking advantage of abundant populations of anchovies and horse mackerel in national waters (Hardy and Castro 1994). Estimates of the rates at which manufactured feed is converted to salmon flesh vary widely; Marine Harvest (2010) claims that it takes 2.4 kilograms of wild fish to extract the fish oil needed to produce 1 kilogram of farmed salmon in Europe. Feed conversion efficiencies have improved in general as a result of changes in feeding methods and a decline in the percentage of fish-derived products in the feed. Nevertheless, improvements made between 1997 and 2001 were more than offset by increases in total annual salmon production, which means that aquaculture is contributing to, not alleviating, stress on catch fisheries (Naylor and Burke 2005).

Concentrating fish in a confined area to feed them also leads to a concentration of wastes. In both Northern and Southern Hemisphere fish-farming sites, inputs that settle on seabeds have altered the chemical properties and significantly reduced the diversity of microflora in benthic sediments. In Chile, this appears to be due to both low oxygen levels and the deposition of copper used in antifouling paints. Even when waste can be diluted before reaching the benthos, increased concentrations of dissolved nutrients can trigger algal blooms that, in turn, negatively affect the large number of shellfish cultivators in the region. Finally, fish farms further pollute marine environments by releasing chemicals used to control diseases, parasites, and organisms that foul sea-pen structures. In addition to copper, significant quantities of antibiotics (tetracycline and quinolones) and parasiticides (the now-banned malachite green and emamectin benzoate) have been used in Chile (Teet 2008; Buschmann et al. 2009).

Parasites are present in virtually all sea pens. The first cases of parasitosis in farmed Atlantic salmon appeared in Norway in the 1960s. Subsequently, the condition has been reported in Atlantic salmon farms in Scotland, Ireland, and Canada (Zagmutt-Vergara et al. 2005). In Chile, sea lice (*Caligus rogercresseyi*) feed on the

populations plummeted in the 1960s following the introduction of largemouth bass by North American employees of the United Fruit Company interested in sport fishing (Stover 1989).

mucus, skin, and blood of fish, which negatively affects the growth of salmon and increases their susceptibility to other infections (Bravo, Erranz, and Lagos 2009). Sea lice may also serve as a vector for pathogens like ISA. As is often the case with parasitic organisms, sea lice populations have increased in conjunction with the increase in densities of host populations of Atlantic salmon.[16] Aquaculture firms have tried to check sea lice populations with a combination of parasiticides (in feed) and management techniques. However, parasite populations resistant to diflubenzuron, teflubenzuron, and emamectin benzoate have already emerged, which suggests that chemicals will not provide a long-term solution.[17]

Other aspects of sanitation control include removing dead fish and cleaning sea pens. These routine practices tend not to be addressed in assessments of aquaculture's ecological effects, but the work has proved extremely dangerous for the four to five thousand scuba divers (*buzos*) contracted to clean, monitor, and repair sea pens (Pinto 2007). Fourteen divers died on the job over a fifteen-month period between 2006 and 2007, and at least eight divers perished in 2008 (Pinto 2007; *Ecocéanos News* 2008, 2009). The organization of work and the absence of enforceable safety regulations appear to have exacerbated the intrinsic dangers of open-water diving. For example, in April 2008, a diver named Nelson Andrés Rebolledo Bustamante died while working in a salmon pen. Precisely when Rebolledo initiated his dive, how long he remained submerged, and the depth to which he descended remain in dispute. The company for which he worked stated that Rebolledo was diving to a depth of twelve to fifteen meters to repair a sea lion net; he and his partner had permission to dive to a depth of twenty meters. However, according to statements filed by the deceased's spouse and the head of the divers' union, Rebolledo's dive was thirty meters deep (*Ecocéanos News* 2009). The chronology of events is disputed, but Rebolledo does not appear to have reached a hospital in Puerto Montt until several hours after he finished his dive, as a result of the lack of specialized medical equipment (including decompression chambers) in proximity to work sites.

Aquaculture industry officials have implicitly blamed the divers themselves for the high accident rate by noting that the boom in production created a shortage of professional divers. During the initial years of operation, companies made extensive use of local divers known as *mariscadores* (shell fishers), who were prohibited by law to dive to depths beyond twenty meters. However, in 2000, the industry began installing deeper sea pens, thereby increasing demand for divers who possessed training and equipment that most mariscadores did not possess. Consequently, the industry successfully lobbied the government to allow for the creation of a new category of diver, the *buzo mariscador intermediario,* legally permitted to descend to thirty-six meters (Chile, Cámara de Diputados 2007). The meanings of these changes are disputed: some nongovernmental organizations

16. I was unable to find a published study on the relationship between fish densities in pens and sea lice in southern Chile. Costello (2006) provides a general overview of parasitic sea lice on farmed fish.

17. A study conducted in 2000 found that a single treatment of emamectin benzoate controlled sea lice for more than ten weeks. However, a study carried out in 2006 and 2007 found that parasites persisted in sea pens that received eleven treatments (Costello 2006; Bravo, Erranz, and Lagos 2009).

have stressed the increased risks associated with diving to greater depths; government commissions have noted that many divers lost their jobs because they were unable to obtain the training needed to qualify as a mariscador intermediario. The contradictory stories and interpretations notwithstanding, Rebolledo's death reveals a critical way in which social and ecological dynamics intersect at salmon production sites. The work needed to maintain sea pens, which includes sanitation measures, is both crucial and dangerous. The inherent dangers of diving in open ocean water are exacerbated by limited accountability because of subcontracting, limited job security, the absence of third-party monitoring, and a paucity of medical facilities equipped to treat diving maladies.

One can safely assume that few banana workers donned wet suits before heading to work; in this regard, there is an undeniable and important particularity to the working environments that Atlantic salmon production creates. Nevertheless, the production model of salmon farms is remarkably similar to those of banana farms and other kinds of large-scale terrestrial agriculture insofar as the work of disease control is carried out through a combination of manufactured inputs and often-dangerous manual labor. For example, an outbreak of Sigatoka disease in the 1930s compelled United Fruit to install an expensive, labor-intensive spray system. Thousands of young men worked as spray applicators in Central America from the late 1930s to the early 1960s, a relatively well-paying job that nevertheless was dreaded on account of the cosmetic and respiratory effects that resulted from repeated exposure to copper sulfate, which Honduran workers simply dubbed *veneno* (poison). Fruit company doctors had a poor understanding of the potential health effects of chronic exposure to copper sulfate and rarely, if ever, provided treatment. Workers in both Costa Rica and Honduras tended to endure short stints as spray workers (Marquardt 2002; Soluri 2005). *Veneneros* and *buzos*, then, have occupied very different working environments, but their risky livelihoods share origins in a need for dense monocultures to be protected from pathogens and parasites.

FISH ON DEMAND

In the United States, salmon, unlike bananas, has historically been consumed in several ways, including dried, canned, smoked, frozen, and chilled. Describing and explaining consumption of farmed salmon in Japan and the United States, the two largest markets for Chilean exports, is crucial because both advocates and critics of salmon farming tend to describe production as meeting a demand the origins of which is seldom explained in detail or supported by evidence (Wilkinson 2006). Although a thorough examination of consumption habits in these two nations with distinct foodways is beyond the scope of this article, some basic trends can be identified for the United States.[18] Before the 1980s, salmon was

18. Japanese aquaculture dates back centuries, and Japan continues to be a center for aquaculture research. Nevertheless, the traders and sushi chefs who purchase fish at Tokyo's famed Tsukiji market generally view cultivated fish as inferior to caught fish. Not unlike patterns in the United States, cultivated fish in Japan retail in supermarkets, midlevel restaurants, and processing plants (Bestor 2004).

a seasonal food available primarily between June and August. Inverse seasons have provided comparative advantages for aquaculture firms operating in Chile in much the same way that they have benefited Chilean fruit growers who tapped into Northern Hemisphere markets. Such comparative advantages are seldom purely natural. In 1991, the U.S. government levied a hefty antidumping tariff on salmon imported from Norway, effectively closing U.S. markets to Norwegian farmed salmon at a time when that country dominated the global trade. Six years later, the surge in U.S. salmon imports from Chile was sufficient to prompt some U.S. salmon fishers to file an antidumping suit against Chile (Phyne and Mansilla 2003).

The rise in U.S. imports of fish from Chile coincided with important changes in the aquaculture industry. Many companies greatly expanded production of Atlantic salmon because it could be harvested throughout the calendar year, largely eliminating the seasonality of consumption patterns (Bittman 1992). Adopting a strategy developed by Chicago-based meatpackers one hundred years earlier, salmon firms in Chile began exporting chilled fillets to reduce freight costs associated with exporting whole fish (Cronon 1992; Horowitz 2005). Between 1996 and 2000, exports of salmon fillets increased fivefold; in 2001, fillets constituted 60 percent of all U.S. salmon imports (Duchene 2001). Intensive aquaculture, then, enabled institutional buyers like Costco or Red Lobster to purchase salmon fillets of uniform size and age at virtually any time of year—essentially salmon on demand. These innovations created their own problems: as exports expanded, the wholesale and retail prices of salmon fell sharply as markets became saturated. Aquaculture firms responded by turning to value-added products geared for sushi markets in Japan or U.S. consumers seeking to minimize meal preparation time by buying frozen fillets with prepared condiments and recipes (*Businessweek* 2000).

An important difference between the eras of Chicago beef and Chilean salmon is the mode of transport: the railroads that brought beef, bananas, and oranges to major consumer markets have been replaced by jet planes that carry salmon fillets to destinations in Japan and the United States. From an environmental standpoint, Chilean salmon exports reflect the lengthening of "food miles" and a concomitant increase in carbon dioxide emissions. The ability to transport salmon, along with most other mass-produced perishables, also depends on refrigeration or freezing, storage techniques that require a significant amount of electricity to maintain a "fresh" aesthetic (Freidberg 2009). Behind all these technologies that function to compress time and space are fossil fuels and the energy networks that, along with human labor, make industrial food happen.

The technological ability to move massive quantities of salmon around the world does little to explain why people want to eat it in the first place. Today, salmon, not unlike bananas, is a food whose consumption signifies a "healthy" lifestyle. A series of medical studies suggesting that the omega-3 polyunsaturated fat contained in salmon provided health benefits coincided with an increase in annual per capita consumption rates that by 2004 exceeded one kilogram. "Heart-friendly" salmon became the most popular finfish served in restaurants in the

United States (Wright 2006). However, to keep this gain in popularity in perspective, note that annual per capita consumption of chicken and beef stood at an estimated 34.4 and 30.6 kilograms, respectively, in 2000. In fact, between 1983 and 2000, U.S. per capita consumption of beef, chicken, and salmon combined appears to have increased from fifty-six kilograms to approximately sixty-six kilograms (Blair and Sobal 2006). Farmed salmon from Chile appears to be supplementing, not replacing, other sources of protein in a society whose protein consumption, total available calories, and waistlines all grew significantly over the past twenty-five years.

The popularity of Atlantic salmon fillets changed the nature of work in the Chilean salmon industry. As Schurman (2003) has described, the first boom in Chilean fish exports took place during the Pinochet dictatorship, when both labor laws and political repression effectively prevented labor organizing. Low wages, long hours, and frequent layoffs characterized work in fish-processing plants. The restoration of democracy and the boom in salmon exports in the late 1980s ushered in an era when real wages rose significantly, unemployment dropped, and workers acquired greater bargaining power as a result of changes in labor laws and an end to violent repression. The rapid expansion of Atlantic salmon production increased demand for labor in processing plants throughout the calendar year, potentially permitting more stable employment (Phyne and Mansilla 2003). However, when overproduction led to sharply falling prices, salmon firms responded by increasingly linking wages to productivity via piece-rate systems.

Piece-rate systems are notorious for encouraging workers to increase their earnings (and productivity) at the expense of their own health. This is particularly true in food-processing industries such as salmon, where constant exposure to low air temperatures and cold water combined with rapid, repetitive motions carried out while standing for several hours tend to produce work-related injuries. Chilean government statistics for 2005 indicate that injury rates in the salmon industry were 33 percent greater than the national average (Pinto 2007). Unsurprisingly, company officials and union representatives hold widely divergent views of wages and working conditions. However, there is no denying that the emphasis on labor "flexibility" set in place by Pinochet, and left largely unchanged by subsequent center-left coalition governments, has meant that processing-plant workers, like the contracted mariscadores, bear the brunt of both routine and extraordinary risks associated with the salmon industry. This means laboring under fast-paced conditions and not working when severe weather, diseases, or saturated markets threaten their employers' profits. The meanings of a fish-processing-plant job in southern Chile are likely to vary on the basis of gender, age, and the life histories of individual workers (Délano and Lehmann 1993). My point is not to impose a single meaning—exploitation—but simply to remind readers that labor processes, along with ecological ones, are crucial factors to consider when assessing the sustainability of the salmon industry.

Here again, southern Chile's salmon industry displays some significant similarities to the twentieth-century export banana industry in Central America. Bananas, like Atlantic salmon, can be delivered in minimally processed form throughout the calendar year because of both the banana's biology and the historical use of low-wage workers in highly undemocratic societies. Although the fruit companies' vertical integration and company-town model contrasts with the cluster model of organization of the salmon industry, short-term contract work and piece rates have been central to labor processes in the banana industry, particularly in the labor-intensive aspects of production, including weeding, harvesting, and fruit packing (Grossman 1998; Striffler 2002; Soluri 2005). In addition, women workers have figured prominently in the packing and processing stages of both industries, as they have in other agro-industries in Chile (Tinsman 2002). This kind of labor organization, though not determined by biological processes, nevertheless reflects a widespread strategy adopted by profit-seeking landowners and agribusinesses to overcome both the challenges in standardizing farm tasks shaped by microvariations in weather, soil conditions, and the crops themselves and the highly variable labor demand during production cycles.

INTERPRETING THE BUST

Many mass-media sources attributed the 2007–2008 ISA outbreak to poor sanitary conditions in production zones (Barrionuevo 2008a; *Economist* 2008; Gardner 2009; *El Mercurio* 2010). These views are accurate insofar as the rapid transmission of the virus suggests that production practices, including the live transport of fish in well boats and wastewater discharges from processing plants, facilitated the pathogen's movement on a regional scale. Parasitic sea lice commonly found in sea pens may have also spread ISA (Murray, Smith, and Stagg 2002). In contrast, mass-media coverage has tended to downplay the transnational flows of capital, brood stock, and production models that have linked salmon aquaculture in southern Chile to other parts of the world since its inception.

Infectious salmon anemia first became a problem in the place where Atlantic salmon aquaculture began: Norway. Between 1984 and 2005, no fewer than 437 reported outbreaks occurred on Norwegian salmon farms. Disease incidence peaked in 1990, after which time regulations put in place by the Norwegian government succeeded in lowering, but not eliminating, outbreaks (Lyngstad et al. 2008). A similar dynamic has taken place in New Brunswick, Canada, where salmon farmers implemented several changes in their practices only to see ISA return with a vengeance: between 1997 and 2005, millions of fish were destroyed, leading to the loss of tens of millions of dollars (McClure, Hammell, and Dohoo 2005). In summary, ISA has appeared everywhere that intensive salmon aquaculture has taken place in the Northern Hemisphere, including the Faeroe Islands, Scotland, and the United States. Furthermore, ISA showed up in a fish farm in Chile as early as 1999, but because the infected fish (coho salmon) were not highly susceptible to ISA, the event does not appear to have prompted any significant response, even though by that point the industry was shifting to Atlantic salmon, a species whose susceptibility to ISA had been thoroughly demonstrated elsewhere.

The precise transmission routes of the 2007–2008 ISA outbreak in Chile remain unclear, but DNA-based evidence indicates that ISA arrived to the region via salmon eggs imported from a Norwegian brood stock company.[19] However, one need not rely exclusively on DNA identifications to understand the origins of ISA in Chile in light of an increasingly well-documented history of commodity diseases that have followed cash crops such as bananas, cacao, coffee, and sugar across the globe (Marquardt 2001; McCook 2002, 2006; Soluri 2005). For example, during the first half of the twentieth century, the export banana industry in Central America was plagued by Panama disease (fusarial wilt), a soil-borne fungal pathogen that reduced the yields of Gros Michel bananas, the variety that dominated commodity markets in the United States and Europe. By 1960, Panama disease had reached virtually every region where Gros Michel monocultures existed. The pathogen defied the efforts of researchers to eradicate it or even predict its advance, despite quarantine measures that included mandating that field workers disinfect their tools, shoes, and even the hooves of mules. Facing this persistent but unpredictable obstacle, the banana companies eventually renegotiated concessions received from host governments to relocate production. This strategy enabled the companies to maintain their production levels and continue to cultivate Gros Michel bananas for a few decades. However, at local levels, this response to Panama disease destabilized thousands of livelihoods and triggered migrations, the collapse of local economies, and high rates of conversion of forests and wetlands to agriculture. Of course, the places to which the fruit companies relocated experienced new cycles of export expansion, employment, and opportunities for accumulation (Soluri 2005). The history of export banana production suggests that, from an ecological perspective, geographical dispersal is a two-edged sword because it enables producers to temporarily escape debilitating pathogens while further spreading introduced species and pollution problems.

The response to ISA in Chile today is remarkably similar. The Chilean government, after initially downplaying the disease's severity, declared a three-month fallow period for the entire industry. Companies began harvesting Atlantic salmon prematurely to salvage some economic value from the fish and to remove the pathogen's host from the waters, hoping that ocean currents would essentially wash the pathogen away or at least reduce its population significantly. At least one hatchery in the region has implemented strict "biosecurity" measures reminiscent of those established by fruit companies in the 1920s: hatchery workers change their shoes before entering the plant, and the tires of entering trucks are subject to mandatory disinfections.[20] The recent Marine Harvest (2010) *Sustainability Report* declared that the company was also reducing its stocking densities and fallowing production sites. The industry has successfully negotiated with the Chilean government to revive production under new regulations that would disperse production sites in an effort to reduce the density of fish pens. Investors are already securing concessions to water columns in Magallanes, the southernmost region of Chile.

19. Gene sequencing indicates that the virus is in a clade (genogroup) with Norwegian viruses (Vike, Nylund, and Nylund 2009).

20. The author spent one week in December 2009 in Hornopirén, documenting active and abandoned farm sites and conducting informal interviews.

Banana companies also responded to Panama disease by seeking a disease-resistant variety. The United Fruit Company and the British government sent botanical missions to tropical Africa and Asia in the 1920s and again in the late 1950s to collect specimens of bananas for breeding experiments. The sterile Gros Michel variety presented a technical challenge to plant breeders, but market standards for a first-rate banana created more of an obstacle than did the plant's reproductive biology, an obstacle that current biotechnologies have yet to overcome. The banana industry finally converted to Panama disease–tolerant varieties in the early 1960s, when dwindling amounts of suitable land, political opposition to new concessions, and the expansion of self-serve supermarkets provided an opportunity for the fruit companies to convert to Cavendish varieties, which required on-farm packing before export. The new varieties proved susceptible to pathogens both new and old; an increased use of inputs accompanied the switch to Cavendish, including frequent aerial applications of fungicides to control Black Sigatoka (Soluri 2005). In summary, commodity pathogens like Panama disease and Sigatoka have not eliminated export banana production in Latin America, but they have changed virtually every aspect of the industry, whose survival and profitability depend on chemical inputs, fossil fuels, and "flexible" labor forces (i.e., including contract growers; Raynolds 2003).

Differences in both the biology of and the markets for Atlantic salmon may create opportunities for aquaculture businesses to minimize the economic importance of ISA. First, unlike sterile Gros Michel banana plants, there is evidence that Atlantic salmon can be selectively bred for resistance to diseases, including ISA, under controlled conditions (Kjøglum et al. 2008). However, as already noted, farm strains of Atlantic salmon have experienced a drastic reduction in their genetic diversity as a result of selection processes. In addition, self-reproducing populations of Atlantic salmon are facing extinction throughout the North Atlantic, which means that potential sources of genetic diversity for farmed salmon are disappearing.

Second, consumer markets, which have historically constrained efforts to produce disease-resistant bananas because of the very limited ways in which consumers in Europe and the United States eat bananas, may provide greater flexibility for aquaculture firms, because Atlantic salmon, if less universally popular than a dessert banana, is typically prepared in several ways. Furthermore, restaurants and markets have historically offered customers different kinds of fish based on price and availability. In other words, because market practices and consumer habits are already accustomed to seasonal variability, it may prove easier to replace a significant portion of Atlantic salmon production with other kinds of farmed finfish than it has been for fruit companies to introduce new banana varieties. In contrast, mass markets' standardizing tendencies in terms of the size, appearance, cooking properties, and availability of food commodities tend to restrict the diversity of production practices, as does the need to accumulate capital on an annual basis. If the history of the banana industry is any indication, foodways and market structures in Japan and the United States will play a critical role in determining the future of aquaculture in Chile.

REALITY CHECK: COMMODITY DISEASES, ACCUMULATION, AND SUSTAINABILITY

The ecological dynamic that ISA, Panama, and Sigatoka diseases share is clear enough: the continuous cultivation of a single organism at high densities.[21] The absence of spatial barriers or fallow periods increases the probability that populations of fungi, viruses, and parasites will be able to proliferate. In reality, the dynamics of commodity diseases are far messier. For one thing, rates of ISA infection in sea pens where the virus is present can be highly variable, ranging from 2 percent to 50 percent. Scientific studies to determine risk factors are few in number and have yet to yield precise causal relationships: stocking densities and the distance between sea pens are important but not always determining factors (Turnbull et al. 2004; Scheel et al. 2007). Needless to say, it is far easier to measure the actual densities of banana plants or even cattle than it is to measure submerged fish. However, the challenges are also social in character and suggest that understanding commodity pathogens requires methodologies that are not reductionist. "Density" is not simply about how many fish occupy a given volume of water but also concerns the networks and flows of people and technologies involved in mass-producing farmed salmon or bananas for profit. Salmon, parasites, bacteria, divers, well boats, and feed are just some of the elements that constitute these dense, dynamic networks.

The responses of both the banana and the salmon industries to density-related problems (diseases and parasites) have involved both sanitary measures and the use of various kinds of biocides to check the populations of offending organisms. These strategies often depend on new technologies and human labor for their success. If new kinds of employment are created, so too are new occupational risks, including exposure to toxic chemicals and/or dangerous work environments. The availability of a labor force willing to take on these risks at comparatively low wages is a crucial condition that many biocommodity production systems share across time and space. But the most taken-for-granted risk that workers assume in agricultural industries is the frequency with which workers are not employed, either because of seasonal variations in labor demand or because of less predictable events such as disease outbreaks. As Marine Harvest Chile's general manager Alvaro Jiménez candidly declared in 2009, "Marine Harvest is not willing to risk great amounts of money and incur major losses brought about by the elimination of sick fish" (qtd. in Fish Information Services 2009). The company chose to avoid such losses by temporarily shutting down production and laying off large numbers of workers, thus compelling the Chilean state to provide unemployment compensation. In 2009, Marine Harvest released 1,669 employees in Chile, of whom the company claims to have assisted some 150 in finding new livelihoods (Marine Harvest 2010). These measures indeed helped the company avoid losing money: after absorbing financial losses in 2008, Marine Harvest turned a profit of

21. Published reports on the population densities of Atlantic salmon pens in southern Chile are not easy to find. One study conducted in 1997 indicated that Marine Harvest operations in Scotland stocked between 14,000 and 17,500 salmon in sea pens measuring 1,800 cubic meters (Stone et al. 2000).

approximately US$220 million in 2009 (Marine Harvest 2010). Salmon farming in southern Chile, then, functions to produce food and make money for a transnational class of investors.[22]

My comparison of the export banana and salmon industries suggests that large-scale commodity production based on intrinsically unstable organisms is dynamic. One implication of this dynamism is that rising rates of production and profits will be possible only where political, legal, and technological conditions facilitate externalizing risks both by deferring opportunity costs to anonymous future generations and by having less powerful people—often field-workers and processors, in the case of food industries—bear the burdens of ecological variability at local levels. If it is true that the process of industrializing organisms produces outcomes that are rather unpredictable in any given locality, the environmental history of Latin America's biologically based commodities demonstrates that boom-and-bust cycles, long-lasting ecological changes, and unstable livelihoods are overdetermined outcomes of monocultures directed by profit-seeking investors and/or managers intent on minimizing variations in perishable goods even as they seek out the biogeographical diversity and social inequalities that lend (temporary) comparative advantages.

This is not to suggest that nothing of significance has changed between the 1920s, when Panama disease prompted United Fruit to abandon banana farms throughout Central America, and 2008, when Marine Harvest and other salmon firms shut down sea pens en masse in the waters of southern Chile. In the interim, environmental, consumer, and small-scale producer movements have emerged that are dedicated to documenting the dangers of industrial food production and proposing alternatives. Furthermore, the expansion of private and public research institutions during the twentieth century means that far more studies are published on Chilean aquaculture than were available a century ago on the banana industry. Finally, many of the actors who shape the flow of farmed salmon, including aquaculture firms, supermarket chains, scientists, environmentalists, consumers, professional chefs, and fisherfolk, invoke "sustainability" in their public discourses. Indeed, Marine Harvest's (2010, 9) *Sustainability Report 2009* includes a lengthy list of "potential environmental impacts"—something that would be hard to imagine in an early twentieth-century United Fruit Company publication.

Although its meanings are undeniably contested and slippery, "sustainable development" may possess the ability to link a diverse set of social movements and intervene in a wide range of public policy debates, including those related to aquaculture (Sneddon, Howarth, and Norgaard 2006; Barton and Fløysand 2010). The immediate intimacy of eating has made food politics a hot topic among educated elites and has compelled many transnational agribusinesses and retailers to respond with new products that carry third-party certifications related to the social and environmental conditions under which they are made (Diana 2009). But for sustainability discourses to produce durable and widespread changes in economic policies and development practices, both the dynamics of biological

22. Marine Harvest Group, the parent company of Marine Harvest Chile, is based in Oslo, Norway; major shareholder groups are based in Cyprus and the United States.

commodity production and the problem of accumulation will have to be confronted. Unfortunately, Marine Harvest appears to be guided by a utopian vision in which no conflict exists between maximizing value creation and operating in a sustainable way, a declaration that flies in the face of historical evidence (Marine Harvest 2010).

So, what does this all mean for the immediate future of aquaculture in southern Chile? There can be little doubt that the mass introduction and raising of salmonids in southern Chile is damaging both endemic species of freshwater fish and marine benthic communities while simultaneously reducing the genetic diversity of populations of farmed fish, a situation that may undermine the resiliency of both regional economies and ecosystems in the face of new stresses associated with ever-evolving pathogens, nutrient overloads, and climate change.[23] Furthermore, the profits enjoyed by aquaculture companies resulted to some significant degree from an ability to pass off risks by taking advantage of preexisting social inequalities that simultaneously became a rationale for transforming ecosystems and a necessary condition for profit making.

Fish vaccines, improved sanitation practices, and the geographical dispersion of production will likely reduce the severity of future ISA outbreaks in Chile over the short term, but there is little historical or ecological basis for thinking that pathogens and parasites will cease to "surprise" the aquaculture industry.[24] The geographical extension of the industry guarantees the proliferation of introduced species, parasites, and sea-pen-related pollution. Heightened production costs (and lower profit margins) associated with the foregoing measures will probably lead to greater financial and administrative consolidation and fewer jobs than in the past. That said, if sustainability is conceptualized on a sectoral or national level, commodity diseases alone are unlikely to bring an end to Chile's farmed salmon industry any more than they caused the end of export banana or coffee production in tropical Latin America. But the story will be quite different when told from the vantage point of residents and/or workers in specific localities, for whom Chile's blue revolution may leave little more than a lingering smell of something fishy.

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23. Farm-raised populations of salmon in Norway exhibit both genetic differentiation from wild populations and a reduction in genetic variation, tendencies that could limit the industry's ability to respond to environmental change (Ferguson et al. 2007).

24. Since the ISA outbreak, Chilean, Norwegian, and U.S. pharmaceutical companies have gained approval from the Chilean government to market vaccines, an example of companies turning a commodity disease into a business opportunity (Fish Information Services 2010). The efficacy of the vaccines is unknown.

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