ConsumerReports®

For more information, please contact:
Jen Shecter
Director, Content Impact & Corporate Outreach
(914) 378-2402, jshecter@consumer.org
greenerchoices.org

Printed on 100% recycled paper using non-toxic inks and renewable wind-powered energy.

ConsumerReports FOOD SAFETY AND SUSTAINABILITY CENTER
SHRIMP REPORT
APRIL 2015

SHRIMP REPORT

ConsumerReports®

FOOD SAFETY & SUSTAINABILITY CENTER

Current Contributors to the Consumer Reports Food Safety and Sustainability Center

The following individuals are currently associated with Consumer Reports Food Safety and Sustainability Center. Highlights of their roles and expertise are provided below.

CR Scientists

Dr. Urvashi Rangan leads Consumer Reports' Consumer Safety and Sustainability Group and serves as the Executive Director of its Food Safety and Sustainability Center. Dr. Rangan directs all of the organization's food-safety testing and research in addition to the scientific risk assessments related to food and product safety, which she translates into actionable recommendations for lawmakers and consumers. She is an environmental health scientist and toxicologist and is a leading expert, watchdog, and spokesperson on food labeling and food safety. Dr. Rangan received her Ph.D. from the Johns Hopkins School of Public Health.

Charlotte Vallaeys is a senior policy analyst and writer for the Consumer Reports' Food Safety and Sustainability Center. She focuses on sustainability and justice in the food system and works on a variety of food policy and food safety issues, including food labeling and organic policy. She regularly attends National Organic Standards Board meetings as a watchdog for the organic label and has done work for the National Organic Coalition. She previously worked as Policy Director at The Cornucopia Institute. She received her master's degree in theological studies from Harvard University, where she studied social and environmental ethics, and a master's of science in nutrition from the Friedman School of Nutrition Science and Policy at Tufts University.

Dr. Doris Sullivan is the Associate Director for Product Safety in Consumer Reports' Consumer Safety and Sustainability Group. She oversees product safety testing, research, and prioritization. She is also an expert in compiling and analyzing large datasets. She received her Ph.D. in chemistry from Boston University and completed postdoctoral research at the Free University of Brussels and University of Pennsylvania.

Dr. Michael K. Hansen is a Senior Scientist with Consumers Union, the policy and advocacy arm of Consumer Reports. He works primarily on food safety issues, including pesticides, and has been largely responsible for developing the organization's positions on the safety, testing and labeling of genetically engineered food and mad cow disease. Dr. Hansen served on the Department of Agriculture's Advisory Committee on Agricultural Biotechnology from 1998 to 2002 and on the California Department of Food and Agriculture Food Biotechnology Advisory Committee from 2001 to 2002.

Dr. Keith Newsom-Stewart is a Statistical Program Leader at Consumer Reports. During his tenure, he has worked on a wide range of projects, including those related to meat, seafood, and poultry safety and food additives. He specializes in linear and nonlinear mixed models, experimental design, and analysis of complex surveys. Prior to coming to CR, he worked for the Cornell Biometrics Unit and College of Veterinary Medicine. His educational background is in statistics, general biology, and genetics. He is an adjunct math professor at Western Connecticut State University and a member of the American Statistical Association.

CR Communications

Jennifer Shecter is the Director of Content Impact & Corporate Outreach. In this capacity, she manages the center's partnerships and relationships, coordinates its overall public service activities, and pursues strategic initiatives to build support for its mission. She has been with Consumer Reports for more than a decade, serving first in its Communications Department, promoting food and product safety issues, then working as the Senior Adviser to the President—writing speeches, op-eds, and briefing materials—and advising on key organizational issues.

CR Advisers

Chantelle Norton is an artist and designer and is a lead designer of Consumer Reports' Food Safety and Sustainability Center reports. She has worked in many fields of design, from fashion to print to costume to graphic design. She lives in the Lower Hudson Valley with a medley of animals, including her pet chickens. Her latest paintings take the chicken as muse and feature portraits of her feathered friends in landscapes inspired by the Hudson Valley and Ireland.

Contents

Preface 4

Introduction 5

Where Do Shrimp Sold in the U.S. Come From? 6

Shrimp and Sustainability - Why Our Choices Matter 7
- Aquaculture/Farmed Shrimp 8
- Shrimp Farming and Sustainability 10
- Diversity and Polyculture 10
- Stocking Density 11
- Chemical and Drug Use 11
- Protecting Natural Resources 12
- Sustainability of Feed 14
- Worker Welfare and Local Communities 15
- Animal Welfare 15

Farming Shrimp Sustainably - A Look Behind the Labels 15
- Labels Guide 16
- Reliable Labels 20
- Unreliable Labels 22

Fishing Wild Shrimp Sustainably 24

Regulations of Shrimp Safety in the U.S. 26

Consumer Reports Testing 30

Testing Methods 36

Testing Results and Discussion 36

Key Findings 48

Key Recommendations 50

Policy Recommendations 51

References 52

Preface

THE CONSUMER REPORTS Food Safety and Sustainability Center is committed to ensuring that consumers have access to a fair, just, and safe food system.

The center works in many domains, and one of its core goals is to eliminate the inappropriate use of antibiotics and other chemicals in the food system.

We tested shrimp for bacterial contamination, antibiotic resistance and antibiotic residues. While we found low antibiotic residue levels, the use and presence of antibiotics in shrimp production is a public health concern because heavy antibiotic use accelerates the selection for antimicrobial resistant bacteria which are then present in the product, production, and environment where they are raised. When those bacteria infect people, the infection can be more difficult to treat. Given that no antibiotics are approved for use in the U.S. for shrimp production, it is concerning that 5% of the imported shrimp we tested had illegal antibiotic residues.

The current investigation looks at the interconnection of food safety and sustainability, with a focus on the use of drugs and chemicals in shrimp production.

Introduction

IN THE U.S., shrimp is the single most popular seafood item, accounting for 3.6 of the 14.5 pounds of per capita seafood consumption.[1] In 2013, 1.1 billion pounds of shrimp sold in the U.S. were imported from foreign aquaculture operations, representing $5.3 billion.[2] In order to increase levels of production, intensive systems have been developed to raise shrimp. As the name suggests, those operations produce more shrimp in smaller spaces and do so by adding feed as well as a variety of antibiotics and pesticides to limit the growth of bacteria and parasites that can cause disease in crowded conditions.[3] The systems can also be subject to complete collapse when disease overtakes them.[4] In addition to creating poor conditions for the shrimp themselves, those types of unsustainable systems can cause many public health problems, including harm to the environment and to workers, and the overuse of antibiotics, including those critical for human medicine.[5]

Though many other countries allow the use of antibiotics in shrimp farming[6, 7, 8], no antibiotics are approved by the U.S. Food and Drug Administration (FDA) for use in shrimp farming. The FDA does permit licensed veterinarians to prescribe some antibiotics for use in shrimp farming in the U.S. (through a mechanism known as extra-label use[9]) and residue tolerances are applied to domestic, farmed shrimp. However, the FDA does not permit any antibiotic residues for imported shrimp. If the FDA finds residues of any antibiotics in just one sample from an imported shipment, the whole shipment would be rejected. Unfortunately, the FDA conducts laboratory testing on very few samples. In fact, in 2014, only 0.7 percent of shrimp import lines were tested.

As is the case in any situation in which antibiotics are used, it has been shown that the use of antimicrobial agents in shrimp farming can select for bacteria resistant to the drugs used as well as to similar antimicrobials in the same class of drugs.[10] Antimicrobial resistance is a major public health crisis. The national Centers for Disease Control and Prevention (CDC), the World Health Organization, and other medical organizations have stated that drug-resistant bacteria are currently a bigger threat to world health than AIDS, and the CDC's Threat Report 2013 states that a minimum of 2 million illnesses and 23,000 deaths annually can be attributed to antibiotic resistance in the U.S.[11]

Chemical- and drug-intensive shrimp aquaculture systems are not sustainable. The use of chemicals and drugs is a short-term, band-aid solution for problems that occur due to overcrowding, poor management and inadequate hygiene. Conditions that give rise to higher bacteria prevalence and more antibiotic-resistant bacteria have other adverse effects on public and environmental health.

In order to illustrate the problems with shrimp production, we report here the results of our extensive testing of retail shrimp for bacteria, antibiotic resistance in bacteria present, and drug residues. We will also discuss the conventional practices for raising shrimp and how the FDA regulates imported shrimp.

We believe that farmed food should be produced in a way that does not rely on drugs and chemicals to maintain health. A sustainable farming system relies on good hygiene and health-promoting management practices, rather than on chemicals and drugs that mask underlying problems and can adversely impact the environment, public health, and ultimately personal health.

It is possible to raise shrimp in a more sustainable manner. This report, by discussing test results and reviewing labels found on shrimp, will help readers find more sustainably produced shrimp.

Where Do Shrimp Sold in the U.S. Come From?

Origin

According to the FDA, "shrimp imports represent 94 percent of total shrimp consumed in the United States," and "the vast majority of shrimp comes from aquaculture operations in Asian countries."[12] In 2014, about 78 percent of the total import volume to the U.S. came from the following five countries: India, Indonesia, Ecuador, Vietnam, and Thailand (**Figure 1**).[13] Country of origin labeling (COOL) has been required for seafood since 2005, and as a result consumers are often able to determine where the shrimp they purchase comes from based on the label.[14, 15]

Processing

Import data from the Department of Commerce indicates that the majority of imported shrimp arrive frozen.[16] In 2014, frozen shrimp represented 78.8 percent of all imported shrimp; prepared shrimp (canned, breaded, or otherwise prepared—and also usually frozen) accounted for 20.9 percent and fresh shrimp accounted for only 0.3 percent of imports. Frozen shrimp are sold in two forms: raw (uncooked) and cooked. In the latter form, shrimp are considered a ready-to-eat food, which has different implications for food safety. All types of shrimp come in a variety of "cleaned" states, including shell on, deveined with shell intact (EZ-Peel), and completely peeled and deveined.

Influences on Availability

The supply of retail shrimp can vary due to the year-to-year influences of disease and the environment.[17] For instance, there are a variety of significant shrimp diseases that have had documented catastrophic effects on aquaculture operations in some countries. White spot syndrome virus, which causes wasting and high mortality among shrimp, is highly contagious and has led to intermittent collapses within the industry, particularly in East and South Asia, beginning in the early 1990s.[18, 19] More recently, the industry has been plagued by outbreaks of the emerging shrimp disease Early Mortality Syndrome (EMS) that causes hepatopancreatic necrosis in shrimp, likely due to ingestion and gastrointestinal tract colonization by a unique strain of *Vibrio parahaemolyticus* that produces a toxin.[20] Though *Vibrio* bacteria exist naturally in many water sources, the devastation caused by EMS is likely enabled by the environmental stresses associated with large-scale shrimp farming.[21] EMS first caused large-scale die-offs among shrimp farming operations in Asia in 2010, and as recently as the spring of 2014 has been detected or appears to have impacted production in Thailand, Malaysia, Vietnam, and Mexico.[22, 23, 24] Additionally, unfavorable weather has been reported as a problem influencing the ability of farming operations to meet expected yields.[25] Environmental conditions can have significant effects for capture fisheries, as well.[26, 27]

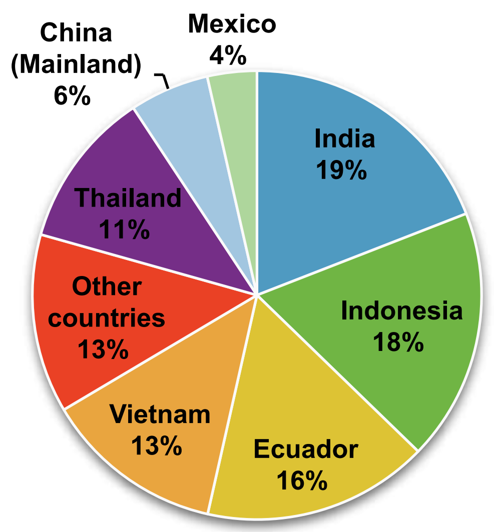


Figure 1. Percent of 2014 shrimp import volume to U.S.

Shrimp and Sustainability—Why Our Choices Matter

As with other foods, our choices matter when we buy shrimp.

Whether the shrimp we eat are harvested from the wild or farmed (70 percent of worldwide shrimp production is farmed),[28] the fisheries and farms that bring us shrimp rely on and interact closely with the natural environment, workers, and communities. There are different ways to fish and farm shrimp—and many choices that fisheries and farmers make impact people and the environment.

For wild shrimp, for example, fishing vessels can use nets that will catch everything in their path, including endangered species such as turtles that can be injured or killed in the process. Or the nets can be outfitted with devices that allow creatures larger than shrimp, including turtles, to escape and remain largely unharmed. In the U.S., federal law requires that fishing vessels, with some exceptions, in the Atlantic or Gulf must be equipped with an approved turtle exclusion device (TED) in each net.[29] However, a state law in Louisiana prohibits state officials from enforcing the federal law in that state.

Shrimp farmers can also make choices that impact the environment and local communities. They can focus on maximizing the production of shrimp, increasing their numbers in ponds to levels that create crowded and unsanitary conditions, which then increases the animals' vulnerability to disease, leading in turn to the need for antibiotics, chemical disinfectants, and other drugs that can have serious ramifications for the environment and public health. Or farmers can choose a more sustainable system without drugs and chemicals, and carefully manage the shrimp in biologically diverse systems at densities that maintain health.

AQUACULTURE/FARMED SHRIMP

Aquaculture is the farming of aquatic species.[30] When shrimp is labeled "farmed" or "farm-raised," it means that the shrimp were raised in captivity, in ponds or tanks. In warm climates, shrimp farming often takes place outdoors. In colder climates, shrimp farming can take place indoors in smaller tanks in climate-controlled spaces.[31] Depending on the system, shrimp ponds can range in size from less than 0.1 acre[32] to as large as 74 acres outdoors,[33] and are generally 0.25 to 2.5 acres.[34] The ponds can be stocked with post-larvae (young shrimp) that are captured from the wild or from commercial hatcheries.[35] Shrimp ponds used to be located primarily in coastal areas, but today, due to the cost of coastal land and environmental concerns, many shrimp farms have moved inland.[36]

Systems and Trends in Shrimp Aquaculture

The general trend in shrimp farming parallels that of land-based animal agriculture: beginning with raising animals at low densities in farms that mimic their natural habitat and use minimal outside inputs, giving way to more intensive cultivation at higher stocking densities focused primarily on producing shrimp, requiring considerable outside inputs to maximize yields and maintain the system.[37] Though crowded monoculture farms may maximize yields in the short term, they raise concerns about the overall health, long-term viability and sustainability of shrimp production.

Sustainable food systems can meet the needs of today's generation without sacrificing the ability of future generations to meet theirs. That means that sustainable farms aim to preserve natural resources and reduce waste and pollution. Just as importantly, sustainable farms promote health, self-reliance, and resilience on the farm. Sustainable systems must also be economically and socially just, and worker welfare is another critical cornerstone of sustainability.

As is the case with all types of food, there are many different systems of shrimp farming. Understanding the type of shrimp production systems is essential to framing the most important environmental and social concerns associated with shrimp farming. The different ways of farming shrimp are roughly categorized, and briefly summarized, as follows:

Extensive System

The traditional way of raising shrimp is known as an "extensive system." In this system, shrimp larvae are introduced into large outdoor ponds, where they grow gradually by feeding on algae, small benthic plants and animals, and plankton that appear naturally in the water.[38] The system involves very little management or inputs. Stocking densities in extensive systems are low, and so are the yields.[39, 40]

Semi-Intensive System

In the mid-1970s, feed companies began experimenting with supplemental feeding in extensive systems, which gave rise to the semi-intensive system.[41] In a semi-intensive system, farmers feed the shrimp once or twice per day and raise the stocking densities.[42] The higher stocking density requires more management, such as refreshing the water, in addition to outside sources of feed.[43] Other outside inputs and management practices can be introduced, from pesticides to drugs to chemical disinfectants.[44] As stocking density rises, so do the yields.[45]

Intensive System

Intensive systems aim for maximum productivity. Intensive systems are generally in smaller-sized outdoor ponds (0.25 to 2.5 acres) with higher stocking densities.[46] In this type of system, the shrimp density exceeds the availability of natural sources of feed in the water, and the shrimp must be given a formulated feed three to five times daily to meet their nutritional needs.[47] The stocking density also exceeds the natural oxygen supply in the water and the ability to absorb waste, so intensive ponds need careful and constant intervention by the shrimp farmer to maintain appropriate levels of oxygen in the water, prevent buildup of harmful waste, and prevent disease.[48]

This type of system is heavily reliant on outside inputs, including feed, drugs, and disinfectants. Intensive systems have been shown to be more fragile and prone to disease outbreaks and collapse. As shrimp industries in Asian countries moved to intensive systems, a boom-and-bust pattern emerged as Taiwan, China, Thailand, and the Philippines all experienced total collapses of their national shrimp industries in the 1980s and 1990s.[49]

Super-Intensive System

There is a relatively new system of farming shrimp that is growing in popularity in places with colder climates that do not support outdoor shrimp farming: a super-intensive system.[50] A super-intensive system generally takes place in indoor tanks in climate-controlled spaces.[51] Stocking densities can be very high—higher than in intensive outdoor systems—and yields can be as high as 60,000 pounds per acre.[52]

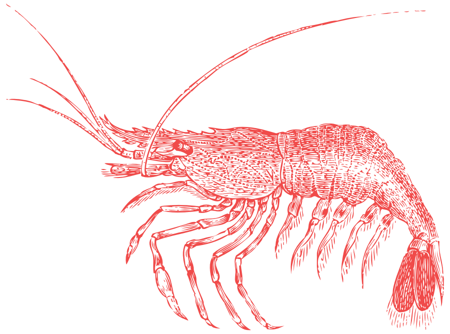
Recirculating Aquaculture Systems (RAS)

Recirculating aquaculture systems (RAS) raise shrimp in tanks and use a water filtration system to continuously clean the water for reuse.[53] Water can be filtered with mechanical filters or biological filters ("biofilters"). Biofilters are a combination of bacteria, algae, and other organisms that metabolize the pollutants in the water and thereby clean it.[54] Because water is recirculated, it means there is reduced use of freshwater,[55] which is a valuable natural resource, and reduced amounts of waste released from the farm;[56] however, RAS do require the use of electricity.

RAS can be located indoors or outdoors, depending on the climate.[57] They can be less dependent on drugs and chemical inputs because water is continuously cleaned and the closed system keeps out potential pathogens.[58] If managed with a focus on sustainability, for example by using renewable and nonpolluting sources of energy to supply the water pumps and organically grown feed, recirculating farms can be sustainable.

Hatcheries and Nurseries

Regardless of the type of system used—extensive or intensive—many shrimp farms have shifted from sourcing young shrimp from the wild to sourcing from hatcheries.[59] Sourcing from hatcheries means that wild young shrimp (post-larvae) and the sensitive coastal habitats where shrimp spawn are left undisturbed for the purpose of stocking shrimp farms.[60] One reason that shrimp farms source from hatcheries and nurseries is to help prevent the introduction of disease into the ponds.[61] Shrimp farmers can buy juvenile shrimp from nurseries that are "Specific Pathogen Free" (SPF) certified, which means that the shrimp have been screened and determined to be free from specified pathogens (most typically those are viruses and parasites) of concern to shrimp farmers.[62] Hatcheries and nurseries can also be intensive operations that use drugs and chemicals to prevent disease, and some of the sustainability issues outlined below apply to shrimp hatcheries and nurseries as well as "grow-out" ponds.[63, 64]



Shrimp Farming and Sustainability

Sustainability is a complex issue, and there is no one way to measure it. Neither is there a single system that is inherently and absolutely sustainable. Some concerns, including the destruction of important ecosystems such as mangroves or wetlands to make room for shrimp farms, can happen whether the farm is an extensive polyculture system or an intensive monoculture system. Indoor and inland ponds, which do not directly impact coastal ecosystems, can be heavily dependent on formulated feed, which can indirectly affect coastal areas from the synthetic fertilizers, pesticides, and other pollutants in the runoff from the farms that grow the shrimp feed ingredients. It is therefore not possible to necessarily generalize that one type of system is always sustainable or not.

Yet, in many ways, some systems are more sustainable than others. Systems that are heavily dependent on outside inputs are generally not sustainable. Increasing stocking densities and reducing biological diversity can lead to conditions that promote disease, waste, and pollution. Improving sustainability of food-production systems happens along a continuum. Steps can be taken to improve the sustainability of shrimp production, starting with choosing a system that is more likely to be resilient and self-reliant, then taking individual steps to ensure that the farm is managed in ways that promote sustainability, environmental stewardship, worker welfare, and animal welfare.

For the purpose of understanding and comparing labels on shrimp, we have reviewed measurable sustainability attributes below. We acknowledge that there are many more sustainability measures, but we chose these attributes as especially important. After discussing the individual elements below, we will compare how four certified labels on farmed shrimp address these particular sustainability issues.

Diversity and Polyculture

Monoculture refers to a farming system that raises one particular crop, whereas polyculture systems raise two or more crops in an interconnected farming system. Traditionally, extensive farms were not monoculture operations that focus exclusively on shrimp production (as many are today),[65] but polyculture operations, farming two or more species.[66] Polyculture pond farming can mix shrimp farming with tilapia, milkfish, barramundi, mussels, clams, crabs, and seaweed.[67]

Polyculture farms harness the natural behavior and functions of different types of organisms to create a more balanced system, which reduces dependence on outside inputs and can reduce waste and pollution. Like a monoculture system, polyculture systems still require a lot of management if they are to be sustainable, but they are managed in different ways and based on different principles. Shrimp yields on polyculture farms are generally lower than on intensive monoculture farms, but the farmer generally requires fewer inputs (lowering costs), can use or sell other crops produced on the farm, and is less susceptible to total losses from disease outbreaks.[68]

One type of shrimp polyculture farm is a shrimp-tilapia farm. The tilapia in a shrimp pond can reduce the presence of parasites,[69] promote beneficial algal blooms,[70] reduce accumulation of waste,[71] and consume diseased or dead shrimp.[72] Those factors may also contribute to preventing illness in the shrimp.[73]

Diverse systems can also be more economically sustainable. Though polyculture farms have lower shrimp yields compared with intensive farms, there are other benefits to the farmer. The system promotes health and reduces diseases, thereby reducing the need for chemicals and the costs of sourcing those inputs.[74] Also, if prices drop for one type of crop or if a farmer loses one type of crop to disease, the losses can be weathered more easily in a diverse system than in a monoculture system.[75]

More farmers are choosing polyculture over monoculture as one of many ways to make shrimp farming more sustainable.[76]

Stocking Density

Like other complex living organisms, shrimp become more susceptible to disease when they are raised in crowded conditions.[77] Viruses or bacteria that would not otherwise harm shrimp can lead to disease and mortality when the animals are stressed from crowding, poor water quality, and/or poor nutrition.[78, 79] Poor water quality can also result from the accumulation of waste and depletion of oxygen, which can result from high stocking densities and poor management. Keeping shrimp healthy in outdoor ponds with high stocking densities is a challenge that many farmers have attempted to address with the use of drugs and chemicals.

However, very densely stocked shrimp ponds or tanks also can be managed using environmentally sustainable methods. For example, indoor recirculating farms can have very high stocking densities yet use no drugs or other chemicals if the water is cleaned using biological filters.

Chemical and Drug Use

ANTIBIOTICS

Some of the most devastating diseases in the shrimp industry have been caused by viruses (e.g., white spot disease, Taura syndrome).[80] Only an estimated 20 percent of losses from disease have been caused by bacterial pathogens that could be treated with antibiotics.[81] Most major disease outbreaks in the shrimp industry have been caused by a combination of production practices and the weak immune systems of shrimp, leading to infections with viruses that cannot be treated with antibiotics.[82]

Nevertheless, rather than change the conditions that can lead to disease outbreaks, shrimp farmers in major shrimp-producing countries have turned to drugs as short-term, band-aid solutions to support a vulnerable system, including antibiotics to attempt to prevent or treat bacterial diseases.[83] No antibiotic drugs are specifically approved for shrimp sold in the U.S., and it is illegal for any imported shrimp to have any antibiotic residues. However, extra-label use (discussed below) of some drugs is permitted in U.S. farmed shrimp. In other countries, the use of many antibiotics appears to be permitted in aquaculture.[84, 85, 86] Some of the countries that are exporting shrimp to the U.S., such as China and Vietnam, appear to allow up to 20 and 32, respectively, antibiotics and other chemicals to be used in shrimp farming.[87] The use of antibiotics in shrimp aquaculture has been documented in studies and government programs that have detected antibiotic residues in shrimp.[88, 89, 90] Many of those drugs in turn carry risks to public health and the environment.[91]

One of the most serious public health risks of using antibiotics in food production, especially for non-therapeutic reasons, is the development of antibiotic resistance. In 2013, the CDC noted that 23,000 human deaths could be attributed to the development of antibiotic resistance from overuse of antibiotics, including in agricultural settings.[92]

SYNTHETIC PARASITICIDES

In addition to using antibiotics to control bacterial diseases, shrimp farmers can attempt to prevent disease with the use of certain other drugs and chemicals.[93, 94] One example is the parasiticide formalin, an aqueous solution containing formaldehyde gas.[95, 96, 97, 98] Formalin is approved for shrimp aquaculture in the U.S. and abroad.[99]

Formalin, as well as other chemical disinfectants such as chlorine and iodine, can be used in hatcheries and nurseries to treat shrimp eggs and larvae, often for preventive rather than therapeutic reasons.[100, 101] Formalin baths can also be used to treat certain diseases, at concentrations that are not toxic to shrimp but are effective for disease control.[102 103] There is no mandatory withdrawal time prior to food animal harvest and no residue tolerance set by the FDA.[104]

Formaldehyde/formalin is a known human carcinogen.[105] It is also classified as a "hazardous substance" by the Environmental Protection Agency in accordance with the Clean Water Act.[106] Substances that are designated as "hazardous" by the EPA are compounds which, when discharged in any quantity in water, "present an imminent and substantial danger to the public health or welfare, including, but not limited to, fish, shellfish, wildlife, shoreline, and beaches."[107]

PESTICIDES

In addition to using antibiotics to control bacterial diseases, shrimp farmers can attempt to prevent disease with the use of certain other drugs and chemicals.[93, 94] One example is the parasiticide formalin, an aqueous solution containing formaldehyde gas.[95, 96, 97, 98] Formalin is approved for shrimp aquaculture in the U.S. and abroad.[99]

Formalin, as well as other chemical disinfectants such as chlorine and iodine, can be used in hatcheries and nurseries to treat shrimp eggs and larvae, often for preventive rather than therapeutic reasons.[100, 101] Formalin baths can also be used to treat certain diseases, at concentrations that are not toxic to shrimp but are effective for disease control.[102 103] There is no mandatory withdrawal time prior to food animal harvest and no residue tolerance set by the FDA.[104]

Formaldehyde/formalin is a known human carcinogen.[105] It is also classified as a "hazardous substance" by the Environmental Protection Agency in accordance with the Clean Water Act.[106] Substances that are designated as "hazardous" by the EPA are compounds which, when discharged in any quantity in water, "present an imminent and substantial danger to the public health or welfare, including, but not limited to, fish, shellfish, wildlife, shoreline, and beaches."[107]

CHEMICAL DISINFECTANTS

Another way to attempt to prevent disease outbreaks is by treating incoming seawater with chemical disinfectants, such as chlorine and iodine.[111, 112] Chemical disinfectants can also be used to disinfect shrimp eggs and nauplii in hatcheries.[113, 114] Chlorine appears to be a commonly used chemical in shrimp production. A survey of Thai shrimp farmers found that 67 percent reported using chlorine as a disinfectant.[115] According to a 1998 report, in Thailand, 50,000 tons of chlorine is used annually on shrimp farms.[116]

Protecting Natural Resources

MANGROVES

One of the most devastating environmental impacts of shrimp farming has been the destruction of mangroves and other important ecological systems.

Mangroves are "coastal woodlands" or "tidal forests" found along sheltered tropical and subtropical coastlines.[117] Mangroves provide numerous benefits to the local environment, including significant social and economic benefits to people living in coastal communities.[118, 119] The many functions of mangroves include mitigating floods; protecting coastal areas from storms and waves; wildlife habitat, including providing nurseries and feeding grounds for commercially important fish, shrimp, and shellfish;[120] removing toxicants and pollutants from the environment; controlling erosion; and more.[121]

In certain countries, over 80 percent of the mangroves have been destroyed.[122] Not all is due to the conversion to shrimp farms—shrimp aquaculture, especially extensive systems, played a role, especially in Southeast Asia.[123] In Thailand, for example, the Royal Thai Forest Department estimated in 1993 that 17.5 percent of the country's original mangrove areas were occupied by shrimp farms.[124]

A survey of 12 Asian countries by the Asian Development Bank found that 41.9 percent of extensive shrimp farms and 19 percent of intensive shrimp farms were built on land that used to be mangroves.[125]

Many countries have laws and regulations in place to protect mangroves.[126] The shrimp industry has also voluntarily moved away from siting shrimp farms in former mangrove areas, not only to respond to environmental concerns but also

because former mangrove sites are not optimal sites for shrimp farms and land above the intertidal zone is more accessible, manageable, and productive.[127, 128] Nevertheless, even siting shrimp farms in inland locations still often requires access to the ocean, and some mangroves may need to be disturbed.[129] Sustainable shrimp production should ensure that no mangroves are disturbed or lost.[130]

LOCAL WILDLIFE

Local wildlife can take advantage of shrimp ponds and hatcheries as an easy source of food, which can become a serious problem for shrimp farmers.[131] There are many species that can become problematic predators, including snakes, birds (herons, kingfishers), fish, amphibians (frogs), crustaceans (crabs), and mammals (otters).[132] To protect local wildlife, shrimp farmers should use methods that deter predators rather than aim to injure or kill them. That is especially important when predators are threatened or endangered species.

NATIVE SHRIMP

There are two main threats from shrimp aquaculture to the well-being of local wild shrimp populations. The first is the introduction of shrimp that may be genetically different from the wild species living in surrounding waters. When farmed shrimp are released into the environment, either intentionally or unintentionally, they can compete with native shrimp and other crustaceans.[133] The introduction of non-native species is considered a relatively major ecological risk associated with aquaculture.[134]

Second, shrimp aquaculture can source young shrimp larvae either from wild harvesting or from commercial hatcheries.[135] Collecting young shrimp from wild areas influences the ecosystem and can affect aquatic biodiversity.[136] Larvae of other crustaceans, fishes, and other animals are often caught and discarded as bycatch.[137]

Many shrimp farms have turned to commercial hatcheries as a source of juvenile shrimp stock, not for ecological reasons but in an attempt to prevent disease outbreaks. Hatcheries can supply Specific Pathogen Free shrimp, which means the post-larvae have been sourced from hatcheries that are biosecure and have been screened and determined to be free from specified pathogens (mostly viruses and some parasites) that are of concern to shrimp farmers.[138]

EUTROPHICATION

Shrimp ponds receive a large volume of nutrients, either in the form of fertilizers added to the water to promote the growth of naturally occurring feed sources or as formulated shrimp feed. Some of those nutrients will accumulate and be discarded in wastewater.[139] That can cause nutrient pollution, also known as eutrophication, of nearby water bodies.[140]

Eutrophication results when the nutrients and organic matter in wastewater exceed the ability of the receiving water to accumulate them.[141] The nutrients in the wastewater feed algae and cyanobacteria in the receiving water, which then in turn can lead to high concentrations of toxins and low levels of oxygen in the water. Those conditions can change the ecosystem and decrease biodiversity.[142]

SALINIZATION

If not managed properly, shrimp ponds can contribute to salinization (contamination with salt) of local water and land. Salt can leach from the pond water unintentionally, if the pond is not properly sealed, or salty pond water can be discharged intentionally into freshwater bodies or surrounding land between crops (most intensive systems have two shrimp crops per year).[143]

Contamination with salt from shrimp ponds leads to numerous negative impacts on the local environment and communities. A major concern is that salinization makes nearby land unsuitable for agriculture.[144, 145] Salinization of freshwater bodies can harm the wildlife living in those bodies of water.[146] The impact on local communities can be serious, as salinization can make water unsuitable for irrigation in agriculture and for drinking. In a study of the Nellore District in India, the quality of drinking water wells in villages near shrimp farms was affected in 17 of 26 villages.[147]

Sustainability of Feed

As stocking densities rise, so does the need for outside sources of feed.[148] In extensive systems, no or very little feed is added to the ponds because the shrimp are able to meet their nutritional needs by feeding on naturally occurring algae, plankton, and small benthic animals and plants.[149] In semi-intensive systems, shrimp are fed one to two times daily, and in intensive systems, formulated feed is added to the ponds up to five times daily.[150] As with land-based animal agriculture, the sources of feed and whether its ingredients are produced sustainably or harvested sustainably (in the case of wild fish meal) are important factors when assessing the sustainability of aquaculture operations.[151]

WILD FISH

Though it may seem logical to assume that buying farmed seafood relieves pressure on ocean fisheries, that is not always the case. For many farmed seafood species, including shrimp, feed contains wild fish meal and wild fish oil. For shrimp specifically, traditional formulations of feed contain 20 percent to 30 percent fish meal.[152, 153] In fact, the shrimp aquaculture industry is the single largest global aquaculture consumer of wild fish meal, with an estimated 24 percent to 27 percent of fish meal used for aquaculture being used for shrimp.[154]

If fish meal in shrimp feed is made from the byproducts of fish that are processed for human consumption (and those fish were sustainably caught), it can be a relatively sustainable source because it turns a waste product into food. But fish meal can also contain low-value (in marketing terms) but food-grade fish, such as anchovy, sardine, and mackerel. Those fish are sometimes referred to as "trash fish."[155] Trash fish are usually caught as bycatch (unintended catch) when non-selective fishing gear is used.[156] Using fish that could be used directly for human consumption as feed for farmed aquatic species, including shrimp, raises serious social and environmental concerns.[157] That is especially true because most shrimp farms consume more seafood—from wild fisheries to feed the shrimp—than they produce.[158]

One way to lower the dependence on fish meal and fish oil is to lower stocking densities, which allows the shrimp to meet more of their nutritional needs from natural feed sources and requires farmers to use less formulated feed. Another way is to substitute other protein-rich ingredients, sourced from sustainable aquaculture and agriculture.

LAND-BASED ANIMAL PRODUCTS

Land-based animal slaughter byproducts have been identified as an alternative protein source that can replace wild fish meal.[159] They include all of the parts of livestock that are not marketed for human consumption, such as lungs, intestines, livers, and other organs, as well as the bones, feathers, and hides.[160]

If animal byproducts are derived from animals that were raised in densely stocked confined animal feeding operations—which often give rise to concerns with animal welfare, pollution, drug use, and unsustainable feeding practices—it simply substitutes one unsustainable feed source for another.

PLANT-BASED INGREDIENTS

Plant-based protein sources that can replace wild fish meal in shrimp feed include soybeans, corn, and peas.[161] Sustainable shrimp farming should source feed ingredients from sustainable farms.

In the U.S., the vast majority of soybeans have been genetically engineered for pest or herbicide resistance. The adoption of genetically engineered crop varieties has increased the use of herbicides in U.S. agriculture and has led to the development of "superweeds" that are resistant to those herbicides and require more toxic herbicides to control. Genetically engineered crops are not required to be independently tested for long-term safety before they can be grown commercially for human food and animal feed. Given the intensive pesticide use required for growing genetically engineering plants, we do not consider genetically engineered soy to be a sustainable feed source for shrimp.

Worker Welfare and Local Communities

Shrimp aquaculture can have a positive impact on local communities if managed responsibly, by providing income and employment opportunities.[162] However, in order to have a positive impact, it is important to ensure that workers are treated fairly, are protected from hazardous working conditions, and are paid a living wage.

The Department of Labor lists shrimp from Bangladesh, Cambodia, and Thailand among its list of goods that it has reason to believe can be produced by child labor, and shrimp from Burma and Thailand is listed among its list of goods that it has reason to believe can be produced by forced labor in violation of international standards.[163]

Respecting basic human rights and meeting higher social standards is important not only on the shrimp farm itself but also along the entire supply chain. In June 2014, the British newspaper The Guardian revealed that slaves were forced to work for no pay for years at a time under threat of extreme violence in Thailand's shrimp industry.

The slaves were held on boats that provided fish meal to the world's largest shrimp producer in Thailand.[164]

Many of the environmental attributes discussed above are relevant to the local communities and workers on shrimp farms. Respecting the communities nearby means respecting the local environment and natural resources on which those communities depend.

Animal Welfare

A common practice in the shrimp industry that directly impacts animal welfare is the removal of one eyestalk of female shrimp in hatcheries. Hatcheries capture female shrimp from the wild in order to produce post-larvae for grow-out ponds. The removal of one eyestalk of each wild-caught female shrimp induces maturation and spawning.[165, 166]

Farming Shrimp Sustainably— A Look Behind the Labels

For the major issues we covered above, we briefly summarize how they are addressed by four labels that can be found on packages of shrimp. The four labels we review are the Global Aquaculture Alliance's Best Aquaculture Practices Certified label (GAA BAP), the Aquaculture Stewardship Council's Certified "Farmed Responsibly" label (ASC), the Whole Foods Market "Responsibly Farmed" label (Whole Foods), and the Naturland label. Those are the only labels we identified that are third-party certified to standards that are publicly available. Full label reviews are available on GreenerChoices.org. Our label reviews determine whether the label is not meaningful, somewhat meaningful, meaningful, or highly meaningful by evaluating many attributes, including the rigor of the standards, the independence of the verification process, whether the organization behind the label is free from conflict of interest, whether the standards were developed with broad public input, and other factors.

Some labels that may be found on shrimp, such as "natural," "environmentally aware," and "turtle safe," are not verified and are not backed by a set of consistent standards. In some cases, companies use those labels when they are certified to one of the label standards that we reviewed, such as Naturland. But we have also seen the labels used on shrimp packages that have no independent certification to verify those claims.

ConsumerReports FOOD SAFETY & SUSTAINABILITY CENTER

SHRIMP LABELS GUIDE

✗	NO; OR NOT ADDRESSED IN THE STANDARDS
✓–	SOME RESTRICTIONS
✓	YES
✓+	STRONG STANDARD

1-star means only the processing plant is certified.

2, 3, and 4-stars means the farm where the shrimp are grown is certified.

	Naturland	Whole Foods - Responsibly Farmed	Aquaculture Stewardship Council Certified - Farmed Responsibly	Best Aquaculture Practices Certified (1-Star)	Best Aquaculture Practices Certified (2, 3, and 4-Star)	"Turtle Safe," "Natural," and "Environmentally Aware"
GENERAL						
Prohibits monoculture	✗	✗	✗	✗	✗	✗
Max. stocking density	✓+ 15/m²	✗	✗	✗	✗	✗
DRUG & CHEMICAL USE						
Prohibits antibiotics	✓+ Prohibited in grow-out ponds and hatcheries, including broodstock.	✓ Prohibited in grow-out ponds and hatcheries; permitted for treating broodstock.	✓ Prohibited in grow-out ponds and hatcheries; permitted for treating broodstock.	✗ Processing plants are required to periodically test for presence of antibiotic residues.	✗ Only antibiotics that are "proactively prohibited" in the importing country cannot be used.	✗
Prohibits other drugs: parasiticides	✓+	✓+	✗	✗	✗ Only chemicals that are "proactively prohibited" in the producing or importing country are prohibited.	✗
Prohibits chemical disinfectants	✓+	✗	✗	✗	✗ Only chemicals that are "proactively prohibited" in the producing or importing country are prohibited.	✗
Prohibits pesticide use	✓+ Pesticides are prohibited, including "natural" pesticides such as rotenone.	✓– Only organophosphates are prohibited.	✓– Only pesticides banned by international convention or those rated "extremely hazardous" or "highly hazardous" by WHO are prohibited.	✗	✓– Only pesticides that are proactively prohib-ited in the importing country are prohibited. Standards require that agricultural chemicals be labeled, stored, used and disposed of in a "safe and responsible manner".	✗
FEED						
Standards for sustainable sourcing of aquatic animal ingredients in feed (fish meal)	✓+ From organic aquaculture, fish pro-cessing byproducts, or sustainable fisheries.	✓ Prohibition of "trash fish" in shrimp feed.	✓ From sustainable fisheries, within 5 years of certification.	✗	✓ From BAP-certified feed mills [for 3-star if feed mill is certified, and 4-star] or mills with a "written plan for responsibly sourcing fish meal." [for 2-star and 3-star if feed mill is not certified].	✗
Standards for sustainable sourcing of nonaquatic animal ingredients in feed	✓+ Slaughter by-products must be from organic agriculture.	✓+ Slaughter by-products are prohibited.	✗	✗	✗	✗
Standards for sustainable sourcing of plant ingredients in feed	✓+ Ingredients must be certified organic.	✗	✗ By 2019, 80% of soy and palm oil should be from sources certified by an ISEAL member's certification scheme that addresses environmen-tal and social sustainability.	✗	✗	✗
Prohibits GMOs in feed	✓+	✗ Labeling planned for 2018.	✓– Labeling is required when GMOs are present in feed.	✗	✗	✗

Visit greenerchoices.org for more information

✗	NO; OR NOT ADDRESSED IN THE STANDARDS
✓–	SOME RESTRICTIONS
✓	YES
✓+	STRONG STANDARD

ConsumerReports FOOD SAFETY & SUSTAINABILITY CENTER

SHRIMP LABELS GUIDE

1-star means only the processing plant is certified.

2, 3, and 4-stars means the farm where the shrimp are grown is certified.

	Naturland	Whole Foods - Responsibly Farmed	Aquaculture Stewardship Council Certified - Farmed Responsibly	Best Aquaculture Practices Certified (1-Star)	Best Aquaculture Practices Certified (2, 3, and 4-Star)	"Turtle Safe," "Natural," and "Environmentally Aware"
PROTECTING NATURAL RESOURCES						
Prohibits destruction of mangroves and wetlands	✓+	✓+	✓+	✗	✓+	✗
Requires protecting local wildlife	✓ "Native animals shall be protected." No synthetic chemicals for predator control. Measures that do not harm the animals are preferred.	✓ Vulnerable and endangered species cannot be killed. Lethal predator control must be last resort.	✓ Protected, threatened, or endangered animals cannot be killed. No lead shots or chemicals for predator control.	✗	✓– Endangered species cannot be killed.	✗
Requires protecting native shrimp from farm pond escapes	✓ Preference for native species; "ecological harmlessness" of other species must be proven before they can be farmed.	✓ Non-native species can be farmed when a substantial commercial industry for farming that species already exists.	✓ Non-native species can be farmed when in production already locally.	✗	✓– Farms must comply with national legislation regarding non-native species.	✗
Prohibits harvesting wild shrimp larvae	✓+	✓+	✓+	✗	✓+	✗
Requires protecting water from shrimp pond pollution	✓+ Requirement for regular monitoring of nutrient pollutants, and "adequate measures must be taken to minimize outflow of nutrients".	✓ Requirement for effluent monitoring program, and producers must work to minimize the negative impacts of effluent on receiving waters by reducing inputs of nitrogen and phosphorus. No maximum levels of nutrient pollutants are set.	✓ Maximum levels of nutrient pollutants are set; additional requirements to prevent eutrophication, such as treatment of effluents before discharge.	✗	✓ Maximum levels of nutrient pollutants are based on U.S. point discharge levels.	✗
Requires preventing salinization of land and water	✓ Farms must prevent salinization of nearby land; no standard for water.	✓+	✓+	✗	✓+	✗
ANIMAL WELFARE						
Prohibits eyestalk ablation of female shrimp	✓+	✗	✗	✗	✗	✗
SOCIAL RESPONSIBILITY						
Prohibits forced labor	✓ Forced labor is prohibited, but not verified on fishing boats that supply fish meal.	✓– Standards do not specifically prohibit forced labor but farms must comply with local labor laws. Forced labor is prohibited worldwide.	✓ Forced labor is prohibited, but not verified on fishing boats that supply fish meal.	✓– Industry baseline; forced labor is prohibited and verified in the processing plants but not on the farms that grow the shrimp or on fishing boats that supply fish meal.	✓	✗
Prohibits child labor	✓ Some exceptions: Children may work on family or neighbor farms if properly supervised and the work does not interfere with education or development and is not hazardous.	✗ Local labor laws must be followed.	✓+	✓– Prohibited in the processing plant. No standard for the workers on the farms.	✓ No children under age 14; children 14-18 should not engage in hazardous work.	✗
Requires minimum wage for workers	✓ At least minimum wage or industry standard; applies to temporary workers also.	✗ Standards do not set or require a minimum wage.	✓+ Permanent workers receive a living wage. Temporary workers receive at least minimum wage.	✓– At least the minimum wage in the processing plant. No standard for wages on the farm.	✓ At least minimum wage in the processing plant and on the farm.	✗

Visit greenerchoices.org for more information

Reliable Labels

Naturland

HIGHLY MEANINGFUL

The Naturland label means that the shrimp were raised on farms that are managed in accordance with comprehensive standards by Naturland, a German organic certification organization, that include environmental, social responsibility, and animal welfare components.[167] The label means that the shrimp were raised in outdoor ponds without the use of antibiotics, synthetic parasiticides, synthetic pesticides, synthetic fertilizers, and synthetic processing aids that can pollute the environment.[168]

Of all shrimp labels we have reviewed, the Naturland label is the only one with standards that require low stocking densities to prevent the overcrowded conditions that increase the likelihood of disease outbreaks.[169]

It is also the only label we reviewed that comprehensively covers feed, requiring certified organic ingredients (genetically engineered ingredients are prohibited).[170] Wild fish meal is allowed, as long as it consists of byproducts of wild fish caught for human consumption or bycatches of captures for human consumption in line with internationally established sustainability standards, with some exceptions.[171] Shrimp feed cannot contain more than 20 percent fish meal, which is in line with the industry standard.[172]

The standards also prohibit the removal of the eyestalks of female breeding shrimp in hatcheries.[173] The social responsibility requirements ensure that the workers on shrimp farms are paid at least the minimum wage and are treated fairly.[174]

Consumers should not see shrimp labeled "organic" with the Naturland logo on shrimp packages because the Department of Agriculture (USDA) organic standards do not permit organic certification of aquatic animals.

Aquaculture Stewardship Council—Farmed Responsibly Label

MEANINGFUL

The label means that the shrimp were raised on farms that met standards aimed at reducing the negative environmental and social impacts of shrimp farming. The standards for ensuring worker welfare are especially strong and go beyond preventing the most egregious abuses,[175] such as forced labor and child labor.[176] The standards, for example, require that a "fair or living" wage (rather than a minimum wage) be paid to all permanent workers. A fair or living wage is defined as "a wage level that enables workers to support the average-sized family above the poverty line."[177]

The environmental standards are meaningful, although there is no requirement for a maximum stocking density or for polyculture.[178] The standards do set maximum limits for certain pollutants in wastewater,[179] prohibit the destruction of mangroves[180] and the salinization of nearby water and soil,[181] and prohibit lethal predator control for local endangered or threatened wildlife species.[182]

The standards also prohibit selling shrimp with the label if they were treated with antibiotics[183] but do allow certain other drugs and chemical treatments,[184] such as synthetic parasiticides.[185] And though the most hazardous and persistent pesticides are prohibited,[186] many pesticides are allowed.[187]

The Aquaculture Stewardship Council's shrimp standards are relatively new. The first version of ASC standards for shrimp was finalized in 2014. Though shrimp with the label were not yet available when we did our study, they became available in 2015.

Whole Foods Market—Responsibly Farmed Label

MEANINGFUL

The standards behind the Whole Foods Market Responsibly Farmed label focus especially on eliminating the use of drugs and some, but not all, chemicals used in shrimp farming, as well as other environmental protections.[188] The standards prohibit selling shrimp with the label if they have been treated with antibiotics, parasiticides including formalin, or with the artificial processing chemical sodium metabisulfite.[189] The standards also address protecting native wildlife around shrimp farms, preserving mangroves, and protecting the local environment from farm pollution.[190]

There are no strong standards for worker welfare and animal welfare. The standards only state that local labor laws must be followed.[191]

All farmed shrimp sold in Whole Foods stores are third-party certified to the standards.

Unreliable Labels

Global Aquaculture Alliance—Best Aquaculture Practices Label

1-STAR (only the processing plant is certified)
SOMEWHAT MEANINGFUL*
**The farm, feed mill and hatchery are not certified to the BAP standards. Though the BAP 1-star certified label is still rated as "somewhat meaningful," it only covers the processing plant and is less meaningful than the 2-star, 3-star and 4-star labels.*

2-STAR (the processing plant and farm are certified)
SOMEWHAT MEANINGFUL

3-STAR (the processing plant, farm, and either feed mill or hatchery are certified)
SOMEWHAT MEANINGFUL

4-STAR (the processing plant, farm, feed mill and hatchery are certified)
SOMEWHAT MEANINGFUL

Though the BAP label has some standards above the conventional baseline, we found that four of the 11 samples of imported shrimp with illegal residues were BAP certified. Therefore, we do not recommend the BAP label at this time.

The Global Aquaculture Alliance's Best Aquaculture Practices Certified label should mean the shrimp were processed in a certified plant that met standards that aim to ensure that the food safety requirements in overseas facilities are equivalent to those required in U.S. processing plants. The processing plant standards also have social responsibility and wastewater management components.[192] If only the processing plant is certified, the blue logo can appear on the front without qualification, but on the back of the package it will be accompanied by one star and the word "processor." There are also standards for the farms where the shrimp are raised. If the processor and the farm where the shrimp are raised are certified, the blue logo on the back of the package will be accompanied by two stars and the words "processor" and "farm." Three stars means the processor, farm, and either the feed mill or the hatchery are certified. Four stars means the processor, farm, feed mill, and hatchery are certified.

The standards for shrimp farms aim to reduce the most serious negative environmental and social impacts associated with shrimp farming, such as the destruction of ecologically important mangroves[193] and the pollution of nearby water and land with waste from the farms.[194]

In many cases, such as drug use and wastewater pollution, the standards mirror the industry standard in the U.S. and will therefore ensure that shrimp farms in foreign countries meet the basic environmental and public health regulations that U.S. shrimp farms would meet. The standards allow the use of antibiotics, including for preventive purposes, except those that are "proactively prohibited" for use in aquaculture in the importing country.[195] That means that BAP standards permit the use of antibiotics such as tetracyclines, since those are not "proactively prohibited" for use in shrimp farms in the U.S. Drugs allowed in the importing country—such as formalin, which is allowed in the U.S.—are also permitted.[196] Drugs can be used for preventive purposes with veterinary oversight.[197]

The standards have no restrictions on the use of pesticides and allow artificial processing materials as long as they are discharged in wastewater responsibly.[198] There is no requirement for a maximum stocking density.

Shrimp with the GAA BAP label are widely available in U.S. stores.

Organic Labeling on Shrimp

In the U.S., food can only be labeled "organic" if it has been certified to the federal organic standards. Currently, however, there are no federal organic standards for aquaculture. As a result, shrimp cannot be labeled as organic in the U.S., even if they were raised on farms that are certified to private or other countries' organic standards (such as Naturland organic standards).

The USDA, which is responsible for developing and maintaining the national standards for organically produced agricultural products, is currently drafting standards for organic aquaculture. Those standards will be proposed to the public for comment before being finalized.

Organic aquaculture standards should be written in a way that promotes a sustainable system of shrimp farming and prevents monoculture operations with high stocking densities from qualifying for organic certification.

We believe that organic standards should have rigorous requirements for all of the sustainability attributes covered in this report. The following should be included:

- Prohibition of the use of synthetic inputs, including synthetic pesticides, fertilizers, and drugs.
- Requirement for 100 percent organic feed and prohibit wild fish in feed.
- Prohibition of natural pesticides that pose dangers to workers, such as rotenone, which currently remains approved for use in organics.
- Maximum stocking density.
- Requirement for the cultivation of more than one species (polyculture) to prevent monoculture operations.
- Requirements to control major inputs and outputs in closed farming systems, such as waste management and nutrient recycling, to minimize environmental impacts and ensure quality of the shrimp.*

**Though it does not apply to shrimp farming, we also believe that the organic aquaculture standards should prohibit open ocean net pens. Open ocean net pens make it difficult to control major inputs (e.g., contaminants, pollutants) and outputs (e.g., waste, fish escapes, disease, and parasites) in the farming system.*

Fishing Wild Shrimp Sustainably

BUYING WILD SHRIMP raises different sustainability issues than buying farmed shrimp. A major concern with wild shrimp is the method of catching, which can disrupt the marine environment and can result in many pounds of bycatch for every pound of shrimp caught. Bycatch is non-intended, or nontargeted, catch and can include fish, ranging from small or juvenile fish to large sharks, nontarget crustaceans, sea turtles, and dolphins.[199] According to the Monterey Bay Aquarium, "in the worst cases, for every pound of shrimp caught, up to 6 pounds of other species are discarded."[200]

One of the most common pieces of equipment used to catch shrimp is an otter trawler, which is a cone-shaped net that is designed to work optimally at the bottom of the sea floor.[201] According to the National Oceanic and Atmospheric Administration (NOAA), an agency of the Department of Commerce, incidental capture, injury, and mortality during fishing operations is one of the major threats to sea turtles in the marine environment.[202]

Sea turtle mortality can be reduced drastically when trawlers are equipped with a Turtle Exclusion Device (TED), which is a grid of bars with an opening that allows small animals such as shrimp to pass through the bars and into the net while larger animals, such as sharks and turtles, are given the opportunity to escape through the opening.[203] The devices can reduce turtle bycatch by 97 percent or more, thereby drastically reducing, though not eliminating, mortality of nontarget animals.[204] However, those devices are not without costs to the shrimp industry; first the device has to be purchased, and the use of the device can result in some reduction in shrimp catch.[205]

Federal law and regulations require that any shrimp trawlers, with some exceptions, in the Atlantic or Gulf must be equipped with an approved turtle exclusion device (TED) in each net.[206] Imported shrimp needs to be accompanied by an import certificate declaring that the shrimp are harvested in a way that does not harm turtles, using devices similar to those required in the U.S.[207]

In response to that law, the Louisiana state legislature, believing "that the imposition of TEDs on Louisiana shrimpers is unjustified, inequitable, and unworkable," passed a state law in 1987 prohibiting the enforcement of federal regulations requiring the use of TEDs in Louisiana waters.[208] The Monterey Bay Aquarium recommends avoiding wild shrimp from Louisiana.[209] Wild shrimp from Mexico is also listed as "avoid" by the Monterey Bay Aquarium.[210]

A skimmer trawl is another type of fishing gear that can be used to catch shrimp.[211] Skimmer trawls are used in shallow, near-shore waters.[212] Federal regulations exempt skimmer trawls from the requirement to use turtle exclusion devices.[213] According to NOAA, though sea turtle mortality has historically been considered low for fisheries using skimmer trawls, sea turtles can still become captured, and stress and injury to the animals can occur with the skimmer trawl.[214] NOAA has partnered with the fishing industry to develop TEDs for skimmer trawls, but no regulations have been put in place.[215, 216] Monterey Bay Aquarium's Seafood Watch lists wild shrimp caught with skimmer trawls as options to avoid.[217]

The only wild shrimp with Monterey Bay Aquarium's "Best Choice" rating are the wild spot prawn from Canada and wild shrimp from Alaska.[218] The cold-water shrimp fisheries in the U.S. and Canada have regulations in place to reduce bycatch, and because sea turtles do not live in cold water, the risk to sea turtles from shrimp fisheries in those places is negligible.[219] According to the Monterey Bay Aquarium, stock status is unknown for all shrimp species caught on the west coast of the U.S. But the Monterey Bay Aquarium considers that the small size of many of the fisheries and the measures in place to protect spawning stocks increase the likelihood that those stocks are being fished sustainably.[220]

Wild shrimp that are considered "good alternatives" by the Monterey Bay Aquarium include all shrimp from Canada (wild spot prawn from Canada is a "Best Choice") and all U.S.-caught shrimp except those from Louisiana and those caught by skimmer trawl.[221]

For assurance that the fisheries reduced their impact on nontarget species, and used bycatch reduction devices, consumers can look for wild shrimp with the Marine Stewardship Council (MSC) label. The MSC has recently updated its standards and included stronger requirements for fisheries to reduce bycatch.[222] Shrimp fisheries that are MSC certified (and that consumers may see in U.S. stores), are located in Canada, Oregon, Australia, and Suriname, and those fisheries reduce bycatch by outfitting their nets with bycatch reduction devices.

Making Better Shrimp Choices

For wild shrimp:

- Best choices for wild shrimp, according to the Monterey Bay Aquarium, are wild spot prawn from Canada and all shrimp caught in Alaska.
- U.S. federal law and regulations require approved turtle exclusion devices in shrimp trawlers' nets, with some exceptions. A state law in Louisiana prohibits enforcement of this federal requirement, so look for reliable labels when buying wild shrimp from Louisiana.
- Look for wild shrimp with the Marine Stewardship Council (MSC) label, which provides assurance that shrimping vessels were equipped with turtle exclusion devices or other bycatch reduction devices.
- Whole Foods only sells wild shrimp that is either rated "Best Choice" or "Good Alternative" by the Monterey Bay Aquarium or is certified to Marine Stewardship Council (MSC) standards.

For farmed shrimp:

- Look for "Farmed Responsibly ASC Certified," "Naturland" or "Whole Foods Responsibly Farmed" certification.
- Labels on farmed shrimp such as "turtle safe" or "environmentally aware" are less reliable, since they typically have no standards or verification behind them.
- The GAA BAP label ensures basic requirements are met, but based on our test findings (discussed below), we do not recommend this label.

Regulations of Shrimp Safety in the U.S.

FDA Regulation of Drugs in Shrimp Aquaculture

Drugs Approved for Use in Aquaculture

In the U.S., the Food and Drug Administration (FDA) has regulatory authority over the use of antimicrobial drugs in farmed shrimp. The FDA has not approved any antibiotics for use in shrimp production and has approved only one chemical, formalin (used as a pesticide for controlling protozoan parasites), for shrimp aquaculture.[223]

The FDA does not allow unapproved animal drugs to be administered in any dosage form to an animal (including shrimp). Those drugs are often referred to colloquially as banned drugs, though the FDA still uses the term unapproved. For approved drugs, tissue residue tolerances may be set.[224]

'Extra-Label' Use of Drugs in Shrimp Aquaculture

Though no antibiotics are approved for shrimp production, the Animal Medicinal Drug Use Clarification Act of 1994 allows veterinarians in the U.S. to prescribe approved new animal or human drugs for uses other than those on the approved label. This is called "extra-label use" and is defined by the FDA as:

> *Actual use or intended use of a drug in an animal in a manner that is not in accordance with the approved labeling. This includes, but is not limited to, use in species not listed in the labeling, use for indications (disease and other conditions) not listed in the labeling, use at dosage levels, frequencies, or routes of administration other than those stated in the labeling, and deviation from labeled withdrawal time based on these different uses.*[225]

The FDA prohibits the extra-label use of certain drugs or classes of drugs in food-producing animals that pose a risk to public health. The following drugs or families of drugs are prohibited for extra-label uses in food-producing animals including shrimp (except where noted in parenthesis):[226]

* Chloramphenicol
* Clenbuterol
* Diethylstillbestrol
* Ipronidazole and nitroimidazoles
* Furazolidone
* Nitrofurazone
* Sulfonamide drugs (in lactating dairy cattle except approved use of sulfadimethoxine, sulfabromomethazine, and sulfaethoxypyridazine)
* Fluoroquinolones
* Glycopeptides
* Phenylbutazone (in female dairy cattle 20 months of age or older)
* Cephalosporins (not including cephapirin) (in cattle, swine, chickens, or turkeys)

That means that although no antibiotics are approved for use in shrimp aquaculture, some antibiotics can be legally used in farmed shrimp from the U.S., including those that are approved by the FDA for other animals or types of aquaculture. For example, the FDA has set a permissible residue level of 2ppm for oxytetracycline in U.S. farmed shrimp. (Tetracycline residues are illegal in imported shrimp.) Tetracycline residue limits are based on an acceptable daily intake (ADI) for the sum at 25 ug/Kgbw/day (the tolerance for milk is 0.3 ppm).[227, 228]

Extra-label use does not apply to shrimp farmed in other countries that is imported to the U.S. There are no antibiotic residues allowed in imported shrimp, and if the FDA found residues at any level in a shipment, that shipment would be rejected.

Interestingly, though the U.S. has only one drug approved for shrimp aquaculture (and only nine for aquaculture), many countries exporting shrimp to the U.S. have much longer lists of drugs that may be approved for shrimp aquaculture. For example, China allows as many as 20 and Vietnam as many as 32 antibiotics and other chemicals to be used in shrimp farming.[229] Fluoroquinolones, an important class of antibiotics, for example, are not permitted in shrimp sold in the U.S., however their use is permitted in China,[230] but technically no residues of quinolones are allowed in imported or domestic shrimp.

The use of drugs in farm-raised seafood raises significant public health and environmental concerns. The application of those drugs during the various stages of aquaculture can result in the presence of the drugs or their metabolites in shrimp and the environment. Perhaps even more significant, the overuse of antibiotics can promote the development of antibiotic-resistant bacteria.

FDA Regulation of Imported Shrimp

Under the Federal Food, Drug, and Cosmetic Act, the FDA is responsible for ensuring that the nation's food supply, including imported seafood, is safe, wholesome, sanitary, and properly labeled.[231] When it comes to shrimp, the FDA looks to ensure are that products are not filthy or decomposed, are labeled properly, and do not contain any antibiotic residues and certain other chemicals or additives.[232]

The FDA's main tools for ensuring the safety of imported seafood are the Hazard Analysis & Critical Control Point Regulations (HACCP) with which both domestic and foreign processors and importers must comply (discussed below), inspection of foreign processors (the FDA has not recently published the number of foreign firms it has inspected), and the inspection process at ports of entry, but that can be challenging.[233, 234] HACCP is not necessarily required for shrimp farmers (where many of the problems originate), only processors, [235] but FDA has told us that it holds processors accountable for ensuring that antibiotics are not used on the farms.

Hazard Analysis & Critical Control Points (HACCP)

The FDA requires that all seafood processors—domestic and foreign—and importers conduct a hazards analysis to determine whether chemical and microbiological hazards exist and are reasonably likely to occur at each of the steps involved in processing.[236]

In the case that safety hazards are identified, processors must have and implement a Hazard Analysis & Critical Control Points (HACCP) plan.[237] For shrimp, HAACP is more focused on contamination with chemicals than with bacteria. Specific examples of potential chemical hazards include the use of animal drugs during aquaculture and application of sulfites to raw shrimp.[238] Potential microbiological hazards also exist, including the water used in processing and the handlers.[239] However, although microbiological hazards exist, the FDA does not have any strict quantitative metrics for microbiological contamination in shrimp HACCP, as the USDA does for meat and poultry. We believe that the FDA should address all hazards with quantitative metrics, including both bacterial and chemical contamination.

LIMITED SCOPE FOR VIBRIO CONTROL

The FDA has provided strategies for control of naturally occurring pathogens for molluscan shellfish (e.g., bivalves such as oysters), including control of the potentially problematic *Vibrio* species *V. vulnificus, V. parahaemolyticus,* and *V. cholerae;* however, there are no similar recommendations that explicitly apply to shrimp. The suggested methods for killing *Vibrio* and other pathogenic bacteria in seafood include heat, pressure, irradiating, or individual quick freezing (IQF) with extended storage.[240] The last process, IQF, involves the use of blast freezing technology to quickly lower the temperature of the food below freezing and then, with storage at freezing temperatures for an extended amount of time, is expected to reduce the numbers of *Vibrio* present on molluscan shellfish to non-detectable, as vibrios are considered especially freeze-sensitive.[241]

The FDA does not provide this same guidance for *Vibrio* control in shrimp, probably because,"it is assumed that shrimp will be cooked before consumption, so bacterial pathogens on raw product would not normally be considered a HACCP Critical Control Point to be monitored."[242] Given the established public health risks associated with *Vibrio* and the fact that we found it on a large percentage of our samples (discussed below), the FDA should require control of this pathogen in shrimp.

Interestingly, IQF is a process that is already commonly used for shrimp processing.[243] In the case of shrimp, the IQF process has been adopted to retain texture and moisture (i.e., raw characteristics of the food) and provide a more convenient product for consumers.[31, 244] The FDA indicates that IQF and other processes that it recommends for killing *Vibrio* species may be useful for control of pathogens including *Vibrio* for products other than raw molluscan shellfish; however, the agency notes that "such applications are not presently in commercial use in the U.S. fish and fishery products industry."[245] Our findings, below, suggest that IQF may not be controlling bacteria levels *(Vibrio)* as well as thought.

FDA's Role at the Port of Entry

The FDA requires that entities importing food into the U.S. provide prior notice of that shipment to regulatory authorities.[246] The information, including the importer's identity, address, product identity, country of production, and identity of any country to which the shrimp product has been refused entry, is reviewed by an automated system that can flag products that warrant manual review.[247, 248] Further review may be required if there have been issues found with a particular producer or product from a particular country.[249]

After manual review of the import record, the reviewer determines whether the shipment can enter into the U.S. or will require further detention.[250] Only a very small percentage of imports are subject to a physical field examination. The majority of field examinations are simply a visual inspection to determine whether proper storage conditions have been maintained, to detect rodent infestation, and to perform a label examination. An even smaller number of products will be subjected to laboratory testing.

FDA Import Alerts, also called FDA automatic detention lists, are a mechanism the agency uses to detain imports from companies or countries that have previously been found to be in violation of FDA regulations. If an import alert is issued, all affected shrimp products should be automatically detained. The detained products have to be tested and certified by a third-party lab to show that they are free of the issue that led to the import alert, such as drug residues, before they are allowed into the U.S. commerce. Failure to obtain certification results in the import being refused. Recent import alerts have been issued for nitrofurans in shrimp from China and filth, decomposition, and *Salmonella* in shrimp from India.[251, 252]

We have obtained data from the FDA on the number of shrimp import lines (an import line is a unique product in each import entry) and the number of Detentions without Physical Examination (DWPE), field exams, label exams, and lab tests performed on those imports from 2007 to 2012 (**Table 1**).

Table 1. Shrimp and prawns import lines with inspection activities – FY 2007 – 2012. Data was obtained from the FDA.

FISCAL YEAR	Shrimp & Prawns, Total Import lines	DWPE's - Shrimp & Prawns	Field Exams - Shrimp & Prawns	Label Exams - Shrimp & Prawns	Sample Collections - Shrimp & Prawns	DWPE Refusals - Shrimp & Prawns
2007	104,304	2,174	1,159	262	890	207
2008	104,091	2,905	1,162	229	771	143
2009	99,345	3,186	1,110	394	864	188
2010	96,450	3,210	1,489	573	799	222
2011	99,838	3,953	2,380	842	1,008	333
2012	103,154	4,112	3,435	954	786	220
TOTAL	**607,182**	**19,540**	**10,735**	**3,254**	**5,118**	**1,313**
AVERAGE	**101,197**	**3,257**	**1,789**	**542**	**853**	**219**

Note: An import line is identified as a unique product in each import entry. An import entry may consist of one or multiple import lines.

These FDA import inspection data reveal that while the rate of examination of shrimp and prawns import line has increased from 1.11 percent for field exam and 0.25 percent for label exam in 2007 to 3.33 percent and 0.92 percent, respectively, in 2012, the agency still conducts very few examinations. This rate of inspection is extremely low and considerably lower than that estimated of the EU (20 percent to 50 percent), Japan (12 percent to 21 percent), and Canada (2 percent to 15 percent).[253] It is important to note that neither field exam nor label exam are used to determine whether the shrimp product contain bacteria or the drug residues that the FDA tests. For that, the actual shrimp sample has to be collected and tested, and even fewer samples are subjected to that type of analysis.

Though many unapproved drugs could be used to produce the shrimp imported into the U.S., the FDA tests for only a limited number of them. The drugs that the FDA tests for as part of regulating imports include drugs without tolerances, such as chloramphenicols, flouroquinolones/quinolones, and nitrofurans.[254] In addition, it also has the ability to test for oxytetracycline and sulfa drugs, as well as triaryl dyes. If a drug residue is found, that shipment can be rejected.

The FDA publishes import refusals on its website, at http://www.fda.gov/forindustry/importprogram/importrefusals/default.htm. A review of that data from 2011 to the present reveals that 1,250 imported raw shrimp entry lines were rejected during that period. Just over half (51 percent) of those rejections were contaminated with *Salmonella*, 12 percent were contaminated with nitrofurans, 19 percent were contaminated with veterinary drug residues other than nitrofurans, and none were rejected because of chloramphenicol.

FDA oversight of imported seafood has been criticized by a number of groups, including the U.S. Government Accountability Office (GAO). In 2011, after reviewing documents from the FDA and other agencies, the GAO concluded that the FDA's oversight program to ensure the safety of imported seafood from residues of unapproved drugs is limited, especially as compared with the other countries. For instance, the FDA tests for residues of up to 16 unapproved drugs in imported seafood products, while Canada tests for 40 drugs, some EU members test for 50 drugs, and Japan tests for 57 drugs.[255]

Though the FDA is able to eliminate some contaminated samples with its targeted inspection, its limited sampling is likely to allow some contaminated shrimp to enter the marketplace and reach consumers.

Consumer Reports Testing

Why We Tested

Little information is available regarding the prevalence of bacteria in retail shrimp sold in the U.S., and even less is known about their antibiotic-resistance profiles. The presence of bacteria can put consumers at risk for foodborne disease, including both food poisoning and extra-intestinal infections. Antibiotic resistance is a major public health concern because antibiotic-resistant bacteria are harder to treat if they cause an infection and can increase the risk of suffering and death. The development of antibiotic resistance is promoted by the overuse of antibiotics in any situation, including food production. Data on the prevalence of bacteria and antibiotic resistance on shrimp is especially critical because the majority of shrimp available in the U.S. are produced in intensive aquaculture operations in other countries where numerous important antibiotics can be used. Though the FDA has not approved any antibiotics for shrimp production, there have been reports and FDA findings of illegal residues on shrimp. Because there has been little study of the prevalence of those residues in retail shrimp, we wanted to document them. The presence of most drug residues is less of an individual health concern (from consuming tiny levels of residues) than it is a public health and sustainability issue. The use of those unapproved drugs in shrimp production raises questions about overuse of antimicrobial drugs in intensive aquaculture and promotion of antibiotic-resistant bacteria, which can impact public health. That is particularly important because there is little testing of imported seafood by the FDA, and most shrimp is imported. The use of those important medications is a band-aid solution for problems that could be prevented by healthier, more sustainable production systems.

As such, we also investigated the aspects of various sustainable production systems, including wild systems—which are by their nature less reliant on drugs and chemicals than conventional farmed shrimp—and farmed shrimp with meaningful labels and certifications. We purchased several wild samples from the U.S. and certified farmed shrimp to see whether there were meaningful differences and how consumers may be able to get more value.

Goals for Testing and Sampling

We wanted to assess the prevalence and antibiotic resistance of bacteria isolated from frozen shrimp sold at retail, as well as the prevalence of chemical residues. We also wanted to see whether we could find differences in the prevalence of bacteria, antibiotic resistance, and residues in shrimp from different countries of origin, production systems (farmed, sustainably farmed, and wild), and ways in which the shrimp were processed/cleaned (type). We did not design our sampling plan to differentiate among brands. After a comprehensive survey, using secret shoppers in 27 cities, we designed our sampling plan to:

1. Test a large sample of uncooked frozen shrimp and a smaller sample of cooked frozen shrimp.
2. Include samples from countries where ≥5 percent of the total products found in our survey originated.
3. Obtain a relatively larger sample of shrimp from the U.S. and from each of the four largest exporters identified in our survey: Thailand, Vietnam, Indonesia, and India.
4. Obtain a large sample of wild shrimp. Our marketplace survey revealed that wild-caught shrimp were available from a limited set of countries, with the most available from the U.S.
5. Obtain a large sample of farmed shrimp claiming to be produced sustainably.
6. Obtain a mix of types based on availability.

Sample Procurement

We purchased samples of frozen shrimp from 27 metropolitan areas across the U.S. over a period of about two weeks from March to April of 2014. Samples were purchased at retail from large chain supermarkets, big-box stores, and "natural" food stores. The vast majority of samples purchased were prepackaged. Samples were kept frozen on dry ice and shipped overnight to the testing lab.

A total of 284 frozen uncooked shrimp samples and 58 frozen cooked shrimp samples were purchased for microbiological and chemical analysis.

As planned, the majority of our samples were imported farmed shrimp. Details on the breakdown by country of origin, production type, product type, and label claims are presented below.

COUNTRY OF ORIGIN

Uncooked samples were sourced from 10 different countries, with approximately 21 percent from the U.S., 13 percent to 15 percent from each of the top importing countries (India, Thailand, Vietnam, and Indonesia), and 6 percent or less from several other countries that contributed fewer retail products to the U.S. market in our survey (**Figure 2**).

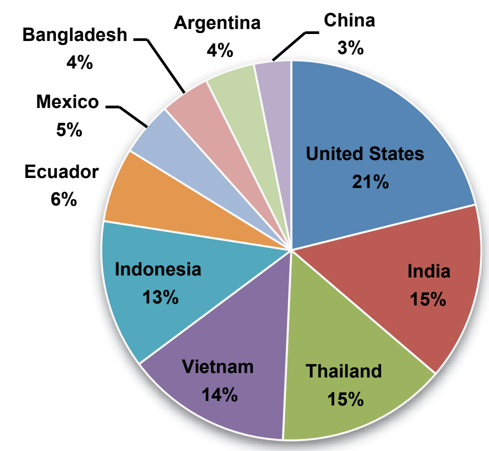


Figure 2. Country of origin listed for *uncooked* shrimp samples.

Cooked samples purchased were from six different countries, with 34 percent of the sample originating from Thailand, about 20 percent each from the U.S. and Vietnam, and smaller proportions from India, Indonesia, and China (**Figure 3**).

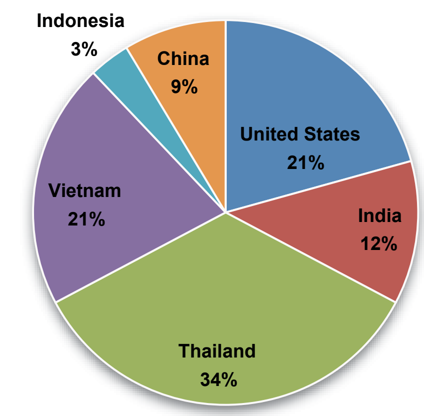


Figure 3. Country of origin listed for *cooked* shrimp samples.

FARMED VS. WILD-PRODUCED SHRIMP

As is the case in the marketplace, the majority of both uncooked and cooked shrimp in our sample were farmed (**Table 2**). At the time of our purchase, wild shrimp were found only from the U.S., Argentina (uncooked only), Mexico (uncooked only), and India (cooked only). All of the shrimp from Argentina were wild, and nearly all of the U.S. shrimp were also wild. All shrimp we purchased from Thailand, Vietnam, Indonesia, Ecuador, China, and Bangladesh were farmed.

Table 2. Production type (farm-raised or wild-caught) for shrimp samples by country of origin.

Country of Origin	Number (%) of samples			
	Uncooked		Cooked	
	Farmed	Wild	Farmed	Wild
U.S.	5 (8.3%)	55 (91.7%)		12 (100%)
India	43 (100%)		4 (57.1%)	3 (42.9%)
Thailand	41 (100%)		20 (100%)	
Vietnam	40 (100%)		11* (100%)	
Indonesia	36 (100%)		2 (100%)	
Ecuador	18 (100%)			
Bangladesh	12 (100%)			
China	9 (100%)		5 (100%)	
Mexico	6 (46.2%)	7 (53.8%)		
Argentina		12 (100%)		
Total	**210 (73.9%)**	**74 (26.1%)**	**42* (73.7%)**	**15* (26.3%)**

Note: Blanks indicate samples were not available for this country and production type. * One cooked sample from Vietnam had an unknown production type and is not included in the table.

Many of our samples from the U.S. had additional information about origin. For our uncooked samples, two-thirds of the wild U.S. shrimp had labels that indicated they were from the Gulf or Key West, while we found and purchased fewer that indicated they were from the Atlantic or Pacific (**Figure 4**).

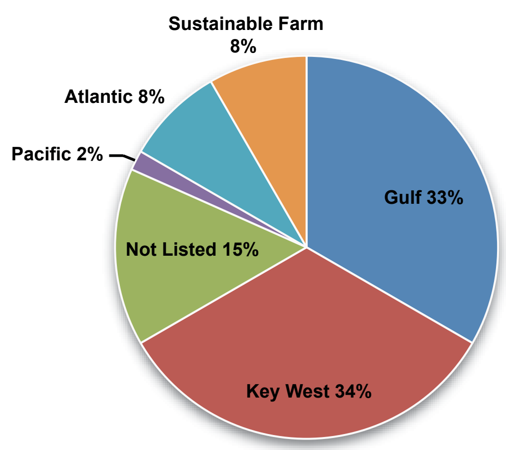


Figure 4. U.S. region listed on domestic farmed and wild-caught uncooked shrimp samples.

'SUSTAINABLE' SAMPLES

Many sustainability claims can be found on packages of shrimp in the market, and these vary in meaning. We found some labels to be meaningful and some to fall short. For a full review of the standards behind sustainable label claims related to shrimp, see pp. 13-21.

WILD

Many wild shrimp are considered sustainable choices, (see labeling section, pp. 22-23) in part because no drugs and few chemical inputs are used in wild systems. As discussed on pages 22-23, there are issues with fishing practices that can vary with origin and that are critical to determining whether wild shrimp are fished sustainably or not.

Making truly sustainable choices when purchasing is possible but can be challenging. We noted that methods used for catching wild shrimp were not explicitly stated on the packaging of most products we tested. In addition, 15 percent of our U.S. wild shrimp samples did not list the specific region where the shrimp were caught.

We found a "Best Choice" by Seafood Watch claim on three of the uncooked U.S. wild-caught samples purchased from Whole Foods Market; two were from the Gulf and one was from the Pacific. We found the MSC Certified Sustainable Seafood seal on four of our cooked samples; all four were from a single brand, and the shrimp were caught in Oregon.

FARMED

The only farmed samples we tested that had a label that we consider to be meaningful were purchased from Whole Foods Market.

We purchased 22 uncooked and six cooked samples from Whole Foods Market that carried a "Responsibly Farmed, 3rd Party Verified" seal. (Note: All shrimp at Whole Foods should carry that seal.) The uncooked samples came from Thailand (n=12), the U.S. (n=5), and Ecuador (n=5), and the cooked samples were from Thailand (n=6).. In addition to the Whole Foods "Responsibly Farmed" label, we rate and recommend additional sustainability labels for farmed fish.

BEST AQUACULTURE PRACTICES CERTIFICATION

The most common certified label we found on the shrimp we purchased was the Global Aquaculture Alliance (GAA) Best Aquaculture Practices (BAP) label. That label was found on 99 samples we purchased (**Table 3**). As previously discussed, the label has different tiers and levels of meaningfulness as indicated by the number of stars in the logo (see p. 20). About 54 percent of the samples with a BAP certification had one star, 34 percent had two stars, and 10 percent had four stars. We found no samples with three stars, and we were unable to identify the number of stars for two packages. All BAP certifications were evaluated and only considered to be somewhat meaningful for sustainability. ***And because four of the 11 samples with illegal residues we found were BAP certified, we do not recommend the label at this time.***

Table 3. Farmed shrimp samples with Best Aquaculture Practices (BAP) claim on package label.

Country of Origin	Number (%) of farmed samples with BAP Label									
	Uncooked	Number of Stars				Cooked	Number of Stars			
		1	2	3	4		1	2	3	4
U.S.	0 (0%)					-				
India	18 (41.9%)	9	9			4 (100%)	1*	2		
Thailand	18 (43.9%)	14	4			4 (20%)	3	1		
Vietnam	23 (57.5%)	8*	13		1	5 (45.5%)	2	2		1
Indonesia	12 (33.3%)	9	3			1 (50%)	1			
Ecuador	6 (33.3%)	6				-				
Bangladesh	0 (0%)					-				
China	3 (33.3%)				3	5 (100%)				5
Mexico	0 (0%)					-				
Total	**80 (38.1%)**					**19 (45.2%)**				

Note: Asterisk (*) means information was missing for one sample from this origin; dash (-) means no cooked samples were available from this country.

OTHER LABEL CLAIMS

Claims related to ingredients—such as no added chemicals, no antibiotics, no hormones, no preservatives, and no sulfites—and organic standards were also found on a small proportion of packages. Some ingredients listed on shrimp packages aside from shrimp included salt, sodium bisulfite (preservative), sodium tripolyphosphate (moisture retention), sodium metabisulfite (to prevent melanosis/black spot), water, sodium bicarbonate (phosphate-free moisture retention), and citric acid. Additionally, artificial coloring agents, including paprika and red food coloring, were listed in the ingredients for three of the samples in this study; all three were cooked samples from India.

A "no antibiotics" claim was found on 10 uncooked samples, all with third-party verification and from Ecuador (purchased at Whole Foods or sold by Ecofish). Though not void of meaning, we would caution that a no antibiotics claim without third-party certification would be less reliable than one with third-party certification.

SHRIMP TYPES

SHRIMP SPECIES

Additional characteristics for the shrimp samples included product type, size, and species. Species was the least consistently available information on retail packages. Less than 45 percent of samples had the genus and species names or type of shrimp (i.e., white shrimp) listed, and a 2014 study by Oceana indicated that species labeling of shrimp can sometimes be inaccurate.

PRODUCT TYPE

Product type refers to the peeled status of the shrimp and whether the vein has been left in or removed. The most common product type for uncooked shrimp was EZ-Peel (deveined) (**Table 4**); EZ-Peel refers to shrimp that have an easy-to-peel shell but their heads have been removed and they have been deveined. The most common product type for cooked shrimp was Peeled & Deveined Tail On (i.e., "traditional" cocktail shrimp).

Table 4. Product types for uncooked and cooked shrimp samples.

Product Type	Number (%) of samples	
	Uncooked	Cooked
EZ-Peel (deveined)	117 (41.2%)	3 (5.2%)
Peeled & Deveined Tail On	50 (17.6%)	27 (46.6%)
Peeled & Deveined (tail off)	58 (20.4%)	8 (13.8%)
Shell On (un-deveined)	46 (16.2%)	1 (1.7%)
Salad Shrimp		15 (25.9%)
Peeled Tail On (un-deveined)	8 (2.8%)	2 (3.4%)
Peeled Un-deveined (tail off)	5 (1.8%)	2 (3.4%)
Total	**284 (100%)**	**58 (100%)**

Notes: - Blanks indicate samples were not available in this product type

Product type also differed by country (**Table 5**). Uncooked shrimp from several countries—India, Indonesia, Thailand, Bangladesh, and China—were mostly EZ-Peel (deveined). Fifty-eight percent of uncooked samples from Vietnam were Peeled & Deveined (with the tail on or off); 51 percent of U.S. wild shrimp were Shell On (un-deveined) and 36 percent were Peeled & Deveined (tail off).

Table 5. Number of uncooked shrimp samples of each product type by country of origin and production method.

Country of Origin	EZ-Peel (Deveined)	Peeled & Deveined Tail On	Peeled & Deveined (Tail off)	Shell On (Un-Deveined)	Peeled Tail On (Un-Deveined)	Peeled Un-Deveined (tail off)
India (Farmed, n=43)	28	11	1	0	3	0
Indonesia (Farmed, n=36)	26	5	3	2	0	0
Thailand (Farmed, n=41)	21	6	12	2	0	0
Vietnam (Farmed, n=40)	16	18	5	1	0	0
Bangladesh (Farmed, n=12)	8	0	0	4	0	0
China (Farmed, n=9)	6	1	2	0	0	0
Ecuador (Farmed, n=18)	5	0	6	2	5	0
Mexico (Wild, n=7)	3	1	1	2	0	0
U.S. (Farmed, n=5)	2	3	0	0	0	0
Mexico (Farmed, n=6)	1	3	2	0	0	0
U.S. (Wild, n=55)	1	1	20	28	0	5
Argentina (Wild, n=12)	0	1	6	5	0	0

n is the number of samples from origin

All of the samples we purchased were headless. Peeling and deveining shrimp are additional processing steps that can require more handling (by manual laborers and/or automated machines). It is generally believed that some contamination of shrimp with pathogens can occur directly from food handlers, equipment, or the environment during processing.[256] We consider the Peeled & Deveined (tail off) shrimp to be the most processed type in our sample; the least handled product type, Shell On (un-deveined). (See *S. aureus* results section on p. 40 for more information on the possible influence of shrimp type on our test findings.)

Testing Methods

Microbiology Testing Methodology

We tested shrimp for *E. coli* (generic), *Salmonella* species, *Listeria monocytogenes*, *Staphylococcus aureus,* and *Vibrio* species because those organisms can cause foodborne illness and/or extra-intestinal infections in humans (i.e., *E. coli* causes extra-intestinal infections and *S. aureus* can cause both). We also tested for *Aeromonas* because, like *Vibrio*, they can occur in marine environments, and we thought they might serve as a common indicator organism. In addition, under specific conditions certain *Aeromonas* species can cause disease in shrimp, as well as in humans.

Test methods were adopted from the FDA NARMS Program, the FDA Bacteriological Analytical Manual (BAM), and papers published in the peer-reviewed scientific literature.[257]

Some bacteria, such as *Salmonella* and *Listeria monocytogenes*, are known to be pathogenic to humans, and there is little or no tolerance for their presence on food because they are considered an inherent food safety risk. For some other bacteria, such as *E. coli*, there are higher tolerances for their presence because they do not typically cause food poisoning, although certain types may be able to do so or may be associated with other extra-intestinal infections.[260]

We also tested isolates of *Salmonella* and *E. coli* that we found to try to determine their virulence. All *Salmonella* isolates underwent further testing to identify serotypes based on the Kaufman-White Scheme and CDC guidelines. In addition, DNA "fingerprinting" by pulsed-field gel electrophoresis (PFGE) was performed based on CDC PulseNet methods. All *E. coli* underwent further genetic testing for extra-intestinal pathogenic *E. coli* (ExPEC) virulence genes using real-time PCR.

After all bacteria we found were identified and confirmed, antibiotic susceptibility testing was performed. Minimum inhibitory concentrations were determined by broth microdilution based on Clinical and Laboratory Standards Institute (CLSI) methods. When available, 2014 CLSI interpretive criteria were used; otherwise breakpoints from the FDA NARMS 2011 Report or FDA were used.

Testing Results and Discussion

Overall Prevalence of Bacteria

We tested 284 samples of uncooked shrimp and 58 samples of cooked shrimp to determine whether several types of potential bacterial pathogens could be found on them. The bacteria we looked for were *E. coli* (generic), *Salmonella* species, *Listeria monocytogenes*, *Vibrio (Vibrio cholerae*, *V. parahaemolyticus*, *V. vulnificus*), *Staphylococcus aureus*, and *Aeromonas* species.

As expected, uncooked samples were significantly more likely to have at least one of the bacteria we looked for than were cooked samples. Overall, 60 percent (n=171) of uncooked samples were contaminated with one or more of the bacteria we were looking for, and we found the organisms on only 15.5 percent (n=9) of the cooked samples. Prevalence rates for the specific organisms are given below (**Table 6**).

Table 6. Prevalence of bacterial species among uncooked and cooked shrimp samples.

Target Bacteria	Number (%) of samples			
	Uncooked		Cooked	
Vibrio spp.	79	(27.8%)	1	(1.7%)
Aeromonas spp.	74	(26.1%)	5	(8.6%)
S. aureus	58	(20.4%)	2	(3.5%)
E. coli	30	(10.6%)	2	(3.5%)
L. monocytogenes	4	(1.4%)	0	(0%)
Salmonella spp.	1	(0.4%)	0	(0%)

We tested a total of 284 Uncooked and 58 Cooked samples.

Because few bacteria were isolated from cooked shrimp, the majority of the following discussion and analysis is focused on the uncooked samples.

Differences in Bacterial Prevalence and Resistance Based on Country of Origin and Production Type

PREVALENCE OF BACTERIA

Shrimp originating from some countries and production methods (farm-raised or wild-caught) were more likely than others to contain the bacteria we looked for.

Overall, U.S. wild shrimp tended to be contaminated with fewer bacteria than other shrimp, but specific rates of contamination varied by country and production method and by type of bacteria. U.S. wild shrimp were statistically less likely to contain at least one type of bacteria compared with uncooked shrimp from Bangladesh, India, and Indonesia (**Figure 5**). Moreover, though 60 percent of U.S. wild shrimp did not have any of the bacteria we tested for, at least 70 percent of samples from India, Bangladesh, Vietnam, and Indonesia had at least one of the types of the bacteria, including 20 percent with two or three of the types of the bacteria in our study. Other countries' contamination rates fell somewhere in between.

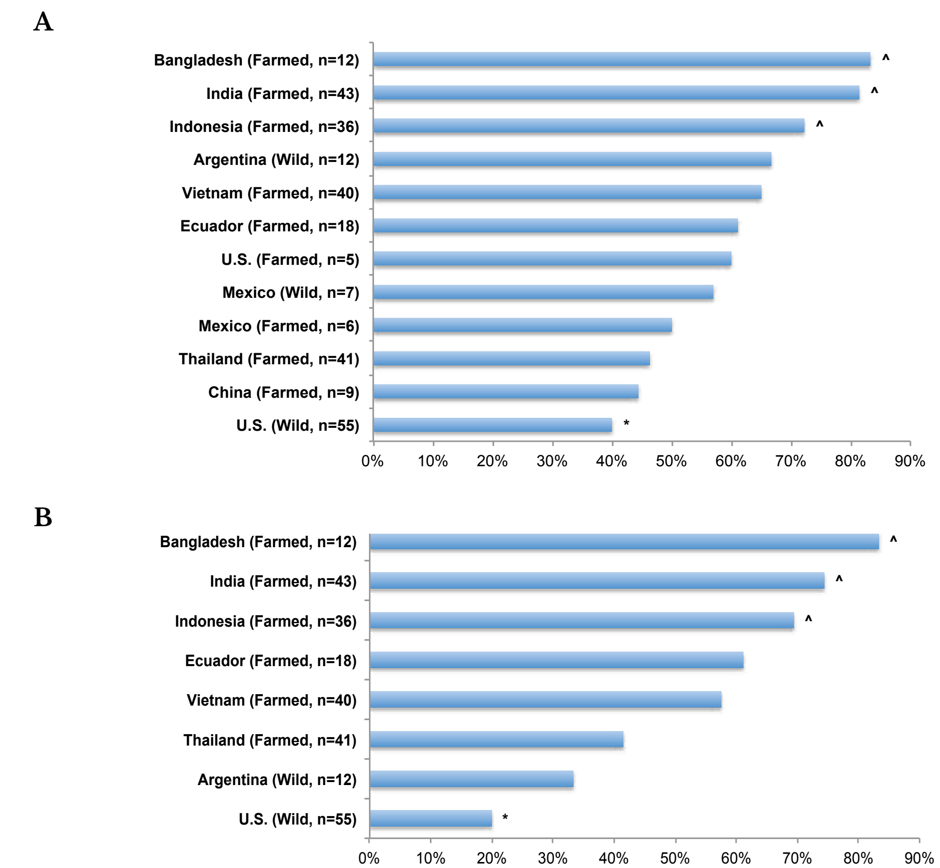


Figure 5. Uncooked shrimp samples with at least one type of bacteria: **A** includes *Aeromonas*, **B** does not include *Aeromonas* and does not show country of origin and production type groupings that had fewer than 10 samples.

U.S. wild samples (marked with *) were significantly less likely to have one or more of the bacteria we looked for than samples from Bangladesh, India, or Indonesia (marked with ^). Samples with n less than 10 had sample size too small for comparison.
n is the number of samples from origin.

Though there were differences in the prevalence of contamination of farmed uncooked shrimp from different countries—for instance, lower rates of contamination among farmed samples from China and Thailand vs. other countries—the differences were not statistically significant.

Antibiotic Resistance

We tested almost all of the bacteria we isolated for antibiotic resistance. Overall, the likelihood of finding bacteria resistant to antibiotic classes (families of antibiotics) also differed by production method and country of origin. Resistance to more than three classes of antibiotics was found for bacteria from farmed shrimp from Ecuador, Vietnam, Bangladesh, and Indonesia (**Table 7** and **Figure 6**). The country and production methods that had the fewest bacteria with resistance (i.e., no resistance) included U.S. wild and farmed shrimp, farmed shrimp from China and Thailand, and wild shrimp from Argentina and Mexico.

Table 7. Proportions of uncooked shrimp samples with bacterial resistance to antibiotic classes.

Country of Origin (Production Type, Number of Samples With at Least One Isolate)	No Resistance	Resistance to 1 Class	Resistance to 2 Classes	Resistance to 3 Classes	Resistance to More than 3 Classes
Ecuador (Farmed, n=11)	18%	9%	46%	9%	18%
Vietnam (Farmed, n=25)	20%	24%	28%	16%	12%
Bangladesh (Farmed, n=10)	20%	20%	20%	30%	10%
Mexico (Farmed, n=3)	33%	33%	0%	33%	0%
India (Farmed, n=35)	40%	34%	17%	9%	0%
Indonesia (Farmed, n=26)	46%	15%	31%	4%	4%
Thailand (Farmed, n=18)	50%	17%	33%	0%	0%
Argentina (Wild, n=8)	50%	37%	13%	0%	0%
Mexico (Wild, n=4)	50%	25%	25%	0%	0%
U.S. (Farmed, n=3)	67%	0%	33%	0%	0%
U.S. (Wild, n=21)	67%	14%	14%	5%	0%
China (Farmed, n=4)	75%	0%	25%	0%	0%

n is the number of samples with at least one bacterial isolate

Looking more closely, bacteria on U.S. wild shrimp were resistant to the fewest number of classes of antibiotics compared with bacteria on farmed shrimp from Ecuador, Bangladesh, and Vietnam (**Figure 6**). Though resistance was low in farmed shrimp from China, the sample size was too small to make it statistically significant.

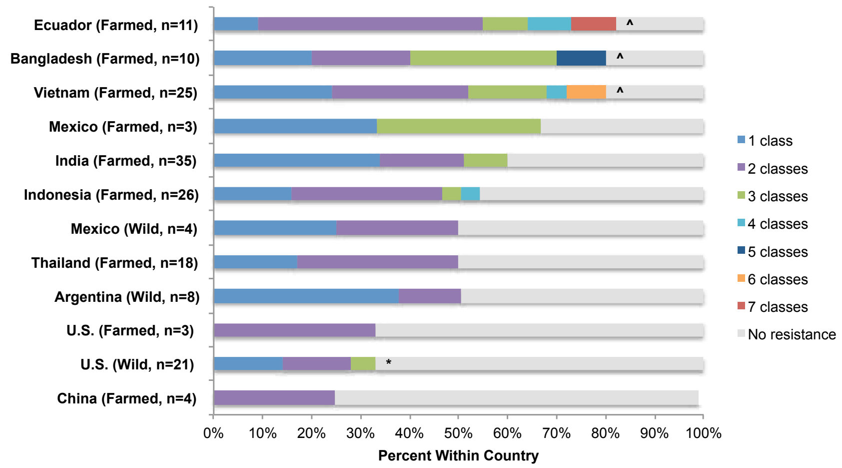


Figure 6. Antibiotic resistance (number of classes) of bacteria from shrimp samples by country and production type. Bacteria found on wild samples from the U.S. (marked with *) were resistant to significantly fewer classes of antibiotics than bacteria found on samples from Ecuador, Bangladesh, and Vietnam (marked with ^). Samples with n less than 10 had sample size too small for comparison.
n is the number of samples with at least one bacterial isolate.

MULTIDRUG-RESISTANT ISOLATES

When a bacterial isolate shows resistance to three or more classes of antibiotics, it is called multidrug resistant (MDR). The proportions of MDR bacterial isolates were compared among countries and production types for samples that had bacteria. We found that farmed samples from Bangladesh (50 percent) and Ecuador (36 percent) had the highest proportions of MDR isolates among samples with bacteria, whereas just one of 21 (5 percent) U.S. wild samples with bacteria had an MDR isolate (**Figure 7**). Among the farmed shrimp with bacteria, those from Thailand, Indonesia, or India were also less likely to have MDR bacterial isolates (0 percent to 9 percent). We also did not find MDR isolates among bacteria from wild shrimp from Mexico or Argentina or farmed shrimp from China, but the number of samples with at least one isolate (n) was not large enough to determine statistical significance. (The numbers of MDR isolates we found for each type of bacteria can be found below in Table 11 and are discussed in greater detail under headings for each type of bacteria.)

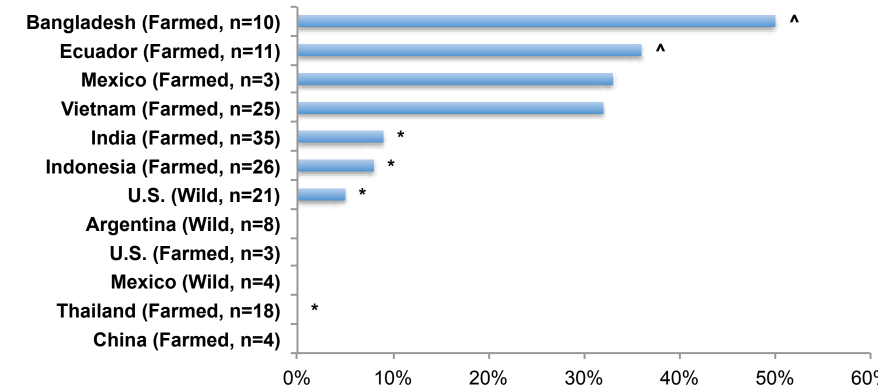


Figure 7. Proportion of uncooked shrimp samples with bacteria that had at least one multidrug-resistant (MDR) bacterial *isolate*. Statistically significant difference found between groups marked with * and those marked with ^. Samples with n less than 10 had sample size too small for comparison.
n is the number of samples with at least one bacterial isolate.

RESISTANCE TO ANTIBIOTIC CLASSES

When we analyzed resistance to specific classes of antibiotics, resistance also varied by production type and country. Wild shrimp from the U.S. had the lowest resistance to each of the classes (**Table 8**). Farmed samples from Vietnam, Ecuador, and Bangladesh were more likely to have higher rates of resistance for several of the classes of antibiotics. However, in the case of phenicol antibiotics, a higher proportion of samples with bacteria (33 percent) from Vietnam were resistant compared with shrimp from the other countries.

Table 8. Resistance to antibiotic classes of uncooked farmed shrimp and wild-caught US shrimp with bacteria.

Antibiotic Class	Lowest Resistance Rates	Highest Resistance Rates
Aminoglycoside	U.S. (Wild)	Ecuador
Penicillin (Beta-lactam)	U.S. (Wild)	Ecuador
Phenicol	U.S. (Wild), Thailand, India, Bangladesh, Ecuador	Vietnam
Sulfonamide	U.S. (Wild), Thailand, Ecuador	Vietnam, Bangladesh
Tetracycline	U.S. (Wild)	Vietnam, Ecuador

Note: Except for U.S., as noted, production method for listed countries is Farmed; HIGH and LOW resistance rates presented are significantly different; the numbers of samples with bacteria were less than 10 for China (Farmed), Mexico (Farmed, Wild), U.S. (Farmed), and Argentina (Wild), so significance could not be determined.

ANALYSIS OF SAMPLES BY LABELS

There was a difference in prevalence and resistance rates in U.S. wild shrimp, which were relatively lower than a number of farmed shrimp. All wild shrimp were also free of any antibiotic residues.

We did not see a meaningful difference in prevalence or measures of resistance among certified farmed shrimp we rated as meaningful or highly meaningful compared with conventionally farmed shrimp. Overall, we also did not see a difference in prevalence or resistance between shrimp with BAP certifications and other conventional shrimp. That may be because there actually is no difference, because our sample size was too small to see a difference, because cross-contamination of those products may have occurred during processing, or because of other reasons.

Details on Findings for Specific Types of Bacteria

We looked for six different types of bacteria. Examining the data on those individual types of bacteria, we see some differences in prevalence and resistance profiles related to production type and country (**Table 9** and below).

Table 9. Comparison of the prevalence of potential bacterial pathogens on uncooked shrimp by country of origin and production type.

Country of Origin (Production Type, Number of Samples)	Number (%) of samples											
	Vibrio spp.		*S. aureus*		*E. coli*		*Listeria* spp.		*Salmonella* spp.		*Aeromonas* spp.	
India (Farmed, n=43)	24	56%	10	23%	8	19%	1	2%	0	0%	21	49%
Indonesia (Farmed, n=36)	17	47%	11	31%	3	8%	0	0%	0	0%	4	11%
Thailand (Farmed, n=41)	16	39%	2	5%	1	2%	0	0%	0	0%	6	15%
Vietnam (Farmed, n=40)	11	28%	10	25%	7	18%	0	0%	1	3%	11	28%
Ecuador (Farmed, n=18)	4	22%	8	44%	0	0%	0	0%	0	0%	1	6%
China (Farmed, n=9)	1	11%	1	11%	0	0%	0	0%	0	0%	3	33%
U.S. (Wild, n=55)	5	9%	4	7%	1	2%	1	2%	0	0%	15	27%
Argentina (Wild, n=12)	1	8%	3	25%	0	0%	0	0%	0	0%	5	42%
Bangladesh (Farmed, n=12)	0	0%	6	50%	9	75%	0	0%	0	0%	2	17%
Mexico (Farmed, n=6)	0	0%	1	17%	0	0%	0	0%	0	0%	3	50%
U.S. (Farmed, n=5)	0	0%	1	20%	0	0%	2	40%	0	0%	0	0%
Mexico (Wild, n=7)	0	0%	1	14%	1	14%	0	0%	0	0%	3	43%

n is the number of samples from origin

VIBRIO SPECIES

Bottom line: Overall, the high frequency with which we detected *Vibrio* species in our uncooked shrimp samples was surprising. Though the government (FDA) requires producers/processors to control *Vibrio* in molluscs, it does not have specific requirements for *Vibrio* or any other bacterial controls for shrimp. The FDA suggests that freezing and heating are control processes to kill or reduce *Vibrio* species for molluscs and suggests freezing may be effective for non-molluscan shellfish as well. Given that we found *Vibrio* on 28 percent of uncooked, *frozen* shrimp, we think that the FDA should reconsider and reassess the effectiveness of freezing to reduce *Vibrio* and should require shrimp producers to also control for *Vibrio* (as part of shrimp HACCP). The presence of *Vibrio* on one cooked sample is not highly alarming, but nevertheless, the contamination with that and other types of bacteria should be prevented from occurring in cooked foods. Ideally, ready-to-eat foods such as cooked shrimp should be free of potentially harmful pathogens.

Background: *Vibrio* species are frequently isolated from marine environments and can cause infections in shrimp. Many environmental isolates are non-pathogenic, but strains that produce *Vibrio* toxins can cause serious infections in people. In fact, *Vibrio* infections are the most common cause of seafood-related outbreaks and deaths in the U.S., though they are usually due to consumption of raw oysters, not shrimp.[261, 262] *V. parahaemolyticus*, *V. vulnificus*, and *V. cholerae* that contaminate shellfish can all cause gastroenteritis if they are consumed. *V. parahaemolyticus* is most likely to cause food poisoning, and the CDC estimates that about 35,000 infections with *V. parahaemolyticus* occur each year.[263] According to the CDC, the incidence of *Vibrio* infections (mostly with *V. parahaemolyticus* and mostly from oysters) increased by 32 percent in 2013 compared with 2010 to 2012 and was at the highest rate noted since data collection began.[264]

Vibrio species were the most common potential pathogen we isolated from shrimp. Although cooking will kill those organisms, they can potentially contaminate cooked foods in the kitchen if proper hygiene is not practiced.[265] *Vibrio* were isolated from 79 (28 percent) uncooked shrimp samples. *V. parahaemolyticus* was recovered from 77 of those samples, *V. cholerae* from four, and *V. vulnificus* from one.

We did not test the *V. parahaemolyticus*, *V. cholerae*, and *V. vulnificus* isolates for toxins, so the virulence of the isolated strains is not known.

Test findings: When we looked at the production types, farmed samples from India and Indonesia were more likely to have *Vibrio*, and farmed samples from Bangladesh and wild samples from either the U.S. or Argentina were the least likely (**Figure 8** and **Table 9**).

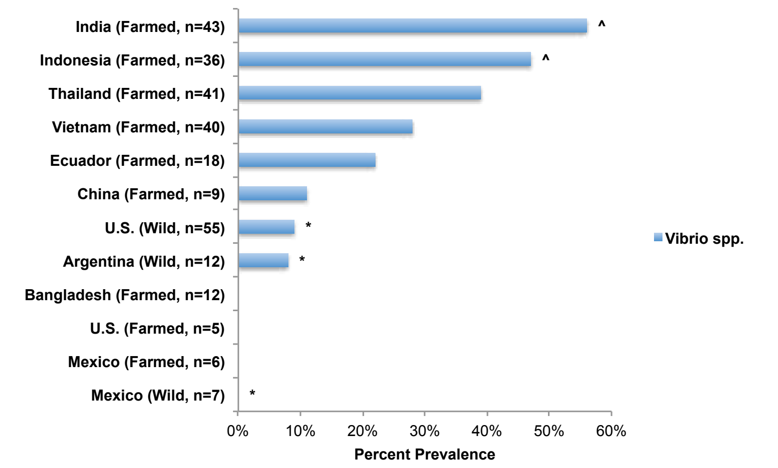


Figure 8. Prevalence of *Vibrio* species on uncooked shrimp by country of origin and production type.
Statistically significant difference found between groups marked with * and those marked with ^. Samples with n less than 10 had sample size too small for comparison.
n is the number of samples from origin.

Food poisoning caused by *Vibrio* is usually self-limited and treated with fluids, not antibiotics. Most people will recover within a few days. Other types of infections caused by *Vibrio* may require antibiotics, and the first line of treatment is doxycycline (which is in the tetracycline class of antibiotics), plus a cephalosporin or a quinolone added.[266] In our tests we found only one MDR *Vibrio* isolate, which was resistant to ceftazidime, a cephalosporin; gentamicin, an aminoglycoside; and tetracycline (**Table 10**).

Table 10. Multidrug-resistant (MDR) bacterial isolates found on uncooked shrimp.

Target Bacteria	Number (%) Samples With MDR Isolates
S. aureus (n=58)	18 (31%)
E. coli (n=30)	2 (6.7%)
Aeromonas spp. (n=73*)	3 (4.1%)
Vibrio spp. (n=69*)	1 (1.5%)
L. monocytogenes (n=4)	0 (0%)
Salmonella spp. (n=1)	0 (0%)

*Ten samples for *Vibrio* and one sample for *Aeromonas* could not be tested, so denominators do not include those samples. n is the total number of isolates for each type of bacteria.
Note: MDR = MRSA or bacterial isolate resistant to ≥1 drug in ≥3 antibiotic classes.

Among samples with vibrios, 14 percent were resistant to tetracyclines and 32 percent were resistant to beta-lactams, the class that includes cephalosporin antibiotics (**Table 11**). The results are especially concerning because those drugs are indicated for treatment of infections with that type of bacteria. We also noted that 17 percent of samples with vibrios were resistant to aminogylcosides. Though aminoglycosides are not first-line agents for treating *Vibrio* infections, they are very important drugs used to treat infections caused by other types of bacteria. There was no resistance to quinolones in the *Vibrio* isolates we found.

Table 11. Resistance of *Vibrio* species isolated from uncooked shrimp samples to important antibiotic classes.

Target Bacteria	Number (%) of samples resistant to antibiotic class								
	Beta-lactam[a]	Macrolide	Phenicol	Quinolone	Lincosamide	Aminoglycoside	Ansamycin	Sulfonamide	Tetracycline
Vibrio spp. (n=69*)	22 (32%)	0 (0%)	0 (0%)	0 (0%)		12 (17%)		2 (3%)	10 (14%)

Ten samples for *Vibrio* could not be tested, so denominators do not include those samples.
n is the total number of samples that contained at least one *Vibrio* isolate.
Notes: Blanks indicate test was not applicable. [a] Beta-lactam class includes third-generation cephalosporins and amoxicillin/clavulanic acid.

STAPHYLOCOCCUS AUREUS

Bottom line: In our study, *S. aureus* was found on 60 (17.5 percent) uncooked and two (3.5 percent) cooked samples. Based on our findings, it appears that samples that were likely to be the least handled (shell on) typically had less *S. aureus* compared with samples that were likely to be the most handled. That varied by country. Because *S. aureus* is a common contaminant of skin and surfaces, the source of *S. aureus* on food may be handling by contaminated workers.[267, 268, 269, 270]

Multidrug-resistant (MDR) *S. aureus* were found on 31 percent of uncooked shrimp samples (**Table 10**, above). On seven of the 18 samples with MDR *S. aureus* isolates, the MDR isolate was a MRSA isolate. That is more MRSA than we have seen in each of our previous studies of chicken, turkey, and pork. Among samples that had *S. aureus*, MDR *S. aureus* were more likely to be from farmed shrimp from Vietnam (70 percent), Bangladesh (50 percent), or Ecuador (50 percent). At least one MDR *S. aureus* was isolated from farmed samples sourced from Indonesia and India, as well as one from a wild shrimp sample from the U.S.

Background: *Staphylococcus aureus* bacteria are commonly found on the skin of humans and animals and can live there without causing disease. Under certain circumstances, though, the bacteria can cause a range of infections, including those of the skin, lungs, and blood. *S. aureus* is also one of the most common causes of food poisonings and is estimated to cause in excess of 241,000 cases in the U.S. each year.[271] In order to cause gastroenteritis, staphylococci must have the ability to make Staphylococcal enterotoxin. Those toxins are heat stable, so although cooking can kill the bacteria on food, the toxins can still remain. It is important to always keep food such as shrimp cold prior to cooking so as not to allow any staphylococci present to grow and produce enough toxin to cause illness. In this study, we did not do testing to determine whether the *S. aureus* isolates we found were capable of producing enterotoxin.

When *S. aureus* becomes resistant to methicillin/oxacillin, it is know as methicillin-resistant *Staphyloccccus aureus*, or MRSA. MRSA is a medically significant, human pathogen that can cause serious infections.[272, 273] MRSA was first recognized for its spread in hospitals but is now also frequently community-acquired through contact with people who are colonized by MRSA, their personal care items (e.g., towels), or surfaces that have been contaminated, including fitness equipment.[274] On the other hand, exposure to MRSA via food, and seafood in particular, is not a commonly discussed route of acquisition. The findings of our study are concerning because they reveal that contamination of shrimp with MRSA may be yet another exposure consumers may have to that increasingly prevalent and difficult-to-treat MDR pathogen.

Test findings: Overall, the highest proportions of *S. aureus* on uncooked samples were farmed shrimp from Bangladesh (50 percent) and Ecuador (44 percent) (**Figure 9**). Bangladesh, Ecuador, Indonesia, and Vietnam (all farmed shrimp) were more likely to have *S. aureus* than were farmed shrimp from Thailand or wild shrimp from the U.S.

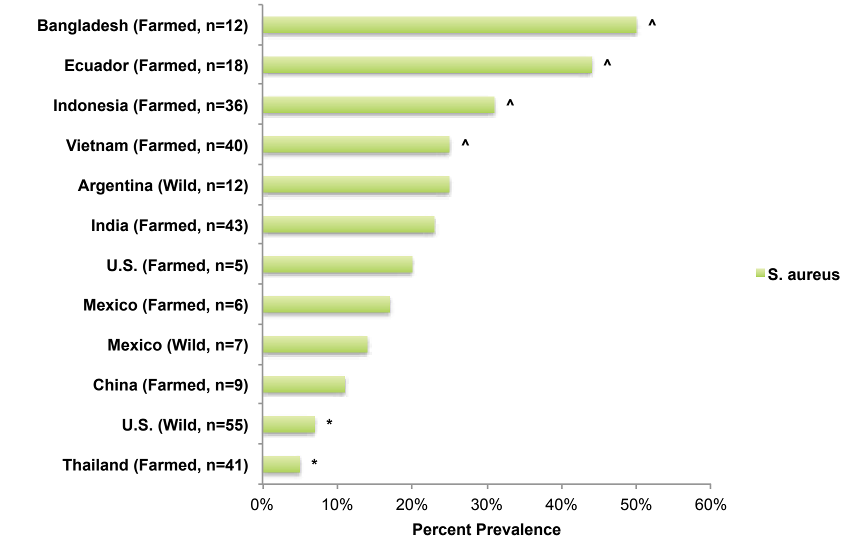


Figure 9. Prevalence of *Staphylococcus aureus* on uncooked shrimp by country of origin and production type.
Statistically significant difference found between groups marked with * and those marked with ^. Samples with n less than 10 had sample size too small for comparison.
n is the total number of samples from origin.

We tested our isolates against a wide array of antibiotics, many of which are potential antibiotic treatments for infections caused by *S. aureus*. Though drugs in the beta-lactam class, including penicillins or cephalosporins, have been commonly used as empiric therapy for *S. aureus* infections, an increasing prevalence of infections caused by MRSA, which are resistant to those antibiotics, has meant that other classes of drugs—including quinolones, tetracyclines, and sulfonamides—are becoming more heavily relied upon.[275, 276] The results of our study revealed that 76 percent of samples with *S. aureus* showed resistance to drugs in the beta-lactam class, 28 percent had resistance to tetracyclines, 24 percent had resistance to sulfonamides, and 24 percent had resistance to macrolides (not a common treatment for *S. aureus*, but common for other types of bacteria) (**Table 12**). Additionally, chloramphenicol resistance was found for seven samples (chloramphenicol is not approved for shrimp farming in most countries, and detection of the drug residue in food is grounds for refusal of imports into the U.S.).

Table 12. Resistance of *S. aureus* isolated from uncooked shrimp samples to important antibiotic classes.

Target Bacteria	Number (%) of samples resistant to antibiotic class								
	Beta-lactam[a]	Macrolide	Phenicol	Quinolone	Lincosamide	Aminoglycoside	Ansamycin	Sulfonamide	Tetracycline
S. aureus (n=58)	44 (76%)	14 (24%)	7 (12%)	4 (7%)		9 (16%)		14 (24%)	16 (28%)

n is the number of samples with at least one *S. aureus* isolate.
Notes: Blanks indicate test was not applicable. (*S. aureus* showed no resistance to nitrofurans, oxazolidinones, lipopeptide, and glycopeptide classes (not presented in table).) [a] Beta-lactam class includes third-generation cephalosporins and amoxicillin/clavulanic acid.

ESCHERICHIA COLI (E. COLI)

Background: *E. coli* is a common inhabitant of the gastrointestinal tract of humans and animals, where it can live without causing illness. However, when *E. coli* infects other parts of the body (extra-intestinal infections) such as blood, the urinary tract, and organs, it can pose serious health risks, especially if it can't be killed easily with antibiotics. Some pathogenic strains of *E. coli* cause foodborne illness (such as the infamous O157:H7), as well. In this test, we looked for generic *E. coli* only as a measure of general filth and did not look for the specific types associated with food poisoning. For each *E. coli*, we looked for a limited number of virulence genes associated with extra-intestinal infections. Bacteria with those genes are known as extra-intestinal pathogenic *E. coli* (ExPEC).[277]

Test findings: We found *E. coli* on 30 (9.4 percent) uncooked and two (3.5 percent) cooked shrimp samples. Farmed samples from Bangladesh had a disproportionately high rate (75 percent) of *E. coli*, especially compared with wild samples from Argentina (0 percent) and the U.S. (2 percent) and farmed samples from Ecuador (0 percent) (**Figure 10**).

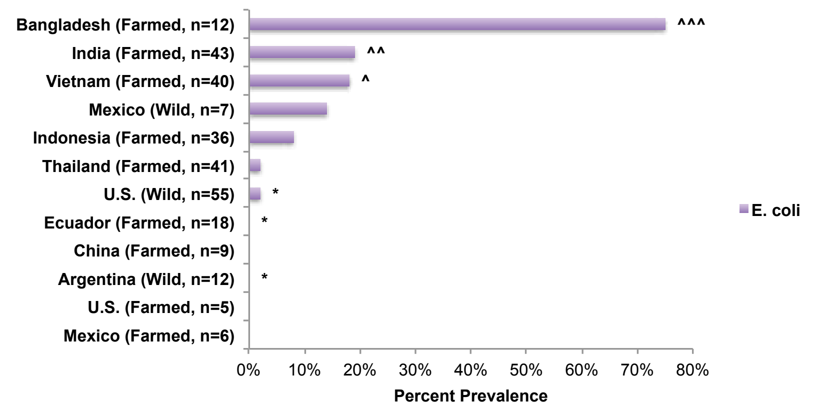


Figure 10. Prevalence of *Escherichia coli* on uncooked shrimp by country of origin.
Statistically significant difference found between groups marked with *, ^^^, ^^, and ^. Samples with n less than 10 had sample size too small for comparison.
n is the number of samples with at least one *E. coli* isolate.

There was significant resistance to sulfonamides in the *E. coli* isolated from our samples (77 percent); sulfonamides have traditionally been an important class of drug for treating simple *E. coli* infections (**Table 13**).[278] Utility of sulfa drugs for treating simple *E. coli* infections has decreased, however, as resistance rates have risen.[279] In addition, there was resistance to tetracyclines among 17 percent of samples, and though that class of antibiotics is not important for treating *E. coli*, it is important for treating other types of bacteria. Of the 30 samples that had *E. coli*, two (6.7 percent) farmed samples from Bangladesh had MDR isolates.

Table 13. Resistance of *E. coli* isolated from uncooked shrimp samples to important antibiotic classes.

Target Bacteria	Number (%) of samples resistant to antibiotic class								
	Beta-lactam[a]	Macrolide	Phenicol	Quinolone	Lincosamide	Aminoglycoside	Ansamycin	Sulfonamide	Tetracycline
E. coli (n=30)	2 (7%)	0 (0%)	0 (0%)	2 (7%)		2 (7%)		23 (77%)	5 (17%)

n is the number of samples with at least one isolate of the bacteria.
Notes: Blanks indicate test was not applicable. [a] Beta-lactam class includes third-generation cephalosporins and amoxicillin/clavulanic acid.

Only one sample contained an *E. coli* that was determined to be ExPEC. That does not mean that the other bacteria we found are not capable of causing extra-intestinal infections, though, because we tested only for a limited number of genes, and almost any bacteria may be able to cause infection if it finds itself in the right place under the right circumstances. That being said, *E. coli* causing urinary tract infections may be less likely to come from shrimp than from other types of food.

LISTERIA MONOCYTOGENES

Bottom line: *L. monocytogenes* was found on only four (1.4 percent) uncooked samples, and none were isolated from cooked shrimp.

Background: Most of the time, *Listeria* is considered an adulterant on ready-to-eat foods, including cooked shrimp, and may sometimes be considered an adulterant on raw foods. *Listeria* can be very serious, particularly for the young, the old, and pregnant women. According to the CDC, *Listeria* causes about 1,600 infections in the U.S. each year and is the third leading cause of death from food poisoning.[280] *Listeria* infections are mostly attributed to deli meats and hot dogs, soft cheeses, unpasteurized milk, smoked seafood, and some produce, including sprouts, cantaloupe, and, recently, prepackaged caramel apples.[26, 281] *Listeria* can be killed by cooking, and even though *Listeria* is not that common, the CDC recommends that the immunocompromised cook deli meats to avoid potential exposure to the deadly pathogen.[26]

SALMONELLA

Bottom line: We did not find any *Salmonella* on cooked shrimp samples, where it should be considered an adulterant. We also found very little on uncooked samples. Only three *S. enterica* isolates were found from one uncooked sample. The sample with *Salmonella* was resistant only to sulfonamide antibiotics. The three *Salmonella* isolates recovered from the sample belonged to the serovar Weltevreden, a very common *Salmonella* serotype isolated from seafood.[282]

Background: *Salmonella* is estimated to cause as many as 1.2 million illnesses in the U.S. every year.[283] The FDA has an extensive list of countries and firms that it has on import alert for *Salmonella* in shrimp.[284, 285]

AEROMONAS SPECIES

Aeromonads, like vibrios, are naturally occurring in marine environments, though under certain conditions they can cause infections in shrimp.[286] We chose to include *Aeromonas* in our testing to investigate whether it could serve as a marker for overall bacterial contamination and help us make comparisons among different types of samples. It is the type of bacteria in our test that is the least concerning for human health, and though some *Aeromonas* species can cause gastroenteritis in humans, they are not a common cause of food poisoning.[287] We found only two shrimp samples with a species (*A. veronii*) associated with human disease.

Aeromonas was the second most frequently isolated. Overall, *Aeromonas* species were isolated from 74 (26.1 percent) uncooked shrimp samples and five (8.6 percent) cooked samples. Among uncooked shrimp, farmed samples from India were most likely (49 percent) to have *Aeromonas*, and samples from Ecuador (6 percent) and

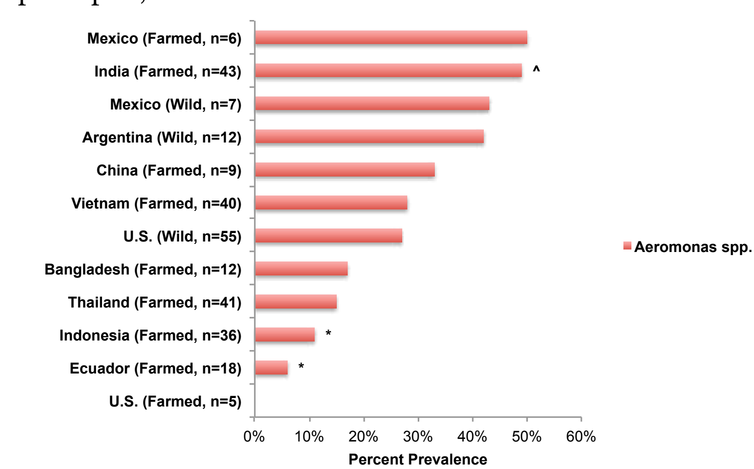


Figure 11. Prevalence of *Aeromonas* species on uncooked shrimp by country of origin and production type.
Statistically significant difference found between groups marked with * and those marked with ^. Samples with n less than 10 had sample size too small for comparison.
n is the number of samples with at least one *Aeromonas* isolate.

Indonesia (11 percent) had significantly lower proportions with *Aeromonas* (**Figure 11**). There was no significant difference in *Aeromonas* rates for any of the wild shrimp from the U.S. or Argentina compared with shrimp sourced from farmed shrimp from countries with higher rates.

The availability of breakpoints for interpreting antibiotic resistance profiles of *Aeromonas* isolates is very limited. Although that type of bacteria may appear to have lower rates of resistance than some of the other bacteria we tested, it is important to remember that it did not have as many data points. In spite of fewer antibiotics being evaluated, three samples had MDR *Aeromonas* isolates, and samples with *Aeromonas* had some resistance to beta-lactam antibiotics (11 percent) and tetracyclines (10 percent) (**Table 14**).

Table 14. Resistance of *Aeromonas* species isolated from uncooked shrimp samples to important antibiotic classes.

Target Bacteria	Number (%) of samples resistant to antibiotic class																	
	Beta-lactam[a]		Macrolide		Phenicol		Quinolone		Lincosamide		Aminoglycoside		Ansamycin		Sulfonamide		Tetracycline	
Aeromonas spp. (n=73*)	8	(11%)			3	(4%)	0	(0%)			2	(3%)			5	(7%)	7	(10%)

*One sample for Aeromonas could not be tested, so denominators do not include that sample.
n is the number of samples with at least one *Aeromonas* isolate.
Notes: Blanks indicate test was not applicable. [a] Beta-lactam class includes third-generation cephalosporins and amoxicillin/clavulanic acid.

Antimicrobial Residue Testing

METHODS

The use of antimicrobial drugs in aquaculture may be quite common, and yet very few studies have examined the extent of their use or the extent of drug residues in retail shrimp. We conducted extensive testing of our sample for residues of antimicrobial drugs. Many of the drugs we tested for are potentially harmful to human health (carcinogens), and their use is completely banned in the U.S. and many other countries. We also tested for antibiotic drugs that are not specifically approved for use in shrimp aquaculture but that are allowed in U.S. shrimp farming through extra-label use. While imported shrimp in the U.S. are not supposed to be farmed with antibiotics according to the FDA, they are permitted to be used in certain countries for shrimp not intended to come to the U.S.. When present, those drugs are often found at such low levels that they are unlikely to have adverse effects on human health. They are nonetheless extremely concerning because of their potential to promote the development of antibiotic-resistant bacteria and that any antibiotic residues are illegal on imported shrimp.

We tested the raw shrimp samples for a wide variety of antimicrobial compounds that may be used in shrimp aquaculture. Shrimp were maintained in a frozen state and shipped to ISO 17025 certified labs for testing. Prior to testing, the shell and tail were removed from the shrimp (as applicable) and edible portions for each individual sample were homogenized.

Testing was conducted for the following classes and individual drugs:

- Aminoglycosides
- Beta-lactams (including cephalosporins)
- Chloramphenicol*
- Lincomycin
- Macrolides
- Nitrofurans*
- Quinolones*
- Sulfonamides
- Tetracyclines
- Triaryl dyes* (malachite green, crystal violet, and metabolites)
- Virginiamycin

Note: For items marked with an asterisk (*), that drug or drugs in that class are not permitted for extra-label use in U.S. farmed shrimp. For unmarked items, that drug or some drugs in that class are permitted for extra-label use in U.S. farmed shrimp if prescribed by a veterinarian. Residues of all drugs listed are illegal in imported shrimp.

All 284 shrimp samples underwent screening for the triaryl dyes using an ultra high performance liquid chromatography–tandem mass spectrometry (UHPLC-MS/MS) method.

All 284 shrimp samples also underwent screening for aminogylcosides, beta-lactams, quinolones, and tetracylines using immunoassays based on biochip array technology. If a positive screen was found, the sample was subjected to confirmation testing using LC-MS/MS methods.

A random representative subsample of shrimp from the 284 samples was selected for screening for chloramphenicol, lincomycin, macrolides, nitrofurans, sulfonamides, and virginiamycin. The chloramphenicol screening was done using an ELISA-based method, and the other drugs were screened using LC-MS/MS methods.

Findings

Overall, we found 11 uncooked, imported, farmed samples that contained one or more drug residues that are not approved for use by the U.S. in shrimp farming. No residues we tested were found. Also, all of the residues we found were in imported shrimp, not domestic (though our farmed domestic sample was very small). That means that 5.4 percent of the imported, farmed shrimp we tested contained an illegal drug residue that should not be allowed for sale in the U.S. We can't say whether drugs were or were not used in farmed samples where we did not detect any residues. We have reported these residue findings to the FDA for further investigation.

We found three imported farmed samples that contained low levels of the quinolone enrofloxacin. One was from Vietnam and two were from Thailand. The sample from Vietnam had a two-star BAP certification. Two-star BAP certification applies to both the processor and farm, and under that program, shrimp producers should not use drugs that are "proactively prohibited" in the country they are destined for.

Nine samples of imported, farmed shrimp were positive for oxytetracycline. Tetracyclines are an important class of drug in both human and animal medicine, and their overuse can promote the development of antibiotic resistance. Eight of the positive samples were from Vietnam and one was from Bangladesh. Four of the samples (all from Vietnam) had a BAP claim; half had one star and the other half had two stars. One of the samples from Vietnam also had a label on the package that said "Chemical Free." (Note: Chemical-free is not a meaningful claim because it does not have defined standards or third-party verification.) One of the samples positive for oxytetracyclines was also positive for enrofloxacin.

Tetracyclines are the most commonly used drug in aquaculture around the globe. Interestingly, according to the FDA, their level of detection for oxytetracycline is 99.19ppb. However, we were able to detect well below that, and three of the nine samples we tested had levels above the FDA's level of detection. Again, we have asked the FDA to investigate these findings.

Two samples that were positive for tetracylines were also positive for sulfonamide drugs. That is a class of antibiotics that is important for both human and animal medicine. Both samples were farmed in Vietnam; one contained sulfamethoxazole residue and the other contained sulfamethazine residue. One came from the package with a "Chemical Free" claim on it. The use of those sulfonamide drugs is concerning because overuse can promote the development of antibiotic resistance. In fact, in our microbiology testing we found significant levels of resistance to sulfonamide drugs in the bacteria we isolated.

We found no detectable levels of chloramphenicols, nitrofurans, or triaryl dyes in our samples—all compounds that are also not approved for use in shrimp production by the U.S. (or for extra-label use in the U.S. farmed shrimp) and have been the subject of FDA import alerts. We also found no detectable levels of aminoglycosides, beta-lactams, lincomycin, macrolides, or virginiamycin.

Key Findings

BACTERIAL PREVALENCE

- As expected, we found more bacteria on uncooked than cooked shrimp.
- The most common bacteria found on our uncooked samples were *Vibrio* (28 percent), followed by *Aeromonas* (26 percent), *Staphylococcus aureus* (20 percent), and *E. coli* (11 percent). We found very low rates of *Listeria* (1 percent) and *Salmonella* (less than 1 percent).
  - Overall, there were fewer bacteria found on wild shrimp from the U.S. compared with farmed shrimp from all other countries.
  - Farmed shrimp from India, Bangladesh, Vietnam, and Indonesia had the highest average number of bacteria, especially compared with U.S. wild shrimp.
  - Significantly more U.S. wild shrimp (60 percent) were free of all the bacteria we tested for compared with only 20 percent to 30 percent of the shrimp from Bangladesh, India, and Indonesia. The farmed shrimp with the lowest contamination rates were from Thailand, China, and Mexico, although they were not statistically significant due to sample size constraints or other factors.
- Based on our findings, it appears that samples that were likely to be the least handled (shell on) typically had less *S. aureus* compared with samples that were likely to be the most handled.
- Farmed shrimp from Bangladesh, Ecuador, Indonesia, and Vietnam were more likely to have *S. aureus* than were farmed shrimp from Thailand or wild shrimp from the U.S.
- ***Vibrio* and *Staphylococcus aureus* can potentially cause extra-intestinal infections, and some can cause food poisoning through release of a toxin. Both types of bacteria are killed by cooking, so shrimp should be handled carefully and cooked well. The toxin produced by *S. aureus* is heat stable and not destroyed by cooking, so the best way to avoid that toxin is to always keep shrimp cold until cooking. Once cooked and hot, keep shrimp hot if they are to be out for longer than 2 hours before being consumed to minimize the risk of toxin production.**[288]

ANTIBIOTIC RESISTANCE IN BACTERIA

- We did not see a high rate of multidrug-resistant bacteria overall. However, improvements can still be made, and there were some notable results:
  - The most common multidrug-resistant bacteria were *Staphylococcus aureus* (18), and almost half (seven) of those were MRSA.
    - That is more MRSA than we have seen present in each of our previous tests of chicken, turkey, and pork.
    - It is concerning because the contamination of shrimp with MRSA may be yet another exposure consumers may have to the increasingly prevalent multidrug-resistant pathogen.
    - Samples from Vietnam were more likely to have MDR *S. aureus* than samples from other countries.
- Overall, bacteria from U.S. wild samples had fewer resistances than farmed samples from most countries.
  - Samples from Ecuador, Bangladesh, and Vietnam had the highest average number of resistances, and wild shrimp from the U.S. had the lowest. The farmed shrimp with the least resistance were from the U.S., Thailand, China, and Mexico, although they were not statistically significant due to sample size constraints or other factors.
- Resistance to the important antibiotic class beta-lactams was high among samples with *S. aureus* or *Vibrio* species; sulfonamide and tetracycline resistance was highest among those with *S. aureus* or *E. coli* (**Table 15**).

Table 15. Resistance of potential bacterial pathogens isolated from uncooked shrimp samples to important antibiotic classes

Target Bacteria	Number (%) of samples resistant to antibiotic class																	
	Beta-lactam[a]		Macrolide		Phenicol		Quinolone		Lincosamide		Aminoglycoside		Ansamycin		Sulfonamide		Tetracycline	
S. aureus (n=58)	44	(76%)	14	(24%)	7	(12%)	4	(7%)			9	(16%)	1	(2%)	14	(24%)	16	(28%)
E. coli (n=30)	2	(7%)	0	(0%)	0	(0%)	2	(7%)			2	(7%)			23	(77%)	5	(17%)
Aeromonas spp. (n=73*)	8	(11%)			3	(4%)	0	(0%)			2	(3%)			5	(7%)	7	(10%)
Vibrio spp. (n=69*)	22	(32%)	0	(0%)	0	(0%)	0	(0%)			12	(17%)			2	(3%)	10	(14%)
L. monocytogenes (n=4)	0	(0%)	0	(0%)	0	(0%)	0	(0%)	5	(9%)	0	(0%)			0	(0%)	0	(0%)
Salmonella spp. (n=1)	0	(0%)	0	(0%)	0	(0%)	0	(0%)			0	(0%)			1	(100%)	0	(0%)

Ten samples for *Vibrio* and one sample for *Aeromonas* could not be tested, so denominators do not include those samples.
n is the total number of samples with at least one of the bacteria.
Notes: Blanks indicate test was not applicable. [a]Beta-lactam class includes third-generation cephalosporins and amoxicillin/clavulanic acid.

DRUG RESIDUES

- Eleven of the 284 samples we tested contained one or more antibiotic residues. Those drugs were found only in imported farmed shrimp, and the FDA permits none of them in imported shrimp.
  - Three of the eleven samples contained enrofloxacin and were from Vietnam and Thailand. One of these samples had a two-star BAP label.
  - Nine of the eleven samples contained residues of oxytetracycline. Eight were from Vietnam and one was from Bangladesh—four had a BAP label. One of the nine also had one of the enrofloxacin residues.
  - Two of the samples that contained oxytetracycline residues also contained residues of sulfonamide antibiotics. Both samples were from Vietnam, and one sample was in a package with a "Chemical Free" claim.

Key Recommendations

Wild Shrimp

- The best choices for safe and sustainable shrimp are wild shrimp from the U.S. identified by the Monterey Bay Aquarium Seafood Watch program as "Best Choice" or "Good Alternative."
- Wild shrimp from other countries with the same ratings from the Seafood Watch program are also good choices.
- The Marine Stewardship Council label provides assurance that shrimping vessels were equipped with TEDs or other types of bycatch reduction devices.

Farmed Shrimp

Meaningful farmed shrimp labels can help consumers make informed decisions and support responsible and sustainable shrimp farming:

- When buying farmed shrimp, consumers should look for labels we rate as meaningful or highly meaningful.
  - The Naturland label is rated "highly meaningful." It is the only label that comprehensively prohibits synthetic inputs, including antibiotics, parasiticides, disinfectants, and pesticides; prohibits genetically engineered soybeans in feed; and prohibits eyestalk removal of female shrimp.
  - Meaningful labels include: Whole Foods Market "Responsibly Farmed" and the Aquaculture Stewardship Council's new certification program.
- The Best Aquaculture Practices Certified label is accompanied by one, two, three, or four stars, noted on the back of the package. Only 2-star certification and higher means that the farms where the shrimp were produced were certified to their standards. We rate all of the BAP labels as "somewhat meaningful." We found that four of the nine samples with tetracycline residues were BAP certified, and one of those four also had an enrofloxacin residue. Based on those findings, we do not recommend this label.
- Buyer beware—labels on farmed shrimp that are not meaningful include "natural," "turtle safe," and "environmentally aware."
- At the current time shoppers should also be wary of shrimp if they are labeled organic. The Department of Agriculture is currently drafting organic aquaculture standards, and until those are finalized, shrimp in the U.S. cannot be labeled "organic." We believe that organic standards should have rigorous requirements for all of the sustainability attributes covered in this report.

Policy Recommendations

- The FDA should increase oversight of imported seafood.
  - Though we found no chloramphenicol or nitrofuran residues in our testing, we did find eleven samples with residues of antibiotics that are not permitted in imported shrimp. The overuse of antibiotics promotes the development of antibiotic resistance. The FDA should receive increased funding so that it can increase inspections of foreign operations abroad, as well as shipments arriving at U.S. ports.
- The FDA should address the potential for *Vibrio* and other bacterial contamination in shrimp and require controls as part of producer HACCP plans.
  - Guidelines already exist for *Vibrio* in other seafood. Given our findings of relatively high levels of *Vibrio* species in this study, we think the FDA needs to treat shrimp like other seafood and provide guidance/standards for producers.
- The FDA should have a zero tolerance for MRSA in shrimp.
- The FDA should post on its website the number of shrimp imports and inspections (by type) per year.
- The FDA should not allow extra-label use of antibiotics in domestic shrimp production.
  - No antibiotics are specifically approved for use in shrimp production and therefore should not be allowed. The FDA should have no tolerances for antibiotics prescribed through "extra-label" use. In cases of disease, the FDA should decide whether there are non-antibiotic alternatives to treat disease and should review and approve any drugs used in shrimp production.
- The USDA should establish credible and meaningful organic aquaculture standards that should prohibit antibiotics, require controls of any inputs and outputs, and mandate 100 percent organic feed. The USDA has been working on the issue for seven years.
- COOL (Country of Origin Labeling) should be improved to include all of the locations where the shrimp were farmed or caught and processed.

References

[1] NOAA. 2014. *Fisheries of the United States.* 2013. p. v/102. http://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus13/FUS2013.pdf.
[2] NOAA. 2014. *Fisheries of the United States.* 2013. p. 64. http://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus13/FUS2013.pdf.
[3] Graslund, S., et al. 2003. "A field survey of chemicals and biological products used in shrimp farming." *Marine Pollution Bulletin.* 46: 81-90. http://mangroveactionproject.org/wp-content/uploads/2013/10/Shrimp-Antibiotics.2003.Graslund.pdf. p. 84-85.
[4] Kautsky, N., et al. 2000. "Ecosystem perspectives on management of disease in shrimp pond farming." *Aquaculture.* 191: 145-161.
[5] Public Citizen. 2004. "Chemical Cocktail: The health impacts of eating farm-raised shrimp." p. 1-2. http://www.citizen.org/documents/ChemicalCocktailWeb.pdf.
[6] Liao, I., et al. 2000. "The use of chemicals in aquaculture in Taiwan, Province of China." SEAFDEC/AQD Institutional Repository. p.195. http://hdl.handle.net/10862/598.
[7] Done, H.Y., et al. 2015. "Reconnaissance of 47 antibiotics and associated microbial risks in seafood sold in the United States." *J. Hazardous Materials.* 282: 10-17.
[8] GAO. 2011. "Seafood Safety: FDA needs to improve oversight of imported seafood and better leverage limited resources." GAO-11-286.
[9] FDA. 2015. "The Ins and Outs of Extra-Label Drug Use in Animals: A Resource for Veterinarians." http://www.fda.gov/AnimalVeterinary/ResourcesforYou/ucm380135.htm#Conditions_for_Extra-Label_Drug_Use_in_Food-Producing_Animals (accessed 3/23/2015).
[10] Cabello, F.C., et al. 2013. "Antimicrobial use in aquaculture re-examined: Its relevance to antimicrobial resistance and to animal and human health." *Environ Microbiol.* 15(7): 1917-1942. http://www.lenfestocean.org/~/media/legacy/Lenfest/PDFs/cabello_2013_minireview.pdf
[11] CDC. 2013. *Antibiotic Resistance Threats in the United States, 2013.* p. 6. http://www.cdc.gov/drugresistance/pdf/ar-threats-2013-508.pdf.
[12] FDA. 2012. Letter from Dr. William R. Jones, Office of Food Safety. http://www.shrimpalliance.com/new//wp-content/uploads/2012/03/FDA-Response-to-Vietnam-Letters.pdf.
[13] Department of Commerce, Bureau of the Census. 2015. *Shrimp Q Yearly.* http://www.ers.usda.gov/data-products/aquaculture-data.aspx (accessed 3/19/2015).
[14] US Government Publishing Office. 2015. "Country of origin labeling for fish and shellfish" (Part 60). Electronic Code of Federal Regulations. Title 7: *Agriculture. §60.300 Labeling.* http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=0bfba9505f9e71f6ad1b482c1fc1c99a&rgn=div5&view=text&node=7:3.1.1.1.7&id-no=7#se7.3.60_1200.
[15] USDA. 2014. Country of Origin Labeling. Agricultural Marketing Service Commodity Areas. http://www.ams.usda.gov/AMSv1.0/COOL (accessed 3/19/2015).
[16] Department of Commerce, Bureau of the Census. 2015. *Shrimp_Q_Yearly.* http://www.ers.usda.gov/data-products/aquaculture-data.aspx (accessed 3/19/2015).
[17] FAO GLOBEFISH. 2014. Shrimp - September 2014. Market Reports. http://www.globefish.org/shrimp-september-2014.html (accessed 3/19/2015).
[18] Lo, G. Chu-Fang. 2014. "White Spot Disease." *Manual of Diagnostic Tests for Aquatic Animals.* 2014. World Organisation for Animal Health. Chapter 2.2.6, p. 178/180. http://www.oie.int/fileadmin/Home/eng/Health_standards/aahm/current/2.2.06_WSD.pdf (accessed 3/24/2015).
[19] Naylor, R.L., et al. 2000. "Effect of aquaculture on world fish supplies." *Nature.* 405: 1017-1024. http://www.nature.com/nature/journal/v405/n6790/pdf/4051017a0.pdf.
[20] Tran, L., et al. 2013. "Determination of the infectious nature of the agent of acute hepatopancreatic necrosis syndrome affecting penaeid shrimp." *Dis Aquat Org.* 105:45-55.
[21] De Schryver, P., et al. 2014. "Early Mortality Syndrome Outbreaks: A Microbial Management Issue in Shrimp Farming?" *PLOS Pathogens.* 10(4): 1-2. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3999206/pdf/ppat.1003919.pdf.
[22] Lightner, D.V., et al. 2012. "Early mortality syndrome affects shrimp in Asia." *Glob Aquacult Advocate.* Jan/Feb 2012:40. http://pdf.gaalliance.org/pdf/gaa-lightner-jan12.pdf.
[23] NACA FAO. 2011. Quarterly aquatic animal disease report (Asia and Pacific Region). 2014/1. p. 20/22/35-37/39. http://enaca.org/publications/health/aquatic-animal-disease-report/qaad-q1-2014.pdf.
[24] FAO GLOBEFISH. 2014. Shrimp - November 2014. Market Reports. http://www.globefish.org/shrimp-november-2014.html (accessed 3/23/2015).
[25] FAO GLOBEFISH. 2014. Shrimp - November 2014. Market Reports. http://www.globefish.org/shrimp-november-2014.html (accessed 3/23/2015).
[26] Gillett, R. 2008. "Global study of shrimp fisheries." FAO Fisheries Technical Paper No. 475. p. 41. ftp://ftp.fao.org/docrep/fao/011/i0300e/i0300e.pdf.
[27] Whitaker, et al. 2014. An Information/Education Series from the Marine Resources Division: Shrimp in SC. http://www.dnr.sc.gov/marine/pub/seascience/shrimp.html (accessed 3/19/2015).
[28] Food and Agriculture Organization of the United Nations. 2009. "The state of world fisheries and aquaculture 2008." ftp://ftp.fao.org/docrep/fao/011/i0250e/i0250e.pdf. Last accessed on March 27, 2015. Page 37.
[29] Code of Federal Regulations. Title 50, Section 223.206.
[30] Food and Agriculture Organization of the United Nations. Aquaculture [Webpage]. Retrieved from http://www.fao.org/aquaculture/en/. Last accessed on March 25, 2015.
[31] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 23.
[32] Food and Agriculture Organization. "Cultured Aquatic Species Information Programme. Penaeus Vannamei." Available online at: http://www.fao.org/fishery/culturedspecies/Litopenaeus_vannamei/en. Last accessed on December 22, 2014. Page 7 of 15.
[33] Food and Agriculture Organization. "Cultured Aquatic Species Information Programme. Penaeus Vannamei." Available online at: http://www.fao.org/fishery/culturedspecies/Litopenaeus_vannamei/en. Last accessed on December 22, 2014. Page 6 of 15.
[34] Food and Agriculture Organization. "Cultured Aquatic Species Information Programme. Penaeus Vannamei." Available online at: http://www.fao.org/fishery/culturedspecies/Litopenaeus_vannamei/en. Last accessed on December 22, 2014. Page 6 of 15.
[35] Samocha, T.M. 2010. "Use of intensive and super-intensive nursery systems," pgs. 247-280. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 248.
[36] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 39.
Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 23.
[37] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 1.
[38] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 7.
[39] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K.
Avnimelech, Y. 2010. "Intensive production of shrimp," pgs. 233-246. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K.
[40] Avnimelech, Y. 2010. "Intensive production of shrimp," pgs. 233-246. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K.
[41] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 10.
[42] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 7.
[43] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 7.
[44] Liao, I.C., et al. 2000. "The use of chemicals in aquaculture in Taiwan, Province of China." SEAFDEC/AQD Institutional Repository. http://hdl.handle.net/10862/598. p.194 and 203.
[45] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 7.
[46] Food and Agriculture Organization. "Cultured Aquatic Species Information Programme. Penaeus Vannamei." Available online at: http://www.fao.org/fishery/culturedspecies/Litopenaeus_vannamei/en. Last accessed on December 22, 2014. Pages 6 and 7.
[47] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 7.
[48] Avnimelech, Y. 2010. "Intensive production of shrimp," pgs. 233-246. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Pages 234-235.
[49] Kautsky, N., P. Ronnback, M. Tedengran, and M. Troell. 2000. "Ecosystem perspectives on management of disease in shrimp pond farming." *Aquaculture.* 191: 145-161. Page 148.
[50] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 23.
[51] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 23.
[52] Food and Agriculture Organization. "Cultured Aquatic Species Information Programme. Penaeus Vannamei." Available online at: http://www.fao.org/fishery/culturedspecies/Litopenaeus_vannamei/en. Last accessed on December 22, 2014. Page 7.
[53] Recirculating Farms Coalition. 2013, May. "From out of the blue, green farming." Retrieved from http://www.recirculatingfarms.org/wp-content/uploads/2013/06/RFCreport_FINAL-FINAL.pdf. Last accessed on March 26, 2015. Page 8.
[54] Recirculating Farms Coalition. 2013, May. "From out of the blue, green farming." Retrieved from http://www.recirculatingfarms.org/wp-content/uploads/2013/06/RFCreport_FINAL-FINAL.pdf. Last accessed on March 26, 2015. Page 8.
[55] Sun, W. 2009. "Life cycle assessment of indoor recirculating shrimp aquaculture system." Center for Sustainable Systems, University of Michigan. Report No. CSS09-15. Page iv.
[56] Alliance for Sustainable Aquaculture and Food and Water Watch. 2009. "RAS, Land-based recirculating aquaculture systems." Retrieved from http://documents.foodandwaterwatch.org/doc/RAS1.pdf#_ga=1.14499959.1186187304.1380206619. Last accessed on March 26, 2015. Page 6.
[57] Recirculating Farms Coalition. 2013. "From out of the blue, green farming." Retrieved from http://www.recirculatingfarms.org/wp-content/uploads/2013/06/RFCreport_FINAL-FINAL.pdf. Last accessed on March 26, 2015. Page 7.
[58] Recirculating Farms Coalition. 2013. "From out of the blue, green farming." Retrieved from http://www.recirculatingfarms.org/wp-content/uploads/2013/06/RFCreport_FINAL-FINAL.pdf. Last accessed on March 26, 2015. Page 17.
[59] Stern, S.S. and S. Sonnenhelzner. 2010. "Semi-intensive shrimp culture, the history of shrimp farming in Ecuador," pgs. 207-231. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 213.
[60] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 21.
[61] Samocha, T.M. 2010. "Use of intensive and super-intensive nursery systems," pgs. 247-280. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 248.

[62] Food and Agriculture Organization. "Advantages and disadvantages of P. Vannamei and P. stylirostris." Retrieved from http://www.fao.org/docrep/009/a0086e/A0086E08.htm. Last accessed on March 26, 2015. Page 7.
[63] Juarez, L.M., S.M. Moss, and E. Figueras. 2010. "Maturation and larval rearing of the pacific white shrimp," pgs. 305-352. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Pages 326, 334 and 338.
[64] Uddin, S.A. and M.A. Kader. 2006. "The use of antibiotics in shrimp hatcheries in Bangladesh." *Journal of Fisheries and Aquatic Sciences.* 1(1): 64-67.
[65] Troell, M. 2009. "Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects." In D. Soto (ed.). *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO. pp. 47–131. Page 61.
[66] Troell, M. 2009. "Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects." In D. Soto (ed.). *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO. pp. 47–131. Page 51 and 55.
[67] Troell, M. 2009. "Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects." In D. Soto (ed.). *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO. pp. 47–131. Page 60-61.
[68] Troell, M. 2009. "Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects." In D. Soto (ed.). *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO. pp. 47–131. Page 60-61.
[69] Troell, M. 2009. "Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects." In D. Soto (ed.). *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO. pp. 47–131. Page 49.
[70] Yi, Y., and K. Fitzsimmons. "Tilapia-shrimp polyculture in Thailand." Unpublished manuscript. pp. 777-790. Available online at http://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/777.pdf. Last accessed on January 13, 2015.
[71] Yi, Y., and K. Fitzsimmons. "Tilapia-shrimp polyculture in Thailand." Unpublished manuscript. pp. 777-790. Available online at http://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/777.pdf. Last accessed on January 13, 2015. Page 786.
[72] Yi, Y., and K. Fitzsimmons. "Tilapia-shrimp polyculture in Thailand." Unpublished manuscript. pp. 777-790. Available online at http://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/777.pdf. Last accessed on January 13, 2015. Page 778.
[73] Yi, Y., and K. Fitzsimmons. "Tilapia-shrimp polyculture in Thailand." Unpublished manuscript. pp. 777-790. Available online at http://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/777.pdf. Last accessed on January 13, 2015. Page 778.
[74] Yi, Y., and K. Fitzsimmons. "Tilapia-shrimp polyculture in Thailand." Unpublished manuscript. pp. 777-790. Available online at http://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/777.pdf. Last accessed on January 13, 2015.
[75] Troell, M. 2009. "Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects." In D. Soto (ed.). *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO. pp. 47–131. Page 49.
[76] Troell, M. 2009. "Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects." In D. Soto (ed.). *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome, FAO. pp. 47–131. Page 61.
[77] Kautsky, N., P. Ronnback, M. Tedengran, and M. Troell. 2000. "Ecosystem perspectives on management of disease in shrimp pond farming." *Aquaculture.* 191: 145-161. Pages 148-146.
[78] Kautsky, N., P. Ronnback, M. Tedengran, and M. Troell. 2000. "Ecosystem perspectives on management of disease in shrimp pond farming." *Aquaculture.* 191: 145-161. Page 145.
[79] Karunasagar, I., I. Karunasagar, and V. Alday-Sanz. 2010. "Immunostimulants, probiotics and phage therapy: alternatives to antibiotics," pgs. 695-711. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 695.
[80] Corsan, F., and C.V. Mohan. 2010. "Better management and certification in shrimp farming." In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 353.
[81] Flegel, T.W. 2010. "Importance of host-viral interactions in the control of shrimp disease outbreaks," pgs. 623-654. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 623.
[82] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 11 and 12.
[83] Done, H.Y., and R.U. Halden. 2015. "Reconnaissance of 47 antibiotics and associated microbial risks in seafood sold in the United States." *Journal of Hazardous Materials.* 282: 10-17. Page 11.
[84] Liao, I.C., J.J. Guo, and M. Su. (2000). "The use of chemicals in aquaculture in Taiwan, Province of China." In: J.R. Arthur, C.R. Lavilla-Pitogo, and R.P. Subasinghe (Eds.) *Use of Chemicals in Aquaculture in Asia: Proceedings of the Meeting on the Use of Chemicals in Aquaculture in Asia.* 20-22 May 1996, Tigbauan, Iloilo, Philippines (pp. 193-205). Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center. Page 195.
[85] Done, H.Y., and R.U. Halden. 2015. "Reconnaissance of 47 antibiotics and associated microbial risks in seafood sold in the United States." *Journal of Hazardous Materials.* 282: 10-17. Page 11.
[86] Governmental Accountability Office. 2011. "Seafood safety: FDA needs to improve oversight of imported seafood and better leverage limited resources." GAO-11-286. Retrieved from http://www.gao.gov/assets/320/317734.pdf. Last accessed on March 26, 2105.
[87] Governmental Accountability Office. 2011. "Seafood safety: FDA needs to improve oversight of imported seafood and better leverage limited resources." GAO-11-286. Retrieved from http://www.gao.gov/assets/320/317734.pdf. Last accessed on March 26, 2105. Page 9.
[88] Done, H.Y., and R.U. Halden. 2015. "Reconnaissance of 47 antibiotics and associated microbial risks in seafood sold in the United States." *Journal of Hazardous Materials.* 282: 10-17.
[89] Love, D.C., S. Rodman, R.A. Neff, and K.E. Nachman. 2011. "Veterinary drug residues in seafood inspected by the European Union, United States, Canada, and Japan from 2000 to 2009." *Environ Sci Technol.* 45(17): 7232-40. doi: 10.1021/es201608q.
[90] Tittlemier, S.A., J. Van de Riet, G. Burns, R. Potter, … and G. Dufresne. 2007. "Analysis of veterinary drug residues in fish and shrimp composites collected during the Canadian Total Diet Study," 1993-2004. *Food Addit Contam.* 24(1): 14-20.
[91] Done, H.Y., and R.U. Halden. 2015. "Reconnaissance of 47 antibiotics and associated microbial risks in seafood sold in the United States." *Journal of Hazardous Materials.* 282: 10-17.
[92] Centers for Disease Control and Prevention. 2013. "Antibiotic resistance threats in the United States, 2013." Atlanta, CDC. Retrieved from http://www.cdc.gov/drugresistance/threat-report-2013/pdf/ar-threats-2013-508.pdf. Last accessed on March 26, 2015. Page 11.
[93] Cuellar-Anjel, J., M. Corteel, L. Galli, V. Alday-Sanz, and K.W. Hasson. 2010. "Principal shrimp infectious diseases, diagnosis and management," pgs. 517-622. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 587.
[94] Juarez, L.M., S.M. Moss, and E. Figueras. 2010. "Maturation and larval rearing of the pacific white shrimp," pgs. 305-352. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 311.
[95] Cuellar-Anjel, J., M. Corteel, L. Galli, V. Alday-Sanz, and K.W. Hasson. 2010. "Principal shrimp infectious diseases, diagnosis and management," pgs. 517-622. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 587.
[96] Juarez, L.M., S.M. Moss, and E. Figueras. 2010. "Maturation and larval rearing of the pacific white shrimp," pgs. 305-352. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 311.
[97] U.S. Food and Drug Administration. "FDA Approved Animal Drug Products." NADA No. 140-989.
[98] Food and Agriculture Organization of the United Nations. *Aquaculture* [Webpage]. Retrieved from http://www.fao.org/aquaculture/en/. Last accessed on March 25, 2015.
[99] U.S. Food and Drug Administration. "FDA Approved Animal Drug Products." NADA No. 140-989.
[100] Food and Agriculture Organization of the United Nations. *Aquaculture* [Webpage]. Retrieved from http://www.fao.org/aquaculture/en/. Last accessed on March 25, 2015.
[101] Juarez, L.M., S.M. Moss, and E. Figueras. 2010. "Maturation and larval rearing of the pacific white shrimp," pgs. 305-352. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 311-312.
[102] Cuellar-Anjel, J., M. Corteel, L. Galli, V. Alday-Sanz, and K.W. Hasson. 2010. "Principal shrimp infectious diseases, diagnosis and management," pgs. 517-622. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 587.
[103] Juarez, L.M., S.M. Moss, and E. Figueras. 2010. "Maturation and larval rearing of the pacific white shrimp," pgs. 305-352. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 339.
[104] Food and Drug Administration. Chapter 11: Aquaculture Drugs [Guidance Document]. Retrieved from http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM252410.pdf. Last accessed on March 26, 2015. Page 184.
[105] International Agency for Research on Cancer. Formaldehyde. IARC Monographs 100F. Available online at http://monographs.iarc.fr/ENG/Monographs/vol100F/mono100F-29.pdf. Last accessed on December 22, 2014.
[106] Title 40 CFR. Section 116.4.
[107] Federal Water Pollution Control Act, As amended through P.L. 107-303, November 27, 2002. Sec. 311(b)(2)(A).
[108] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNEP. 1997. "Towards safe and effective use of chemicals in coastal aquaculture." Rep.Stud.GESAMP, 65: 40 p. Page 9.
[109] Graslund, S., K. Holmstrom, and A. Wahlstrom. 2003. "A field survey of chemicals and biological products used in shrimp farming." *Marine Pollution Bulletin.* 46: 81-90. Page 83.
[110] Graslund, S., K. Holmstrom, and A. Wahlstrom. 2003. "A field survey of chemicals and biological products used in shrimp farming." *Marine Pollution Bulletin.* 46: 81-90. Page 84-85.
[111] Alday-Sanz, V. 2010. "Designing a biosecurity plan at the facility level: criteria, steps and obstacles," pgs. 655-678. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 670
[112] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNEP. 1997. "Towards safe and effective use of chemicals in coastal aquaculture." Rep.Stud.GESAMP, 65: 40 p.
[113] Juarez, L.M., S.M. Moss, and E. Figueras. 2010. "Maturation and larval rearing of the pacific white shrimp," pgs. 305-352. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 311-312.
[114] Liao, I.C., J.J. Guo, and M. Su. 2000. "The use of chemicals in aquaculture in Taiwan, Province of China." In: J.R. Arthur, C.R. Lavilla-Pitogo, and R.P. Subasinghe (Eds.) *Use of Chemicals in Aquaculture in Asia : Proceedings of the Meeting on the Use of Chemicals in Aquaculture in Asia.* 20-22 May 1996, Tigbauan, Iloilo, Philippines (pp. 193-205). Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center. Page 194.
[115] Graslund, S., K. Holmstrom, and A. Wahlstrom. 2003. "A field survey of chemicals and biological products used in shrimp farming." *Marine Pollution Bulletin.* 46: 81-90. Page 84.
[116] Kautsky, N., P. Ronnback, M. Tedengran, and M. Troell. 2000. "Ecosystem perspectives on management of disease in shrimp pond farming." *Aquaculture.* 191: 145-161. Page 153.
[117] Saenger, P. 2002. *Mangrove Ecology, Silviculture and Conservation.* Springer, Dordrecht, The Netherlands.
[118] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 6.
[119] Primavera, J.H. 1997. "Socio-economic impacts of shrimp culture." *Aquaculture Research.* 28: 815-827. Page 817.
[120] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 5 and 6.
[121] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the

Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 5.

[122] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 9.

[123] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 9 and 38.

[124] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 11.

[125] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 15.

[126] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 25.

[127] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 15.

[128] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 39.

[129] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 39.

[130] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 23.

[131] Food and Agriculture Organization (FAOc). Fisheries and Aquaculture Department. "Shrimp culture: pond design, operation and management." Available online at http://www.fao.org/docrep/field/003/ac210e/AC210E06.htm. Last accessed on December 22, 2014. Page 3 of 8.

[132] Food and Agriculture Organization (FAOc). Fisheries and Aquaculture Department. "Shrimp culture: pond design, operation and management." Available online at http://www.fao.org/docrep/field/003/ac210e/AC210E06.htm. Last accessed on December 22, 2014. Pages 3 and 4.

[133] Klinbunga, S., B. Khamnamtong, R. Preechaphol, et al. 2010. "Genetics and its applications for increasing management and culture efficiency of the giant tiger shrimp," pgs. 149-192. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 164.

[134] Leung, K.M.Y., and D. Dudgeon. 2008. "Ecological risk assessment and management of exotic organisms associated with aquaculture activities." In M.G. Bondad-Reantaso, J.R. Arthur, and R.P. Subasinghe (eds). *Understanding and applying risk analysis in aquaculture.* FAO Fisheries and Aquaculture Technical Paper. No. 519. Rome, FAO. pp. 67–100. Available online at http://www.fao.org/3/a-i0490e/i0490e01e.pdf. Last accessed on December 23, 2014. Page 69.

[135] Food and Agriculture Organization (FAOb). Fisheries and Aquaculture Department. "Marine shrimp farming and genetic resources." Available online at http://www.fao.org/fishery/topic/14762/en. Last accessed on December 22, 2014.

[136] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 21.

[137] Food and Agriculture Organization (FAOb). Fisheries and Aquaculture Department. "Marine shrimp farming and genetic resources." Available online at http://www.fao.org/fishery/topic/14762/en. Last accessed on December 22, 2014.

[138] Food and Agriculture Organization. "Advantages and disadvantages of P. Vannamei and P. stylirostris." Retrieved from http://www.fao.org/docrep/009/a0086e/A0086E08.htm. Last accessed on March 26, 2015.

[139] Boyd, C.E., C.A. Boyd, and S. Chainark. 2010. "Shrimp pond soil and water quality management," pgs. 281-303. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 298.

[140] Boyd, C.E., C.A. Boyd, and S. Chainark. 2010. "Shrimp pond soil and water quality management," pgs. 281-303. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 281.

[141] Boyd, C.E., C.A. Boyd, and S. Chainark. 2010. "Shrimp pond soil and water quality management," pgs. 281-303. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 298.

[142] Boubarina, O., and Z. Rengel. 2011. "Nitrogen removal from eutrophicated waters by aquatic plants," pgs. 355-372. In Ansari, A.A., et al. (eds). *Eutrophication: Causes, Consequences and Control.*

[143] Boyd, C.E., C.A. Boyd, and S. Chainark. 2010. "Shrimp pond soil and water quality management," pgs. 281-303. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 299.

[144] Primavera, J.H. 1997. "Socio-economic impacts of shrimp culture." *Aquaculture Research.* 28: 815-827. Page 819.

[145] National Resources Conservation Service, United States Department of Agriculture. 1998, January. "Soil quality resource concerns: salinization." Retrieved from http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053151.pdf. Last accessed on March 26, 2015.

[146] Canedo-Arguelles, M., B.J. Kefford, C. Piscart, et al. 2013. "Salinization of rivers: an urgent ecological issue." *Environmental Pollution.* 173: 157-167.

[147] Hein, L. 2002. "Toward improved environmental and social management of Indian shrimp farming." *Environmental Management.* 29(3): 349-359.

[148] Tacon, A.G.J. 2002. "Thematic review of feeds and feed management practices in shrimp aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium on Shrimp Farming and the Environment. 69 pages. Page 7.

[149] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 7.

[150] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 7.

[151] Tacon, A.G.J. 2002. "Thematic review of feeds and feed management practices in shrimp aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium on Shrimp Farming and the Environment. 69 pages. Page 18 and 19.

[152] Davis, A., L. Roy, and D. Sookying. 2008. *Improving the Cost Effectiveness of Shrimp Feeds.* 271- 280 pp. Editores: L. Elizabeth Cruz Suárez, Denis Ricque Marie, Mireya Tapia Salazar, Martha G. Nieto López, David A. Villarreal Cavazos, Juan Pablo Lazo y Ma. Teresa Viana. Avances en Nutrición Acuícola IX. IX Simposio Internacional de Nutrición Acuícola. 24-27 Noviembre. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México. Page 3.

[153] Tacon, A.G.J., and M. Metian. 2008. "Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects." *Aquaculture.* 285: 146-158. Page 150.

[154] Tacon, A.G.J., and M. Metian. 2008. "Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects." *Aquaculture.* 285: 146-158. Page 153.

[155] Food and Agriculture Organization. "Asian fisheries today: the production and use of low value/trash fish." Retrieved from http://www.fao.org/docrep/008/ae934e/ae934e04.htm. Last accessed on March 26, 2015.

[156] Food and Agriculture Organization. "Asian fisheries today: the production and use of low value/trash fish." Retrieved from http://www.fao.org/docrep/008/ae934e/ae934e04.htm. Last accessed on March 26, 2015.

[157] Tacon, A.G.J. 2002. "Thematic review of feeds and feed management practices in shrimp aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium on Shrimp Farming and the Environment. 69 pages. Page 25 and 26.

[158] Tacon, A.G.J. 2002. "Thematic review of feeds and feed management practices in shrimp aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium on Shrimp Farming and the Environment. 69 pages. Page 24.

[159] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 26.

[160] Tacon, A.G.J. 2002. "Thematic review of feeds and feed management practices in shrimp aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium on Shrimp Farming and the Environment. 69 pages. Page 27.

[161] Davis, A., L. Roy, and D. Sookying. 2008. *Improving the Cost Effectiveness of Shrimp Feeds.* 271- 280 pp. Editores: L. Elizabeth Cruz Suárez, Denis Ricque Marie, Mireya Tapia Salazar, Martha G. Nieto López, David A. Villarreal Cavazos, Juan Pablo Lazo y Ma. Teresa Viana. Avances en Nutrición Acuícola IX. IX Simposio Internacional de Nutrición Acuícola. 24-27 Noviembre. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México. Page 274.

[162] Lewis, R.R. III, M.J. Phillips, B. Clough, and D.J. Macintosh. 2003. "Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture." Report prepared under the World Bank, NACA, WWF, and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 81 pages. Available online at http://library.enaca.org/Shrimp/Case/Thematic/FinalMangrove.pdf. Last accessed on December 22, 2014. Page 22.

[163] U.S. Department of Labor. Bureau of International Affairs. 2014. List of goods produced by child labor or forced labor. Available online at http://www.dol.gov/ilab/reports/child-labor/list-of-goods/. Last accessed on December 22, 2014.

[164] Hodal, K., C. Kelly, and F. Lawrence. 10 June 2014. "Revealed: Asian slave labour producing prawns for supermarkets in US, UK." *The Guardian.* Available online at http://www.theguardian.com/global-development/2014/jun/10/supermarket-prawns-thailand-produced-slave-labour. Last accessed on December 23, 2014.

[165] Food and Agriculture Organization (FAOa). "Cultured Aquatic Species Information Programme. Penaeus Vannamei." Available online at: http://www.fao.org/fishery/culturedspecies/Litopenaeus_vannamei/en. Last accessed on December 22, 2014. Page 5 of 15.

[166] Chamberlain, G.W. 2010. "History of shrimp farming," pgs. 1-34. In V. Alday-Sanz (ed.), *The Shrimp Book,* 1st ed. Nottingham University Press, Nottingham, U.K. Page 6.

[167] Naturland. 2014. "Naturland standards for organic aquaculture." Version 11/2014. http://www.naturland.de/fileadmin/MDB/documents/Richtlinien_englisch/Naturland-Standards_Aquaculture.pdf.

[168] Naturland. 2014. "Naturland standards for organic aquaculture." Version 11/2014. http://www.naturland.de/fileadmin/MDB/documents/Richtlinien_englisch/Naturland-Standards_Aquaculture.pdf. Standard 2.6 and 6.3.

[169] Naturland. 2014. "Naturland standards for organic aquaculture." Version 11/2014. http://www.naturland.de/fileadmin/MDB/documents/Richtlinien_englisch/Naturland-Standards_Aquaculture.pdf. Standard 5.3.

[170] Naturland. 2014. "Naturland standards for organic aquaculture." Version 11/2014. http://www.naturland.de/fileadmin/MDB/documents/Richtlinien_englisch/Naturland-Standards_Aquaculture.pdf. Standard 8.3 and 8.4.

[171] Naturland. 2014. "Naturland standards for organic aquaculture." Version 11/2014. http://www.naturland.de/fileadmin/MDB/documents/Richtlinien_englisch/Naturland-Standards_Aquaculture.pdf. Appendix 1.

[172] Naturland. 2014. "Naturland standards for organic aquaculture." Version 11/2014. http://www.naturland.de/fileadmin/MDB/

documents/Richtlinien_englisch/Naturland-Standards_Aquaculture.pdf. Standard 8.1.
[173] Naturland. 2014. “Naturland standards for organic aquaculture.” Version 11/2014. http://www.naturland.de/fileadmin/MDB/documents/Richtlinien_englisch/Naturland-Standards_Aquaculture.pdf. Standard 3.4.
[174] Naturland. 2014. “Naturland standards for organic aquaculture.” Version 11/2014. http://www.naturland.de/fileadmin/MDB/documents/Richtlinien_englisch/Naturland-Standards_Aquaculture.pdf. Section III, Social Responsibility.
[175] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 4.3-4.11.
[176] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 4.1 and 4.2.
[177] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 4.5.
[178] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf.
[179] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 7.4.1.
[180] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 2.2.2.
[181] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 2.5.
[182] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 5.2.1.
[183] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 5.3.
[184] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Page 81.
[185] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 5.3
[186] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Criterion 5.3.5.
[187] Aquaculture Stewardship Council. 2014. ASC Shrimp Standard. Version 1.0. http://www.asc-aqua.org/upload/ASC%20Shrimp%20Standard_v1.0.pdf. Page 81.
[188] Whole Foods Market. 2014. “Quality standards for farmed seafood: salmon, other finfish, and shrimp.” http://assets.wholefoodsmarket.com/www/missions-values/seafood-sustainability/WholeFoodsMarketQS_Farmed-finfish-shrimp_Jan1-2014.pdf.
[189] Whole Foods Market. 2014. “Quality standards for farmed seafood: salmon, other finfish, and shrimp.” http://assets.wholefoodsmarket.com/www/missions-values/seafood-sustainability/WholeFoodsMarketQS_Farmed-finfish-shrimp_Jan1-2014.pdf. Section 3.
[190] Whole Foods Market. 2014. “Quality standards for farmed seafood: salmon, other finfish, and shrimp.” http://assets.wholefoodsmarket.com/www/missions-values/seafood-sustainability/WholeFoodsMarketQS_Farmed-finfish-shrimp_Jan1-2014.pdf. Section 7, Section 9 and Section 6.
[191] Whole Foods Market. 2014. “Quality standards for farmed seafood: salmon, other finfish, and shrimp.” http://assets.wholefoodsmarket.com/www/missions-values/seafood-sustainability/WholeFoodsMarketQS_Farmed-finfish-shrimp_Jan1-2014.pdf. Section 1.
[192] Global Aquaculture Alliance. 2014. *Best Aquaculture Practices, Seafood Processing Standards.* Issue 3. Retrieved from http://bap.gaalliance.org/wp-content/uploads/sites/2/2015/02/bap-procplant-114.pdf. Page 4.
[193] Global Aquaculture Alliance. 2014. *BAP Finfish and crustacean farm standard.* Issue 2. http://bap.gaalliance.org/wp-content/uploads/sites/2/2015/02/bap-fishcrust-914_003.pdf. Standards 4.1-4.4.
[194] Global Aquaculture Alliance. 2014. *BAP Finfish and crustacean farm standard.* Issue 2. http://bap.gaalliance.org/wp-content/uploads/sites/2/2015/02/bap-fishcrust-914_003.pdf. Standards 5.1-5.7 and 8.1-8.12.
[195] Global Aquaculture Alliance. 2014. *BAP Finfish and crustacean farm standard.* Issue 2. http://bap.gaalliance.org/wp-content/uploads/sites/2/2015/02/bap-fishcrust-914_003.pdf. Standards 15.1-15.10.
[196] Global Aquaculture Alliance. 2014. *BAP Finfish and crustacean farm standard.* Issue 2. http://bap.gaalliance.org/wp-content/uploads/sites/2/2015/02/bap-fishcrust-914_003.pdf. Standards 15.1-15.10.
[197] Global Aquaculture Alliance. 2014. *BAP Finfish and crustacean farm standard.* Issue 2. http://bap.gaalliance.org/wp-content/uploads/sites/2/2015/02/bap-fishcrust-914_003.pdf. Standards 15.1-15.10.
[198] Global Aquaculture Alliance. 2014. *BAP Finfish and crustacean farm standard.* Issue 2. http://bap.gaalliance.org/wp-content/uploads/sites/2/2015/02/bap-fishcrust-914_003.pdf. Standards 13.1-13.10.
[199] Gillett, R. 2008. “Global study of shrimp fisheries.” No. 475, FAO. 331 pages. Pages 45, 47 and 62.
[200] Monterey Bay Aqaurium. “Learning to catch with care” [Webpage]. Retrieved from http://www.seafoodwatch.org/ocean-issues/wild-seafood/bycatch. Last accessed on March 25, 2015.
[201] Gillett, R. 2008. “Global study of shrimp fisheries.” No. 475, FAO. 331 pages. Page 15.
[202] National Oceanic and Atmospheric Administration. “Turtle Excluder Devices” webpage. Available online at http://www.nmfs.noaa.gov/pr/species/turtles/teds.htm. Last accessed on January 12, 2015.
[203] National Oceanic and Atmospheric Administration. “Turtle Excluder Devices” webpage. Available online at http://www.nmfs.noaa.gov/pr/species/turtles/teds.htm. Last accessed on January 12, 2015.
[204] Gillett, R. 2008. “Global study of shrimp fisheries.” No. 475, FAO. 331 pages. Page 62.
Monterey Bay Aquarium. Shrimp recommendations. http://www.seafoodwatch.org/seafood-recommendations/groups/shrimp?q=Shrimp.
[205] Gillett, R. 2008. “Global study of shrimp fisheries.” No. 475, FAO. 331 pages. Page 62.
[206] Code of Federal Regulations. Title 50, Section 223.206.
[207] U.S. Department of State. Shrimp exporter’s/importer’s declaration. DS-2031.
[208] Louisiana state law, Sec. 57.2.
[209] Monterey Bay Aquarium Seafood Watch. Page 8.
[210] Monterey Bay Aquarium. Shrimp recommendations. http://www.seafoodwatch.org/seafood-recommendations/groups/shrimp?q=Shrimp.
[211] National Oceanic and Atmospheric Administration. 2014. “Skimmer trawls: fishing gear and risks to protected species.” http://www.nmfs.noaa.gov/pr/interactions/gear/skimmertrawl.htm.
[212] National Oceanic and Atmospheric Administration. 2014. “Skimmer trawls: fishing gear and risks to protected species.” http://www.nmfs.noaa.gov/pr/interactions/gear/skimmertrawl.htm.
[213] Code of Federal Regulations. Title 50, Section 223.206(d)(2)(ii).
[214] National Oceanic and Atmospheric Administration. 2014. “Skimmer trawls: fishing gear and risks to protected species.” http://www.nmfs.noaa.gov/pr/interactions/gear/skimmertrawl.htm.
[215] National Oceanic and Atmospheric Administration. 2014. “Skimmer trawls: fishing gear and risks to protected species.” http://www.nmfs.noaa.gov/pr/interactions/gear/skimmertrawl.htm.
[216] Code of Federal Regulations. Title 50, Section 223.206.
[217] Monterey Bay Aquarium. 2013. “Warmwater shrimp: brown shrimp, pink shrimp, rock shrimp, royal red shrimp, sea bob shrimp, white shrimp. U.S. Gulf of Mexico and U.S. South Atlantic Regions.”
Monterey Bay Aquarium. Shrimp recommendations. http://www.seafoodwatch.org/seafood-recommendations/groups/shrimp?q=Shrimp.
[218] Monterey Bay Aquarium. Shrimp recommendations. http://www.seafoodwatch.org/seafood-recommendations/groups/shrimp?q=Shrimp.
[219] Gillett, R. 2008. “Global study of shrimp fisheries.” No. 475, FAO. 331 pages. Page 52.
[220] Monterey Bay Aquarium. 2014. “Coonstripe shrimp, dock shrimp, pink shrimp, northern shrimp, Sidestripe shrimp, spot prawn, ridgeback shrimp. Alaska, California, Washington.” Page 19.
[221] Monterey Bay Aquarium. Shrimp recommendations. http://www.seafoodwatch.org/seafood-recommendations/groups/shrimp?q=Shrimp.
[222] Marine Stewardship Council. 2014. “Summary of changes: fisheries certification requirements,” version 2.0. Page 8.
[223] FDA, “Reminder to Aquaculture Producers About The Use Of Formaldehyde,” June 23, 2006, http://www.fda.gov/AnimalVeterinary/NewsEvents/CVMUpdates/ucm048274.htm.
[224] FDA, Nov. 20, 2008, “Enhanced Aquaculture and Seafood Inspection - Report to Congress.”
http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/Seafood/ucm150954.htm
[225] Animal Medicinal Drug Use Clarification Act of 1994 (AMDUCA). http://www.fda.gov/AnimalVeterinary/GuidanceComplianceEnforcement/ActsRulesRegulations/ucm085377.htm.
[226] Electronic Code of Federal Regulations. Part 530.41—“Extralabel drug use in animals. Drugs prohibited for extralabel use in animals.” http://www.ecfr.gov/cgi-bin/text-idx?SID=054808d261de27898e02fb175b7c9ff9&node=21:6.0.1.1.16&rgn=div5#21:6.0.1.1.16.5.1.2
[227] Alday-Sanz, V., F. Corsin, E. Irde, and M.G. Bondad-Reantaso. 2012. “Survey on the use of veterinary medicines in aquaculture.” In M.G. Bondad-Reantaso, J.R. Arthur, and R.P. Subasinghe, eds. *Improving biosecurity through prudent and responsible use of veterinary medicines in aquatic food production,* p. 43.
[228] CFR. Title 21, Sec 556.720. Tetracycline. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=556.720, M-I-05-5: Tolerance and/or Safe Levels of Animal Drug Residues in Milk (Replaces M-I-03-9 (June 30, 2003) and identifies it as “INACTIVE”) and also identifies M-I-92-1 as “INACTIVE” http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/Milk/ucm077350.htm.
[229] GAO (2011). “SEAFOOD SAFETY: FDA Needs to Improve Oversight of Imported Seafood and Better Leverage Limited Resources.” http://www.gao.gov/assets/320/317734.pdf. p.9.
[230] Import Alert #16-131. http://www.accessdata.fda.gov/cms_ia/importalert_33.html.
[231] GAO-11-286: Published: Apr 14, 2011. Publicly Released: May 16, 2011, “SEAFOOD SAFETY: FDA Needs to Improve Oversight of Imported Seafood and Better Leverage Limited Resources.” http://www.gao.gov/products/GAO-11-286.
[232] 7303.844. Import Seafood Compliance Program (7/1/2010). Food and Drug Administration Compliance Manual. http://www.fda.gov/downloads/Food/ComplianceEnforcement/UCM219993.pdf.
[233] Assessment of the Third-Party Certification Pilot for Aquacultured Shrimp. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/Seafood/ucm265934.htm.
[234] The Imported Seafood Safety Program. http://www.fda.gov/Food/GuidanceRegulation/ImportsExports/Importing/ucm248706.htm.
[235] HACCP FDA. http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf. p. 159-262.
[236] HACCP FDA. http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf. p. 21.
[237] HACCP 1. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/Seafood/ucm176892.htm. p. 3.
[238] Tookwinas. 2004. http://library.enaca.org/AquacultureAsia/Articles/April-June-2004/9haccp-siri.pdf. p. 30-31.
[239] Tookwinas. 2004. http://library.enaca.org/AquacultureAsia/Articles/April-June-2004/9haccp-siri.pdf p. 30-31.
[240] HACCP FDA. http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf. p. 77/79.
[241] HACCP FDA. http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf. p. 331-332.
[242] HACCP 2. https://srac.tamu.edu/index.cfm/event/getFactSheet/whichfactsheet/222/. p. 1.
[243] Venugopal. 2006. 118-119. https://books.google.com/books?id=wom6NuHv0xkC&pg=PA122&lpg=PA122&dq=-methods+for+freezing+shrimp+iqf&source=bl&ots=qEYThXdzSu&sig=4PrglsCVpf-OaDSzTYg71V2sXAc&hl=en&sa=X-&ei=RkLuVPiRLPaHsQTBg4HABw&ved=0CCsQ6AEwAg#v=onepage&q=methods%20for%20freezing%20shrimp%20iqf&f=false.

[244] Venugopal. 2006. 120-121. Venugopal. 2006. 121-122. https://books.google.com/books?id=wom6NuHv0xkC&pg=PA122&lpg=PA122&dq=methods+for+freezing+shrimp+iqf&source=bl&ots=qEYThXdzSu&sig=4PrglsCVpf-OaDSzTYg71V2sXAc&hl=en&sa=X-&ei=RkLuVPiRLPaHsQTBg4HABw&ved=0CCsQ6AEwAg#v=onepage&q=methods%20for%20freezing%20shrimp%20iqf&f=false.
[245] HACCP FDA. http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM251970.pdf. p. 331.
[246] Prior Notice of Imported Foods. http://www.fda.gov/Food/GuidanceRegulation/ImportsExports/Importing/ucm2006836.htm.
[247] Prior Notice For Food Articles Quick Start Guide. http://www.fda.gov/Food/GuidanceRegulation/ImportsExports/Importing/ucm121048.htm.
[248] Predictive Risk-based Evaluation for Dynamic Import Compliance Targeting (2014). http://www.fda.gov/downloads/ForIndustry/ImportProgram/UCM310772.pdf.
[249] Predictive Risk-based Evaluation for Dynamic Import Compliance Targeting (2014). http://www.fda.gov/downloads/ForIndustry/ImportProgram/UCM310772.pdf.
[250] Briefing Slides for Importers and Entry Filers (2011). http://www.fda.gov/downloads/ForIndustry/ImportProgram/UCM176726.pdf&title=PREDICT.
[251] Import Alert #16-131. http://www.accessdata.fda.gov/cms_ia/importalert_33.html.
[252] Import Alert #16-35. http://www.accessdata.fda.gov/cms_ia/importalert_43.html.
[253] Love, D.C., S. Rodman, R.A. Neff, and K.E. Nachman. 2011. "Veterinary drug residues in seafood inspected by the European Union, United States, Canada, and Japan from 2000 to 2009." *Environ Sci Technol.* 45 (17): 7232-7240.
[254] Chemotherapeutics in Seafood Compliance Program. http://www.fda.gov/downloads/Food/ComplianceEnforcement/ucm073192.pdf.
[255] GAO-11-286: Published: Apr 14, 2011. Publicly Released: May 16, 2011, "SEAFOOD SAFETY: FDA Needs to Improve Oversight of Imported Seafood and Better Leverage Limited Resources," http://www.gao.gov/products/GAO-11-286.
[256] Price, R.J. 1990. "Retail Seafood Cross-Contamination." UCSGEP. http://seafood.oregonstate.edu/.pdf%20Links/Retail-Seafood-Cross-Contamination.pdf (accessed 3/10/2015).
[257] Kingombe, C.I.B., et al. 2010. "Multiplex PCR Method for Detection of Three Aeromonas Enterotoxin Genes." *App Env Micro.* 76 (2): 425-433. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2805215/pdf/1357-09.pdf.
[258] FDA. 2012. "Guidance for Industry: Testing for Salmonella Species in Human Foods and Direct-Human-Contact Animal Foods." http://www.fda.gov/downloads/Food/GuidanceRegulation/UCM295298.pdf (accessed 3/23/2015).
[259] FSIS. 2014. "FSIS Compliance Guideline: Controlling Listeria monocytogenes in Post-lethality Exposed Ready-to-Eat Meat and Poultry Products." http://www.fsis.usda.gov/wps/wcm/connect/d3373299-50e6-47d6-a577-e74a1e549fde/Controlling_LM_RTE_Guideline_0912?MOD=AJPERES (accessed 3/23/2015).
[260] CDC. 2014. "E. coli Infection and Food Safety." http://www.cdc.gov/Features/EcoliInfection/ (accessed 3/23/2015).
[261] Bross, M.H., et al. 2007. "Vibrio vulnificus Infection: Diagnosis and Treatment." *Amer Fam Phys.* 76 (4): 539-544. http://www.aafp.org/afp/2007/0815/p539.pdf.
[262] Iwamoto, M., et al. 2010. "Epidemiology of Seafood-Associated Infections in the United States." *Clin Microbiol Rev.* 23 (2): 399-411. http://cmr.asm.org/content/23/2/399.full.pdf+html.
[263] Wilken, J.A., et al. 2014. "Incidence and Trends of Infection with Pathogens Transmitted Commonly Through Food – Foodborne Diseases Active Surveillance Network, 10 U.S. Sites, 2006-2013." *MMWR.* 63 (15): 328-332. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6315a6.htm.
[264] Wilken, J.A., et al. 2014. "Incidence and Trends of Infection with Pathogens Transmitted Commonly Through Food – Foodborne Diseases Active Surveillance Network, 10 U.S. Sites, 2006-2013." *MMWR.* 63 (15): 328-332. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6315a6.htm.
[265] FDA. 2012. *Bad Bug Book, Foodborne Pathogenic Microorganisms and Natural Toxins.* Second Edition. p. 26. http://www.fda.gov/downloads/Food/FoodborneIllnessContaminants/UCM297627.pdf.
[266] Bartlett, J.G. 2013. "Vibrio species (non-cholera)." *POC-IT Guides: Johns Hopkins Antibiotic (ABX) Guide.* http://www.hopkinsguides.com/hopkins/view/Johns_Hopkins_ABX_Guide/540586/all/Vibrio_species__non_cholera_?q=vibrio (sign-in required to access).
[267] Price, R.J. 1990. "Retail Seafood Cross-Contamination." UCSGEP. http://seafood.oregonstate.edu/.pdf%20Links/Retail-Seafood-Cross-Contamination.pdf (accessed 3/10/2015).
[268] Simon, S.S., et al. 2007. "Prevalence of enterotoxigenic Staphylococcus aureus in fishery products and fish processing factory workers." *Food Control.* 18 (12): 1565-1568. http://www.sciencedirect.com/science/article/pii/S0956713507000047.
[269] Gutierrez, D., et al. 2012. "Incidence of Staphylococcus aureus and Analysis of Associated Bacterial Communities on Food Industry Surfaces." *App Env Micro.* 78 (24): 8547-8554. http://aem.asm.org/content/78/24/8547.full p. 8547.
[270] El-Shenawy, M., et al. 2014. "Cross Sectional Study of Skin Carriage and Enterotoxigenicity of Staphylococcus aureus among Food Handlers." *Open J Med Micro.* 4: 16-22. http://www.scirp.org/journal/PaperInformation.aspx?PaperID=43014#.VKNI-FfF9Lw.
[271] Scallan, E., et al. 2011. "Foodborne Illness Acquired in the United States—Major Pathogens." *Emerg Inf Dis.* 17: 1-15. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3375761/pdf/09-1101p1_finalR.pdf.
[272] Cosgrove, S.E., et al. 2003. "Comparison of Mortality Associated with Methicillin-Resistant and Methicillin-Susceptible Staphylococcus aureus Bacteremia: A Meta-analysis." *Clin Infect Dis.* 36: 53-9. http://cid.oxfordjournals.org/content/36/1/53.full.pdf+html.
[273] Liu, C., et al. 2011. "Clinical Practice Guidelines by the Infectious Diseases Society of America for the Treatment of Methicillin-Resistant Staphylococcus Aureus Infections in Adults and Children." *Clin Infect Dis.* 52: 1-38. http://cid.oxfordjournals.org/content/early/2011/01/04/cid.ciq146.full.pdf+html.
[274] CDC. 2013. "General Information About MRSA in the Community." http://www.cdc.gov/mrsa/community/index.html#q1 (accessed 3/24/2015), SHEA. FAQs about "MRSA." http://www.cdc.gov/mrsa/pdf/SHEA-mrsa_tagged.pdf (accessed 3/24/2015).
[275] Baorto, E.P., et al. 2014. "Staphylococcus Aureus Infection Treatment & Management." Medscape Reference. http://emedicine.medscape.com/article/971358-treatment (accessed 3/10/2015).
[276] Liu, C., et al. 2011. "Clinical Practice Guidelines by the Infectious Diseases Society of America for the Treatment of Methicillin-Resistant Staphylococcus Aureus Infections in Adults and Children." *Clin Infect Dis.* 52: 1-38. http://cid.oxfordjournals.org/content/early/2011/01/04/cid.ciq146.full.pdf+html.
[277] Johnson, J.R., et al. 2005. "Antimicrobial-Resistant and Extraintestinal Pathogenic Escherichia coli in Retail Foods." *J Inf Dis.* 191: 1040-9. http://jid.oxfordjournals.org/content/191/7/1040.full.pdf
[278] Auwaerter, P. 2014. "Escherichia coli." *POC-IT Guides: Johns Hopkins Antibiotic (ABX) Guide.* http://www.hopkinsguides.com/hopkins/view/Johns_Hopkins_ABX_Guide/540214/all/Escherichia_coli?q=e.%20coli (sign in required to access).
[279] Auwaerter, P. 2014. "Escherichia coli." *POC-IT Guides: Johns Hopkins Antibiotic (ABX) Guide.* http://www.hopkinsguides.com/hopkins/view/Johns_Hopkins_ABX_Guide/540214/all/Escherichia_coli?q=e.%20coli (sign in required to access).
[280] CDC. 2013. "Protecting people from deadly Listeria food poisoning." *CDC Vital Signs.* June issue. http://www.cdc.gov/vitalsigns/listeria/ (accessed 3/10/2015).
[281] CDC. 2015. "Multistate Outbreak of Listeriosis Linked to Commercially Produced, Prepackaged Caramel Apples Made from Bidart Bros. Apples" (Final Update). http://www.cdc.gov/listeria/outbreaks/caramel-apples-12-14/index.html (accessed 3/24/2015).
[282] Ponce, E., et al. 2008. "Prevalence and characterization of Salmonella enterica serovar Weltevreden from imported seafood." *Food Microbiol.* 25 (1): 39-35. http://www.sciencedirect.com/science/article/pii/S0740002007000986.
[283] CDC. 2013. "An Atlas of Salmonella in the United States, 1968-2011." p. 1. http://www.cdc.gov/salmonella/pdf/salmonella-atlas-508c.pdf.
[284] FDA. 2015. "Import Alert 16-18: Detention Without Physical Examination of Shrimp." http://www.accessdata.fda.gov/cms_ia/importalert_35.html (accessed 3/10/2015).
[285] FDA. 2015. "Import Alert 16-81: Detention Without Physical Examination of Seafood Products Due to the Presence of Salmonella." http://www.accessdata.fda.gov/cms_ia/importalert_49.html (accessed 3/10/2015).
[286] Shakir, Z., et al. 2012. "Molecular Characterization of Fluoroquinolone-Resistant Aeromonas spp. Isolated from Imported Shrimp." *App Env Microbiol.* 78 (22): 8137-8141. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3485934/pdf/zam8137.pdf.
[287] FDA. 2012. *Bad Bug Book, Foodborne Pathogenic Microorganisms and Natural Toxins.* Second Edition. pp. 54-55. http://www.fda.gov/downloads/Food/FoodborneIllnessContaminants/UCM297627.pdf.
[288] CDC. 2010. "Staphylococcal Food Poisoning." http://www.cdc.gov/nczved/divisions/dfbmd/diseases/staphylococcal/ (accessed 3/10/2015).