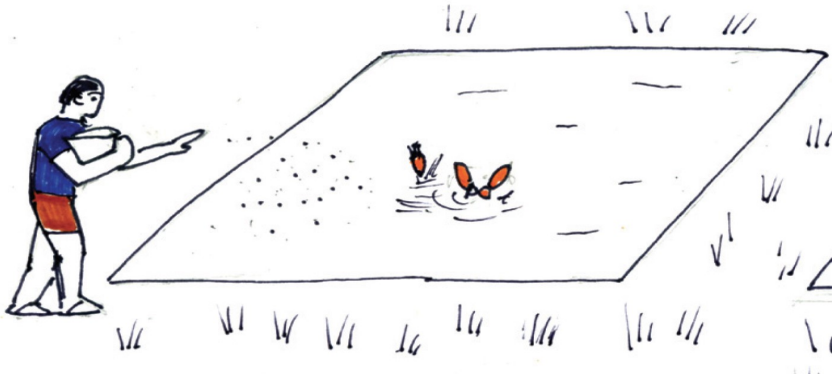
Central Concept 5: Aquatic Animal Nutrition



Fish and other animals being raised in a controlled environment must be fed a nutritionally complete diet that provides nutrients and energy at or above the required levels for optimum growth and feed efficiency. Every species has an optimal diet that will promote quick and efficient growth. Commercially prepared diets for specific species have been developed using research data on specific nutritional requirements of these species, their production systems and their life stages. For other less-researched species, including freshwater and marine ornamentals, nutritional management is based on a combination of application of knowledge generated for the species and the experience of successful aquarists.

Ideally, proper nutrition should be provided throughout the life cycle of the species being cultured for optimal growth, development, health and survival. Often overlooked is the careful selection and husbandry of the broodstock being utilized for spawning. Proper nutrition will help to improve broodstock ova-sperm maturation which will help to improve spawning success, fecundity (total number of eggs released), % fertilization (the number of fertilized vs unfertilized eggs), % hatch rate (the number of hatched larvae vs unhatched eggs), larvae viability (the number of surviving larvae vs dead-dying larvae), etc. In essence, although there is no guarantee, proper nutrition of the broodstock has been shown to improve the odds for a successful culture run.

Similarly, proper nutrition during larval rearing is critical to achieve proper larvae development and survival. Typically, tiny live feeds such as copepods, rotifers, and brine shrimp (Artemia) are utilized during the early stages of larval development. The nutritional enrichment of these live feeds, through the use of various commercially available enrichment media-emulsions, has been successfully used to enhance larvae growth and survival. These enrichment media help to ensure that the larvae are receiving the nutrients they need to successfully go through the various stages of development. Specific nutritious phytoplankton live cultures such as *Nannochloropsis occulata* and/or *Chaetocerus graciliis* have been used to "enrich" the live feeds being fed to the larvae. These algae help to boost

STANDARDS (HS)

Next Generation Science Standards (NGSS):
HS-LS1-3; HS-LS2-7; HS-LS2-8

Hawaii Common Core:
W RST.9-10.7; WHST.9-12.2; HST.9-12.7; WHST.11-12.8; WHST.9-12.9; SL.11-12.5

KEYWORDS

Docosahexaenoic acid (DHA): essential Omega3 fatty acid

Ecosapentaenoic acid (EPA): essential Omega3 fatty acid

Salinity: the amount of salt dissolved in water

Euryhaline: organisms that are able to adapt (and grow) in a wide range of salinities

Ultraviolet light: light used for disinfection by killing germs / destroying their DNA

Enrichment: to improve the quality of something by adding something to it (e.g. soil enrichment with organic matter-fertilizer)

Pathogen: microorganisms that causes a disease

Palatability: taste and/or feed desirability

Availability: proper size and density of live feed/pellets being fed

the beneficial "essential" Omega3 fatty acids of Docosahexaenoic acid (DHA) and Eicosapentaenoic acid (EPA) in the live feeds to maintain the health, growth, and survival of the growing larvae. While there are many other important fatty acids,

Depending on the species being cultured, the larval phase is generally followed by a nursery phase (juveniles) where the larvae has metamorphosed to a miniature adult appearance. During this phase the juveniles are weaned off of the live feeds onto specially prepared pelleted nursery feeds. Various nursery feeds are commercially available that include micro-pelleted feeds, soft or semi-moist pelleted feed, sinking or floating feeds, dried flake feed, etc. that increase in size to accommodate the growth and increasing size of the juveniles. Typically, after fish complete the nursery phase and are ready for stocking, either floating or sinking pelleted feeds becomes the staple diet till harvest.

The individual nutritional requirements for each cultured species are difficult to assess. However, the incorporation of DHA and EPA has been shown to be highly successful during all phases of larval, nursery, juvenile, and adult development.

Formulating Fish Diets

The first step in making an effective aquatic feed is determining the nutrient profile of the target species and formulating a feed based on that profile. Generally, fish diets tend to be very high in protein. Foods for fry and fingerlings frequently exceed 50% crude protein. As growth rate decreases and fish age, protein levels in diets are decreased accordingly. There are a variety of ingredients that are used to make fish feeds. Many aquatic feeds contain fishmeal and/or fish oil as the primary source of protein and fatty acid, typically made from wild caught anchovies and other small fish such as menhaden. There are essential amino and fatty acids that are present in fish meal that are not present in tissue from terrestrial plants or animals. Fishery byproducts that are often discarded as waste (e.g. fish guts, organs, heads, fins, bones) are promising alternative ingredients to either supplement or replace wild caught fishmeal in sustainable aquatic feeds. Selected macroalgae and microalgae are also important and emerging ingredients in fish feeds, and may greatly improve the sustainability of aquaculture feeds. In addition, terrestrial agriculture products and byproducts are used as ingredients,; some are fermented to create ingredients, such as high protein biofungal protein ingredients developed with support from CTSA. For example, a recent project created a protein ingredient by growing yeast on discarded papaya rinds. This type of research not only supports critical development of feed to grow fish for consumption, but also limits food waste going into landfills, thereby helping to create circular food systems.

ACTIVITY IDEAS

Nutrient Profiles

Assign each student a species that is grown in the Pacific region (examples include Mullet, Moi, Tilapia, Amberjack / Kahala, Pacific Oysters, and Marine Shrimp,) and have them research the nutrient profile of that species. Have students distinguish between herbivore, omnivore, or carnivore. Create a book of nutrient profiles for classroom reference.

Nutrient Venn Diagram

Create a Venn diagram for three species that have varying nutrient requirements. Have students research and fill out the requirements that are unique to each species and the requirements that species share.

Critical Thinking One-Pagers

Prompt students with articles on fish nutrition and feed production and ask them to create one-pager based on the articles (quotations, visuals, reactions, questions that remain).

Diet Palatability and Availability

Palatability - Like humans, many cultured species have preferences as to their diet. Culturing experience has shown that "too much of a single dietary item that may taste good and preferred by a cultured species can be detrimental in the long run with slower growth, deformities, and/or a compromised health system." Often a "balanced" diverse nutritional diet comprised of animal and plant ingredients reduces the likelihood of species deformities and helps to improve growth and overall survival. This strategy applies throughout its life cycle from larvae development, juvenile nursery stage, to eventual grow-out and sexual maturity.

Unfortunately, not all prepared diets containing all essential nutrients required by the species are palatable ("tasty/desirable"). If it is not consumed in the required amount, many species will often resort to cannibalism. This cannibalistic behavior is most notable with certain species of finfish and crustaceans, and when held at high densities in captivity, is likely to continue as "normal behavior" throughout the life cycle. A species cannibalizing its neighbor ("clone") ensures it is getting the ideal nutritional requirements it needs to improve its growth and increase chances of its survival. However, this cannibalism over time can result in wide population growth differences and poorer survival.

To help alleviate and limit as much as possible these potential problems, alternative diets of moist, semi-moist, flake diets are available. These diets are often more nutritious and palatable than hard oven dried extruded-pelleted feeds and can be used initially to wean certain species from live feed diets to a less labor intensive artificial diet. While feeding oven dried feeds are more convenient to feed and typically have longer shelf-life, the higher oven temperature used in manufacturing these pelleted diets could result in a breakdown of essential fatty acids. Another, although more expensive, feed processing procedure is referred to as "cold processed" feed where lower temperatures are used to help prevent or reduce the breakdown of these essential fatty acids.

Availability – Larval rearing typically consists of initially providing live feed cultures of rotifers, copepods, brine shrimp, etc. The feeding density of each of these live feeds used throughout larvae culture is critical to the overall success of the larval rearing period. The predominant size, size range, and density of the live feeds being utilized must be monitored and adjusted accordingly on a daily basis. Failure to do so could result in starvation and cannibalism that eventually will result in increasing larvae mortality and lower survival. Nutritionally enhancing these live feeds with specific microalgae and enrichment emulsions will help to alleviate weaker larvae for more robust larvae that will have a greater chance

Local & Sustainable Feed Ingredients

Prompt students to review and investigate sustainable feed ingredients in Pacific Region. Ask them to formulate a mock diet -what they would consider to be a 'sustainable aquaculture feed'- using local ingredients and nutrient profiles of various species.

Make your own tilapia feed

Adapt research supported by CTSA and NOAA SK (W. Dominy) to create a simple activity to make a feed for tilapia you are growing using fish scraps. Grow your own ingredients: utilize a student garden to grow ingredients that are commonly used in fish feed. Harvest, and use to make a feed. Visit the Publications section of the CTSA website to download the booklet that illustrates this process.

and likelihood of reaching the nursery stage. Technology associated with rearing of live foods is improving rapidly. This is having a positive impact on larval rearing, a frequent bottleneck for commercialization of "new" species. Copepods and rotifers are the smallest live foods that are routinely used for larval rearing. Newly hatched brine shrimp are richer in essential fatty acids than older brine shrimp, which rapidly utilize available fatty acids for energy and growth. They are still quite small, and are commonly used in fish hatcheries. Depending on the species being cultured, enrichment media can be used to enrich the newly hatched brine shrimp overnight, to boost its nutritional quality before feeding. While wild caught live foods can provide a source of high quality nutrition, care must be taken to avoid the inadvertent introduction and proliferation of infectious disease.

During the nursery stage, the availability of selected nutritious ingredients in the diet is critical to reduce and to discourage cannibalism. In essence, a full belly discourages cannibalistic behavior. Ideally, automatic feeders are recommended to make sure the proper amount of feed is being fed and if necessary to provide overnight feeding. The amount being fed should be constantly monitored and adjusted daily up or down depending on the density and the total biomass of animals being grown.

Equally important is adjusting the size of the feed with the changes in growth of the larvae, juveniles, and adults. Various sizes of commercially available pelleted feeds can be purchased. Also, variations in the manufacturing process exist for many of these feeds. As mentioned earlier, cold processed feeds vs heat processed feeds are available. Typically, cold processed feeds are more expensive since lower temperatures are utilized to retain more nutritional value. The utilization of these cold processed feeds may make a difference in the survival and development of more nutritionally sensitive species.

Water stability is another important factor in producing aquatic feeds. Commercially milled fish foods are usually sold as dry or semi-moist pellets or as flakes. Pellets are typically the most complete diets. They are cooked, and typically the nutrition in each particle should be uniform. It may be impossible to manufacture a particle small enough for some fish, especially juveniles of many species. For larger animals, a very small pellet may be unacceptable. Flakes have been used extensively in the ornamental fish industry for many years and have the advantage of being small enough for very small fish to consume. They also sink slower than compressed pelleted feeds.

Other Factors Interacting With Nutrition

Nutrition interacts with several other critical factors that eventually result in the successful culture of a particular species. Often these factors individually and/or interactively affect the successful survival and growth of this species during various phases of its growth.

Feeding experiments: Conduct feeding experiments with classroom fish. Experiment prompts include the following: Test a hypothesis about the effect of feeding behaviors on the growth of fish. For example, you can conduct an experiment to determine if fish grow at a different rate if they are fed the same amount of food twice a day, as opposed to only once a day. You can also test to see if different types of feed affect animal function or growth, or the quality of the culture water.

Hatch your own brine shrimp: Follow the instructions to hatch brine shrimp: http://agrilife.org/fisheries2/files/2013/09/Decapsulating-Brine-Shrimp-Eggs.pdf

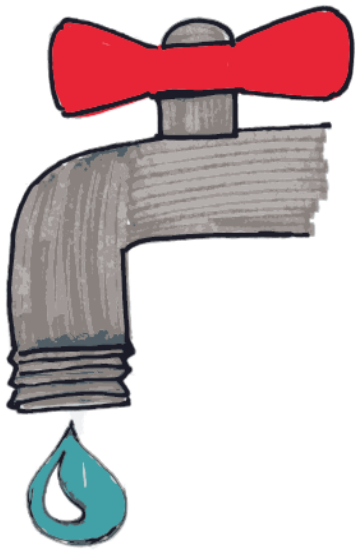
The Race to Replace Fishmeal: Prompt students to investigate what research has been done on fishmeal replacements.

DIVE DEEPER

Fed vs. Non-Fed Aquaculture In the Pacific Islands, there are some regional preferences for aquaculture of non-fed species or species with low-feed requirements. These species include bivalves such as oysters, coral, bath sponges, clams, and others. Research this more with students!

What are some of these critical factors a culturist should be aware of?

Salinity - There are species that are cultured, grow and thrive only in freshwater (FW), while others only in saltwater (SW) or "saline" conditions. Often, some species will grow in brackish water (BW) and are considered euryhaline and capable of acclimating to changing saline conditions. These BW tolerant species allows them to be compatible to various locales in areas normally not suitable because of heavy rainfall and/or coastlines affected by ocean tidal fluctuations.



Water Quality

Equally important is the water quality of the source water (e.g. whether its fresh, brackish, or saltwater) since the salinity will affect the existing phytoplankton-zooplankton fauna and flora within the growing environment. The existing water exchange rate will also have an impact, depending on the standing biomass of what is being cultured.

Offshore open ocean seawater is ideal as a source water because it is typically free of pollutants from land sediment and urban run-off or contaminated by agricultural pesticide-herbicides. However, it has access limitations and high operational expenses.

Available deep ocean seawater, as a by-product of the Natural Energy Laboratory of Hawaii, is a valuable resource that is currently being used by culturists. Its limitation is that its temperature is colder than surface or seawater from wells, which are more appropriate for growing colder water marine species.

Seawater extracted from deep wells using submersible pumps offers a more realistic situation and best option of attaining clean seawater for all islands. The natural coral and/or basaltic features of the islands allows the natural filtration ("cleaning-filtering") of the seawater before it is utilized for culturing purposes. The well's design (depth, surrounding structural features, tidal impacts, etc.) helps to reduce the likelihood of the introduction of biological pathogens and microbes that could be detrimental to what's being cultured. However, governmental restrictions and environmental discharge permits of its wastewater can make this option very costly.

Another option is to mechanically pump the water directly from the source (e.g. reservoir, stream, lake, canal, etc.) and utilize the water "as-is" or pre-treat it through a series of mechanical filters, multiple sand filters, ultraviolet exposure, etc. to "clean" the water before it is used. This option is labor intensive and strict managerial procedures are required. Failure to diligently follow these procedures could jeopardize and contaminate the entire culture system, requiring a costly shut-down and decontamination effort.

In essence, maintaining good water quality and its overall management is vital to the survival of any species being cultured. Water is the environment these species will grow and thrive in. If it is "dirty" and the species is "stressed" to stay alive within this environment, then channeling this nutrition from its diet for growth and development will be wasted and instead channeled to "neutralize" the effect of these contaminants instead of being used for growth.

Central Concept 6: Sustainable Aquaculture & Wild Fisheries Working Together

Securing the seafood supply

Globally, fish provides more than 3.3 billion people with almost 20 percent of their average per capita intake of animal protein, and 4.3 billion people with 15 percent of such protein. Just to maintain this level of per capita utilization, an additional ~47.5 million tons of food fish will be needed in 2050, according to FAO projections.

While NOAA has reported that efforts to rebuild natural fisheries stocks in the U.S. are succeeding, there are still serious threats to the global fish supply from a range of issues, including climate change and overfishing. Total production from capture fisheries worldwide has leveled off since its height in 1990. The total yield of capture fisheries in 2020 was 90.3 million tons, representing an increase of 4% compared with the average over the previous three years. In contrast, global aquaculture production (animals only) increased at an average annual growth rate of 5.3% from 34.43 million tons in 2001 to 87.5 million tons in 2020.

Imports continue to be the major source of seafood for U.S. consumers. In 2019, the total import value of edible and nonedible seafood for the U.S. was $39.7 billion, while edible

STANDARDS (HS)

Next Generation Science Standards (NGSS):
HS-ETS1-1 ; HS-ESS3-1; HS-ESS3-3; HS-ESS3-6

Hawaii Common Core:
W RST.9-10.7; WHST.9-12.2; HST.9-12.7; WHST.11-12.8; WHST.9-12.9; SL.11-12.5

KEYWORDS

Aquaculture: The purposeful farming and subsequent harvesting of both freshwater and marine aquatic plants and animals.

Restorative Aquaculture: When commercial or subsistence aquaculture provides direct ecological benefits to the environment, with the potential to generate net-positive environmental outcomes.

Fisheries: The occupation, industry, or season of taking fish or other sea animals; the wild population of a particular species. Fishing is the harvesting of already existing populations of fish and other aquatic animals.

Restocking: The release of cultured juveniles into wild population(s) to restore severely depleted spawning biomass to a level where it can once again provide regular, substantial yields.

Stock Enhancement: The release of cultured juveniles into wild population(s) to augment the natural supply of juveniles and optimize harvests by overcoming recruitment limitation.

fisheries imports were valued at $22.22 billion. The U.S. seafood trade deficit surpassed the $10 billion mark for the first time in 2010 and reached $16.9 billion in 2019. Aquaculture and fisheries will need to work together to capitalize on new technologies and opportunities to reduce this deficit and produce more US seafood.

The mutually beneficial relationship between aquaculture and fisheries is already on display in some industry sectors. For example, aquaculture for restocking and/or stock enhancement of threatened species of fish, crabs, and other aquatic life helps to rebuild wild populations and increase opportunities for fisheries. Restorative aquaculture of macroalgae and bivalves can help clean up critical habitat and enhance recruitment of wild fisheries stocks. Meanwhile, many fisheries products are essential ingredients in the production of aquaculture feeds, including anchovy, krill, squid, fishmeal, and fish oil, among others. In order to meet the projected food supply demands of the future, there are other important ways that aquaculture and fisheries will need to work together to ensure sustainability in seafood.

Sustainability in Seafood

What is considered "sustainable" aquaculture and fishing is debatable depending on available resources for a particular area, island, location, existing infrastructure, governmental and institutional support (e.g. governmental and non-governmental grants available), etc. An ideal sustainable seafood system is where aquaculture and fisheries complement each other. There are some locations in our region where sustainable models are in use, such as the Republic of the Marshall Islands (RMI). A local moi and rabbitfish farming operation (supported by CTSA) uses by-catch from commercial fisheries to produce aquaculture feed. This reduces the waste stream of the commercial fisheries --which often discard by-catch overboard and sometimes in landfills-- and provides a local source for an ingredient essential to the aquaculture operation. There are other examples where aquaculture and fisheries rely on each other, but more often, both can be competitive against each other depending on existing competitive price structure (e.g. supply and demand). Seasonal recreational fisheries may also affect existing market structure.

The greatest impacts of aquaculture and fishing on seafood supply are relative based on specific location. Across the Pacific region, most islands have a significantly higher per capital consumption than the US average, so there is an increased focus on ensuring sustainability.

Uncontrolled commercial foreign fishing vessels that frequent certain areas can devastate the fisheries in that locale. Another example is the problem of "good intentions" vs "actual fishing practices." In Tahiti, there was an effort many years ago to produce Moi for

ACTIVITY IDEAS

Venn Diagramming

Prompt students to make a Venn Diagram comparing and contrasting aquaculture and fisheries

Essay on Seafood Supply

Prompt students to research and write an essay or other composition explaining how the current availability of wild fish stocks and aquaculture products coupled with changes in climate and the environment are influencing the seafood supply.

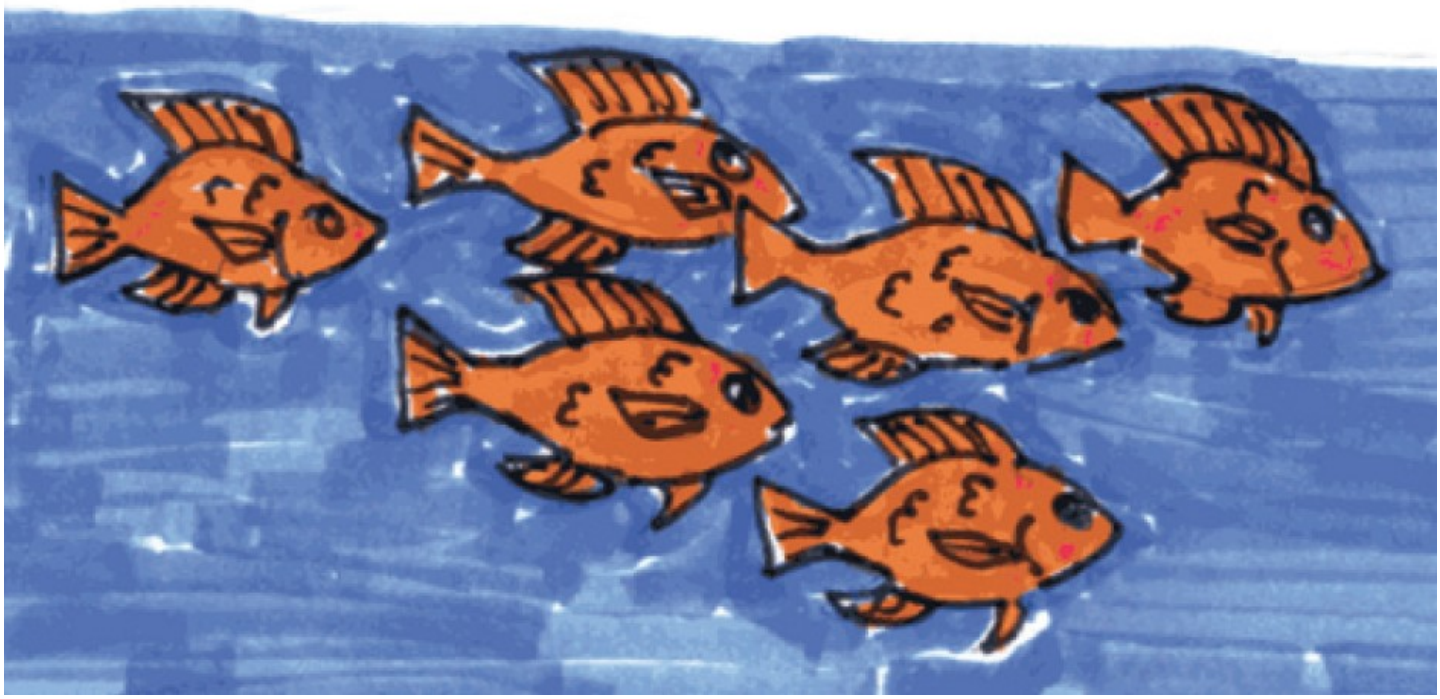
Sustainability of Hawaii's Seafood

Prompt students to visit www.hawaii-seafood.org and explore the Frequently Asked Questions section to Prepare a report on the sustainability of Hawaii's seafood.

Fishbanks

Prompt students to play the simulation game 'Fishbanks: A Renewable Resource Management Simulation.' The simulation can be done together as part of a class or individually as part of an individual learning or homework assignment. Prompt a discussion with students about the results.

Fishbanks is a multiplayer web-based simulation in which participants play the role of fishers and seek to maximize their net worth as they compete against other



aquaculture production and for stock enhancement purposes. It was later learned that there were no enforced fishing regulations in Tahiti; fish could be caught and consumed at any size, presenting a serious challenge to stock enhancement efforts of any marine species. In Hawaii, longline commercial fishermen from the Gulf states were encouraged to fish in Hawaiian waters and sell their catch in Hawaii's local markets in an effort designed by the State to lower fish prices. A lack of understanding of local Hawaiian fishing practices and customs resulted in open ocean "conflict" between local fishermen and these commercial fishing vessels. Fortunately, existing conflicts --especially regarding "overfishing" in designated "koas" (areas where certain fish species will congregate)-- were later respected by these commercial fishermen, who were considered as "outsiders." They learned that if their practice continued, they would have likely destroyed these "koas" and the livelihood of many local fishermen.

With growing fluctuations in ocean temperature, currents, and other environmental factors impacted by climate change, it is more important than ever for aquaculture and fisheries to work together to help heal ocean habitats and aquatic species populations while simultaneously meeting the growing global demand for seafood.

players and deal with variations in fish stocks and their catch. Participants buy, sell, and build ships; decide where to fish; and negotiate with one another. Policy options available to instructors include auctions of new boats, permits, and quotas.

https://forio.com/simulate/mit/fishbanks/simulation/login.html

DIVE DEEPER

https://thehealthyfish.com/important-farmed-wild-fish/

https://www.oecd.org/agriculture/topics/fisheries-and-aquaculture/

https://www.fishwatch.gov/

Central Concept 7: Careers in Aquaculture and Seafood

59.6 million people worldwide are engaged in the fisheries sectors: 19.3 million in aquaculture, 40.3 million in fisheries. More than 50% of people employed in the primary and secondary sectors of fisheries are women.

There are many types of careers and occupations in aquaculture, ranging from on-farm jobs to careers in academia and government. Many of the occupations are highly skilled and require both formal training and on-the-job upgrading.

There are many types of careers and occupations in the seafood industry covering the full cycle of seafood, from catch to plate. These jobs include commercial fishers/harvesters, boat operators and processors, as well as a host of jobs in the seafood business and retail sector.

The following is a partial list of aquaculture careers:

- Fish farm technician
- Farm manager
- Saltwater production manager
- Hatchery technician
- Environmental and regulatory affairs manager
- Fish Health technician
- Animal geneticist
- Aquaculture engineer
- Research scientist
- Instructor
- Policy advisor
- Research and development coordinator
- Regulatory affairs officer
- Aquaculture development specialist
- Aquaculture extension officers
- Habitat biologist
- Environmental assessment technician
- Research technician
- Extension Agent
- Aquaculture diver
- Feed production technician
- Aquatic veterinarian
- Processing line supervisor
- Processing line operator
- Waste management technologist

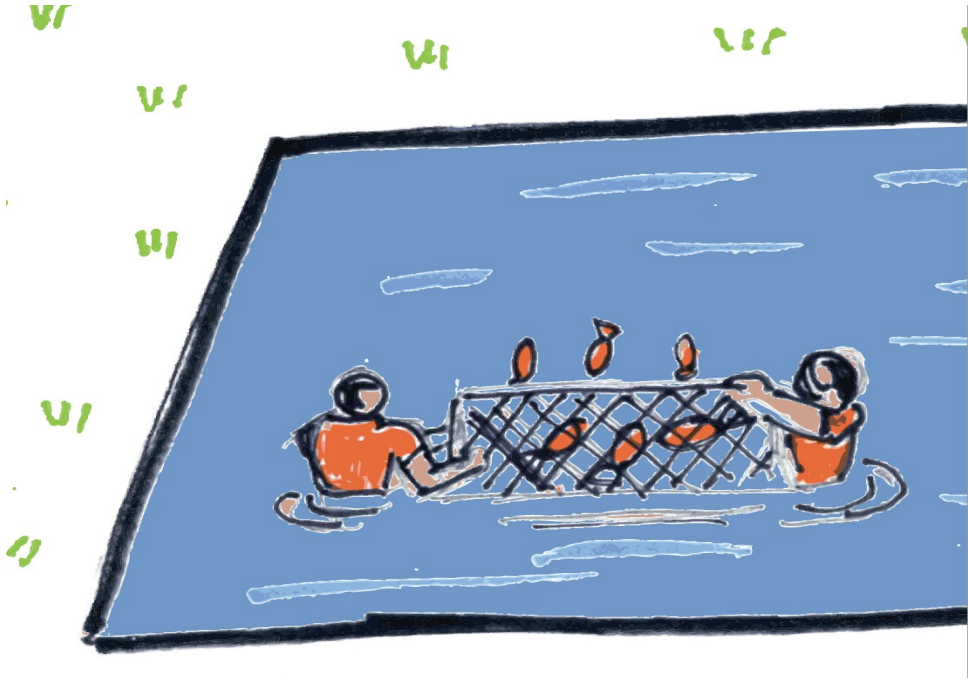
STANDARDS (HS)

Career and Technical Education — Hawaii Content and Performance Standards III

Standard 2: CAREER PLANNING: Explore and understand educational and career options in order to develop and implement personal, educational, and career goals

Benchmark CTE.9-12.2.5 Analyze the demographic, geographic, and technological trends that affect work opportunities

Benchmark CTE.9-12.2.8: Assess the compensation, lifestyle, and other benefits associated with careers of interest



The following is one example of a common aquaculture job:

Hatchery manager: Hatchery managers oversee all aspects of an aquaculture hatchery, including the management of personnel, fish, infrastructure and equipment. Additionally, they meet with federal and state officials to establish priorities for fish production and coordinate research projects. They will also conduct hatchery tours as needed.

WHAT RESPONSIBILITIES WILL I HAVE?

- Track fish life cycles to determine the proper time for harvesting or release
- Look for disease and treat as needed
- Find ways to trap and breed in an environmentally friendly and economical way
- Oversee water quality assurance/quality control program
- Maintain current knowledge of industry trends and information regarding hatchery equipment and operations
- Develop and track hatchery budget
- Manage fish care, maintenance, packing and transfer activities
- Hire and train hatchery staff and supervise employees
- Maintain records and prepare reports on hatchery operations
- Ensure worker safety requirements are met
- Work with nutritionists to develop feeding rations and schedules needed for specified growth rates for a variety of aquatic species
- Meet with federal and state officials to establish priorities for fish production and coordinate research projects
- Conduct hatchery tours, explain operations and answer questions on fish production

RECOMMENDED HIGH SCHOOL COURSES:

The following high school courses are recommended: agricultural education, animal science, mathematics, English, biology, chemistry, wildlife biology and environmental sciences.

EDUCATION/TRAINING REQUIRED:

Hatchery managers typically have a bachelor's degree in fisheries science, aquaculture, hatchery management or hatchery maintenance.

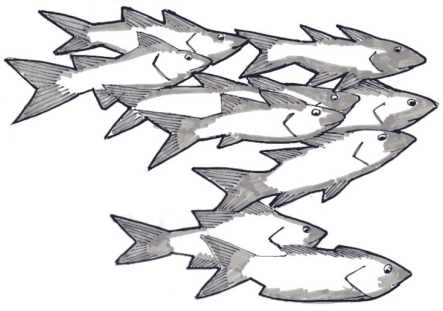
ACTIVITY IDEAS

Explore Aquaculture Careers
Dive deeper and visit the FFA website to explore various careers related to aquaculture: https://agexplorer.ffa.org/career/aquaculturist

Prompt students to choose a potential career to research and put together a one-page fact sheet on the job responsibilities and recommended education and/or training.

Seafood Career Streams
Dive deeper and visit the 'Seafood Career Streams' page on the Alaska Seafood website. View the Career Stream presentations with your students: https://jobs.alaska.gov/seafood/careerstreams.html

Career Finder Quiz
Encourage students to explore various careers in agriculture and take the 'career finder' quiz: https://agexplorer.ffa.org/sites/default/files/career-finder/#/home



The following is a partial list of common careers focused on seafood:

Fishing: There are a variety of roles needed on a fishing vessel in order to keep operations running smoothly. While many tasks are shared between all members of a vessel, the division of duties can generally be summarized between three main roles: Deckhand, Skipper and Engineer.

Processing: The processing sector transforms the fresh fish and shellfish produced by fishermen and fish farmers into the seafood products that are sold to consumers. The range of careers available includes technical managers, supervisory roles, food technologists, operatives, team leaders, filleters, quality assurance roles, engineers, and more.

Fishmongering: Careers in seafood retail will appeal to individuals looking to learn a traditional trade, which involves a great deal of knowledge and skill; this is a highly specialized trade.

Foodservice: The foodservice sector offers a clear and rewarding career path for individuals passionate about customer service. The foodservice sector includes both takeout and seafood restaurants.

Pathways to Careers in Aquaculture: Formal Education

Associate through doctoral degree programs related to aquaculture can be found at many colleges and universities. In Hawaii, the following aquaculture-specific degree programs exist: Windward Community College Marine Option Program; University of Hawaii Marine Option Program; and University of Hawaii at Hilo, Bachelor of Science in Agriculture with a Specialization in Aquaculture.

Undergraduate aquaculture programs cover topics in fish spawning, hatchery maintenance, aquatic plants, fish diseases, aquatic ecosystems, fish nutrition, water quality monitoring, and more. Students in master's and Doctor of Philosophy (Ph.D.) programs in aquaculture and fisheries can choose concentrations that fit with their research or career interests, such as fish nutrition, water quality, aquaculture engineering, fish genetics, hatchery production, fish pathology, and more.

Pathways to Careers in Aquaculture: Training

There are various types of training classes related to aquaculture; two of the most common are aquaculture-specific technical training and general business training.

Technical aquaculture courses teach skills in operational management of aquatic farming including hands-on training in hatchery management, algal culture, and more.

Resources are available for anyone interested in starting their own aquaculture business. General

business training/mentoring resources help entrepreneurs understand business fundamentals, which are the foundation of a profitable sea farm. Entrepreneurship training teaches the ins and outs of starting and operating an aquaculture business including regulatory aspects.

Investing in Regional Aquaculture Workforce Development

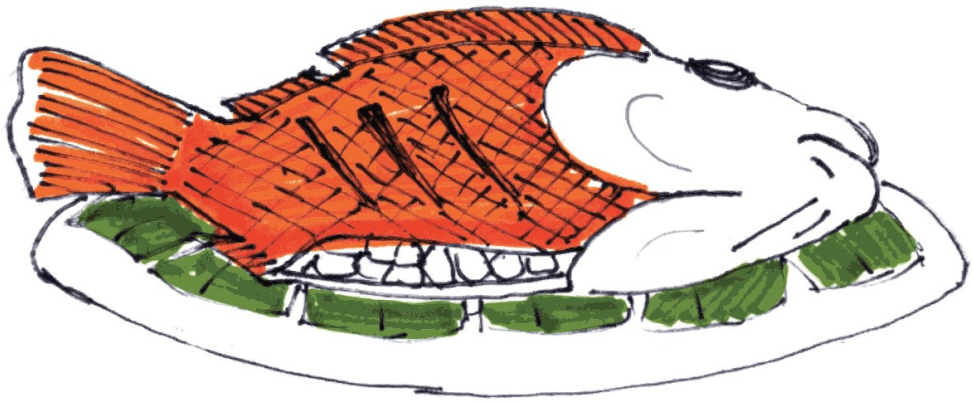
The lack of a skilled aquaculture workforce has been a bottleneck inhibiting the development of aquaculture in the Pacific region. CTSA has invested millions of dollars in aquaculture technical training through its funded projects across the Pacific region.

Several CTSA projects focused on sea cucumber and pearl oyster production in Micronesia successfully employed an innovative technique where the 'trainee becomes the trainer.' In this method, a foreign expert temporarily relocates to an island, conducts an intensive training program, stays on island until there are multiple local technicians capable of training others, and then returns periodically to check on the status. Employing this method has allowed remote island communities to transfer technology among themselves.

A CTSA project to farm moi and rabbitfish in the Marshall Islands has also employed the 'train the trainer' method, resulting in several Marshallese being skilled in all areas of operating a marine finfish hatchery and sea cages, as well as producing feed onsite using local ingredients.

CTSA has also supported projects that provide aquaculture training for students who have temporarily relocated from their home islands in the Western Pacific to Hawaii universities with a goal of bringing what they learn back to their home island for new development.

Central Concept 3: Seafood Nutrition



The University of Idaho has developed a comprehensive free curriculum titled 'Seafood At It's Best' that we strongly encourage teachers to implement. This A.Q.U.A. Lesson is intended to be a regional supplement to the 'Seafood At It's Best' curriculum: https://www.uidaho.edu/extension/seafood-at-its-best

Seafood is an essential part of a healthy lifestyle. The benefits of seafood are so great that the government guidelines for American recommend that average Americans increase their seafood intake to at least 8 ounces a week, or about two servings. Smaller amounts of seafood are recommended for younger children.

Why is Seafood Good for Us?

Studies have shown the omega-3 fatty acids found in a variety of seafood reduce the risk of cardiovascular disease. The federal government specifically mentions benefits of eating fish to "reduce the risk of mortality from cardiovascular disease." Research has revealed omega-3s can help decrease triglyceride levels, slightly lower blood pressure, decrease the growth rate of plaque in blood vessels, and decrease the risk of heart arrhythmias, which are disturbances in the rhythm or rate of the heartbeat. Omega-3 fatty acids also contribute to healthy neurological development of children.

STANDARDS (HS)

National Health Education Standards: Achieving Excellence (NHES)

Standard 1: Comprehending Concepts. Students will comprehend concepts related to health promotion and disease prevention to enhance health.

Standard 2: Analyzing Influences. Students will analyze the influence of family, peers, culture, media, technology, and other factors on health behavior.

Standard 3: Accessing Resources. Students will demonstrate the ability to access valid information, products, and services to enhance health.

RESOURCES

https://www.myplate.gov/

https://seagrant.sunysb.edu/seafood/pdfs/curricula/LessonPlan-SpinOnSeafood.pdf

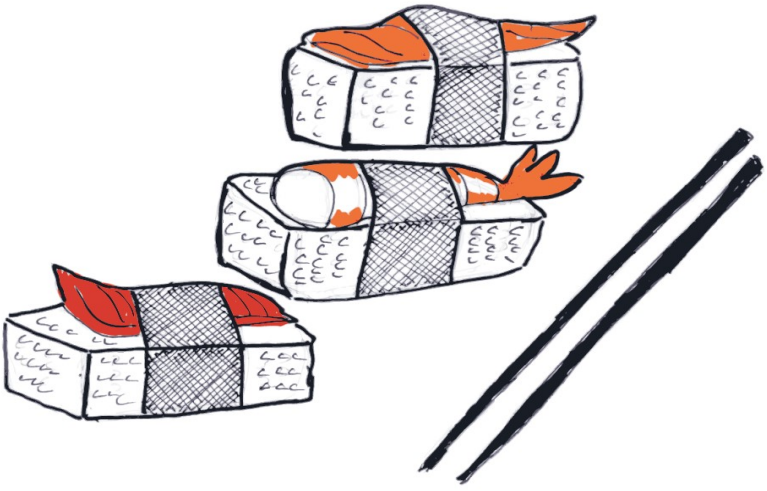
https://seagrant.sunysb.edu/seafood/pdfs/curricula/AquacultureCurriculum.pdf

Seafood is associated with improved infant health outcomes, such as visual and cognitive development. Studies are continuing on the effects of omega-3s to treat mood disorders such as depression, to reduce the risk of Alzheimer's disease, and to help reduce joint pain. Seafood can make a significant contribution to the nutrient needs of all consumers, especially growing children and the elderly. We have known for years that seafood is a good source of protein and a low calorie food. It is low in total fat, saturated fat, and cholesterol. Health experts agree seafood is an important part of a healthy, balanced diet.

Seafood Consumption in Hawaii

The National Oceanic and Atmospheric Administration's (NOAA) latest Fisheries of the United States report – which the National Fisheries Institute uses to compose its routine top species breakdown – found that Americans consumed 19 pounds of seafood per capita in 2020, down from the 19.3-pound average tallied in 2019. The per capita consumption in Hawai'I and the Pacific region is far greater than that of residents on the mainland.

Excerpt from CTARH Publication: "The per capita apparent seafood consumption in Hawai'i is 29 edible pounds without including non-commercial catch and 37 edible pounds with the inclusion of non-commercial catch. The eight-pound per capita differential shows the fairly significant contribution of non-commercial catch to Hawai'i's seafood supply chain. The non-commercial catch is 39% of total seafood production in Hawai'i. The study found that Hawai'i consumes much more fresh and frozen finfish; eight of the top 10 species consumed on a per capita basis are fresh or frozen finfish. In contrast, the U.S. in general consumes more shellfish and processed seafood, led by shrimp and canned tuna."



ACTIVITY IDEAS

EPA and DHA in seafood: Share copies of the enclosed handout on Omega3s in seafood . Prompt students to research EPA and DHA levels in different types of seafood and compare and contrast levels among different species . Assign students fish to research and "make a case" for whether they are a healthy seafood option.

What Is A Serving of Fish?: Show students a 3-ounce serving of seafood. Use food models if you have them available. Show samples of fatty and lean fish to judge fat contents by the color of the fish, or tour a market to observe the colors of seafood flesh.

Seafood Safety: Share copies of the enclosed handouts "Keeping Hawaii Seafood Safe to Eat" and "Seafood Safety: What Consumers Need to Know." Prompt a class discussion on seafood safety.

Preparing Fish: Prompt students to cook a seafood meal with their family and then report on what they cooked and/or share the recipe with the class. Adapt University of Idaho activity.

Report on Dietary Guidelines
Prompt students to research the US Government Dietary Guidelines and prepare a report on the nutritional value and importance of eating seafood. www.dietaryguidelines.gov/resources/2020-2025-dietary-guidelines-online-materials

National Institutes of Health
Office of Dietary Supplements

Omega-3 Fatty Acids Fact Sheet for Consumers

Omega-3s are found in foods such as fatty fish and plant oils.

What are omega-3 fatty acids and what do they do?

Omega-3 fatty acids are found in foods, such as fish and flaxseed, and in dietary supplements, such as fish oil.

The three main omega-3 fatty acids are alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). ALA is found mainly in plant oils such as flaxseed, soybean, and canola oils. DHA and EPA are found in fish and other seafood.

ALA is an essential fatty acid, meaning that your body can't make it, so you must get it from the foods and beverages you consume. Your body can convert some ALA into EPA and then to DHA, but only in very small amounts. Therefore, getting EPA and DHA from foods (and dietary supplements if you take them) is the only practical way to increase levels of these omega-3 fatty acids in your body.

Omega-3s are important components of the membranes that surround each cell in your body. DHA levels are especially high in retina (eye), brain, and sperm cells. Omega-3s also provide calories to give your body energy and have many functions in your heart, blood vessels, lungs, immune system, and endocrine system (the network of hormone-producing glands).

How much omega-3s do I need?

Experts have not established recommended amounts for omega-3 fatty acids, except for ALA. Average daily recommended amounts for ALA are listed below in grams (g). The amount you need depends on your age and sex.

Life Stage	Recommended Amount
Birth to 12 months*	0.5 g
Children 1–3 years	0.7 g
Children 4–8 years	0.9 g
Boys 9–13 years	1.2 g
Girls 9–13 years	1.0 g
Teen boys 14–18 years	1.6 g
Teen girls 14–18 years	1.1 g
Men	1.6 g
Women	1.1 g
Pregnant teens and women	1.4 g
Breastfeeding teens and women	1.3 g

*As total omega-3s. All other values are for ALA alone.

What foods provide omega-3s?

Omega-3s are found naturally in some foods and are added to some fortified foods. You can get adequate amounts of omega-3s by eating a variety of foods, including the following:

- Fish and other seafood (especially cold-water fatty fish, such as salmon, mackerel, tuna, herring, and sardines)
- Nuts and seeds (such as flaxseed, chia seeds, and walnuts)
- Plant oils (such as flaxseed oil, soybean oil, and canola oil)
- Fortified foods (such as certain brands of eggs, yogurt, juices, milk, soy beverages, and infant formulas)

What kinds of omega-3 dietary supplements are available?

Omega-3 dietary supplements include fish oil, krill oil, cod liver oil, and algal oil (a vegetarian source that comes from algae). They provide a wide range of doses and forms of omega-3s.

Am I getting enough omega-3s?

Most people in the United States get enough ALA from the foods they eat. They also get small amounts of EPA and DHA. Recommended amounts of EPA and DHA have not been established.

What happens if I don't get enough omega-3s?

A deficiency of omega-3s can cause rough, scaly skin and a red, swollen, itchy rash. Omega-3 deficiency is very rare in the United States.

What are some effects of omega-3s?

Scientists are studying omega-3s to understand how they affect health. People who eat fish and other seafood have a lower risk of several chronic diseases. But it is not clear whether these health benefits come from simply eating these foods or from the omega-3s in these foods. Here are some examples of what the research has shown.

Cardiovascular disease

Many studies show that eating fatty fish and other types of seafood as part of a healthy eating pattern helps keep your heart healthy and helps protect you from some heart problems. Getting more EPA and DHA from foods or dietary supplements lowers triglyceride levels, for example.

The American Heart Association (AHA) recommends eating one to two servings of seafood per week to reduce your risk of some heart problems, especially if you consume the seafood in place of less healthy foods. For people with heart disease, the AHA recommends consuming about 1 g per day EPA plus DHA, preferably from oily fish, but supplements are an option under the guidance of a healthcare provider. The AHA does not recommend omega-3 supplements for people who do not have a high risk of cardiovascular disease.

Infant health and development

During pregnancy and breastfeeding, eating 8 to 12 ounces per week of fish and other seafood may improve your baby's health. However, it is important to choose fish that are higher in EPA and DHA and lower in mercury. Examples are salmon, herring, sardines, and trout. It is not clear whether taking dietary supplements containing EPA and DHA during pregnancy or breastfeeding affects a baby's health or development. However, some studies show that taking these supplements may slightly increase a baby's weight at birth and the length of time the baby is in the womb, both of which may be beneficial. Breast milk contains DHA. Most commercial infant formulas also contain DHA.

Cancer prevention

Some studies suggest that people who get more omega-3s from foods and dietary supplements may have a lower risk of breast cancer and perhaps colorectal cancer. But a large clinical trial found that omega-3 supplements did not reduce the overall risk of cancer, or the risk of breast, prostate, or colorectal cancers. Other clinical trials in progress will help clarify whether omega-3s affect cancer risk.

Alzheimer's disease, dementia, cognitive function

Some—but not all—research shows that people who consume more omega-3s from food such as fish may have a lower risk of developing Alzheimer's disease, dementia, and other problems with cognitive function. More study of the effects of omega-3s on the brain is needed.

Age-related macular degeneration (AMD)

AMD is a major cause of vision loss among older adults. Studies suggest that people who get higher amounts of omega-3s from the foods they eat may have a lower risk of developing AMD. But once someone has AMD, taking omega-3 supplements does not keep the disease from getting worse or slow down vision loss.

Dry eye disease

Dry eye disease occurs when tears don't provide enough moisture, causing eye discomfort and vision problems. Some studies show that getting more omega-3s from foods or supplements—mainly EPA and DHA—helps relieve symptoms of dry eye disease. But a large, recent study found that the symptoms of people with dry eye disease who took fish oil

supplements of 2,000 mg EPA plus 1,000 mg DHA daily for 1 year did not improve any more than those who took a placebo (a dummy pill). Another study in healthy people found that daily supplements of 460 mg EPA plus 380 mg DHA for 5.3 years did not affect the risk of getting dry eye disease. More research on the effects of omega-3s on dry eye disease is needed.

Rheumatoid arthritis (RA)

RA causes chronic pain, swelling, stiffness, and loss of function in the joints. Some clinical trials have shown that taking omega-3 supplements may help manage RA when taken together with standard RA medications and other treatments. For example, people with RA who take omega-3 supplements may need less pain-relief medication, but it is not clear if the supplements reduce joint pain, swelling, or morning stiffness.

Other conditions

Researchers are studying whether taking omega-3 dietary supplements may help lessen some of the symptoms of attention-deficit/hyperactivity disorder, childhood allergies, and cystic fibrosis. But more research is needed to fully understand the potential benefits of omega-3s for these and other conditions.

Can omega-3s be harmful?

The U.S. Food and Drug Administration recommends consuming no more than 3 g/day of EPA and DHA combined, including up to 2 g/day from dietary supplements. Higher doses are sometimes used to lower triglycerides, but anyone taking omega-3s for this purpose should be under the care of a healthcare provider because these doses could cause bleeding problems and possibly affect immune function. Any side effects from taking omega-3 supplements in smaller amounts are usually mild. They include an unpleasant taste in the mouth, bad breath, heartburn, nausea, stomach discomfort, diarrhea, headache, and smelly sweat.

Are there any interactions with omega-3s that I should know about?

Omega-3 dietary supplements may interact with the medications you take. For example, high doses of omega-3s may cause bleeding problems when taken with warfarin (Coumadin®) or other anticoagulant medicines.

Talk with your healthcare provider about possible interactions between omega-3 supplements and your medications.

Omega-3s and healthful eating

People should get most of their nutrients from food, advises the federal government's *Dietary Guidelines for Americans*. Foods contain vitamins, minerals, dietary fiber, and other components that benefit health. In some cases, fortified foods and dietary supplements are useful when it is not possible to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy). For more information about building a healthy dietary pattern, see the *Dietary Guidelines for Americans* and the U.S. Department of Agriculture's MyPlate.

Where can I find out more about omega-3s?

For general information on omega-3 fatty acids:

- Office of Dietary Supplements Health Professional Fact Sheet on Omega-3 Fatty Acids
- Omega-3 Fatty Acids, MedlinePlus®

For more information on food sources of omega-3 fatty acids:

- U.S. Department of Agriculture's (USDA) FoodData Central
- Nutrient List for ALA (listed by food or by ALA content), USDA
- Nutrient List for DHA (listed by food or by DHA content), USDA
- Nutrient List for EPA (listed by food or by EPA content), USDA

For more advice on choosing dietary supplements:

- Office of Dietary Supplements Frequently Asked Questions: Which brand(s) of dietary supplements should I purchase?

For information about building a healthy dietary pattern:

- MyPlate
- *Dietary Guidelines for Americans*

Disclaimer

This fact sheet by the National Institutes of Health (NIH) Office of Dietary Supplements (ODS) provides information that should not take the place of medical advice. We encourage you to talk to your healthcare providers (doctor, registered dietitian, pharmacist, etc.) about your interest in, questions about, or use of dietary supplements and what may be best for your overall health. Any mention in this publication of a specific product or service, or recommendation from an organization or professional society, does not represent an endorsement by ODS of that product, service, or expert advice.

National Institutes of Health

For more information on this and other supplements, please visit our Web site at: http://ods.od.nih.gov or e-mail us at ods@nih.gov

Updated: July 18, 2022

Guidelines for Keeping Seafood Safe to Eat

Freezing. After shopping, immediately store commercially wrapped frozen seafood in your freezer. Put it in the coldest part of the freezer, at a temperature as close to -20° F as possible. As with other frozen foods, avoid prolonged storage by planning your purchases, keeping in mind "first in, first out." Commercially frozen seafood can be stored in the freezer for up to six months.

Thawing. Plan ahead; defrost fish overnight in the refrigerator. This is the best way to thaw fish to minimize loss of moisture. A one-pound package will defrost within twenty-four hours. Never defrost seafood at room temperature or with hot or warm water as bacteria on the surface will begin to multiply. If you forget to take the seafood out of the freezer in time, place it in the sink (still in the package) under cold, running water. A one-pound package will defrost in about an hour.

You can use your microwave oven to partially defrost fish. Use the lowest defrost setting (10% – 30% power). A pound of fillets defrosts in five to six minutes. The fish should feel cool, pliable, and slightly icy. Be careful not to overheat it and begin the cooking process. Foods defrosted in the microwave oven should be cooked immediately after thawing.

Preparation. Be sure all surfaces and utensils that will touch the food are clean.

Always wash your hands with soap and warm water for at least twenty seconds before starting food preparation, before working with a new food or utensil, after finishing food preparation, before serving, and after going to the bathroom.

Don't let juices from raw seafood, meat, or poultry come into contact with other food.

Wash cutting board, utensils, counter, sink, and hands with hot, soapy water immediately after preparing raw seafood, meat, or poultry.

Cooking. Cook fish and shellfish thoroughly. Fish is cooked when it begins to flake and loses its translucent (raw) appearance. Cook fish until it reaches an internal temperature of 145° F for at least fifteen seconds.

Seafood is usually cooked under moderate to high heat (425° F). You need a reliable, continuous heat source. So don't cook it on a hot plate. Avoid interrupted cooking — completely cook the seafood at one time.

If you're microwaving fish, you need to compensate for uneven heating and shorter cooking times. Be sure to rotate or stir halfway through the cooking process, cover to retain moisture, heat to an internal temperature of 170° F for fifteen seconds, and allow to stand covered for two minutes after cooking.

Scallops and shrimp turn firm and opaque when cooked. It takes three to five minutes to boil or steam one pound of medium-sized shrimp, and three to four minutes to cook scallops.

Shucked shellfish, such as clams, mussels, and oysters, become plump and opaque when cooked. The FDA recommends that shucked oysters be boiled or simmered for at least three minutes, fried in oil for at least ten minutes at 375° F, or baked at 450° F for at least ten minutes. Steam clams, mussels, and oysters in the shell for four to nine minutes after water reaches a full boil. Use small pots to steam shellfish. If too many shells are cooking at once, the centers may not cook thoroughly. Discard clams, mussels, or oysters that don't open during cooking. They may not have received adequate heating.

When cooking frozen clams, mussels, or oysters in the shell, follow the directions on the package.

Marinades. Marinate seafood in the refrigerator in a glass or plastic container; avoid metal. Avoid cross-contaminating other foods by cleaning all utensils, bowls, or surfaces the marinade comes in contact with after it has been combined with raw seafood. Don't save marinades that have been combined with raw seafood unless they are immediately cooked in a sauce. Bring the marinade to a rolling boil before adding other ingredients. Then cook the sauce to at least 160° F.

If fish is to be consumed raw, use only previously frozen fish. Do not consume raw or undercooked fish or shellfish if your immune system is compromised in any way.

Serving. Never put cooked seafood back on the plate that held the raw product. Place leftovers in smaller containers and refrigerate them within two hours when the temperature of the food serving area is below 90° F and within one hour when the air temperature is 90° F or above.

Sea Grant University of Delaware

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NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

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Seafood Safety: What Consumers Need to Know

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Sea Grant

Using HACCP to Keep Seafood Safe

What Is HACCP?

HACCP (pronounced "has-sip") is an acronym for *Hazard Analysis Critical Control Point.* It's an effective way of ensuring the safety of food. It works by preventing food safety problems from developing rather than testing food after production to see if it's safe.

HACCP was developed in the late 1950s and early 1960s as a way to assure that the food produced for the space program was safe. The Pillsbury Company, in cooperation with NASA, worked out this method of controlling food safety problems.

There are two parts to HACCP. Part one includes making a list of things that can cause the food to be unsafe — we call this *hazard analysis.* Part two is deciding at which place in the production of the food the hazards can best be controlled — we call this the *critical control point* for that hazard.

How Does HACCP Make Seafood Safe?

All parts of the seafood processing operation are examined for hazards including raw materials, ingredients, processing steps, storage, and distribution. Hazards include disease-causing organisms, toxins, environmental contaminants (like pesticides), chemicals (cleaners, sanitizers, lubricants, etc.), and physical hazards (wood, metal, and glass). For each hazard, a critical control point is identified where the potential food safety problem is controlled.

Records are kept at each critical control point so inspection agencies can be certain the HACCP system is operating to provide safe food. As an extra measure of safety, certain sanitation activities also must be conducted and documented.

Under the new U.S. Food and Drug Administration regulations, all seafood processors will be required to operate under the HACCP program. All imported seafood also will be covered.

What Do Consumers Need to Do to Keep Seafood Safe?

The most important considerations in safe handling of seafood at home are cleanliness, temperature, and time. Keep your hands, preparation area, and utensils clean. Never let raw seafood come in contact with cooked seafood or other raw (or cooked) foods.

Seafood is highly perishable. If you are buying seafood at the supermarket, make it one of your last purchases. Use your eyes, hands, and nose when selecting fresh fish or shellfish. Your purchase should feel cold to the touch. And it shouldn't smell "fishy." The odor should be similar to that of a sea breeze.

Be aware of temperatures — of the air, of your refrigerator and freezer, of cooking. Keep foods out of the danger zone (40°F – 140°F). Be aware of time — limit how long the fish and shellfish are unrefrigerated.

Finally, to help keep your seafood safe, keep it clean, keep it cool, and keep it moving! By abiding by these rules and adopting the following guidelines, you can be confident that your efforts and the HACCP program are working together to keep seafood safe.

What's the Right Way to Handle and Store Seafood?

The storage life of seafood depends on how well you take care of it, whether a whole fish or a live oyster. When your seafood purchase arrives home, store it immediately in your refrigerator or bury it in ice. When purchasing fresh-frozen seafood, place it in the freezer immediately.

Fish. The shelf life of fish depends on the variety and its quality at the time of purchase. In general, you should use fish quickly — within one to two days.

Shellfish. Buy live shellfish from reputable dealers, or ask to see the certification tags that indicated the shellfish were harvested from safe waters.

Store live shellfish, such as oysters and mussels in the shell, in a shallow dish covered with damp towels or moistened paper towels. Never put live shellfish in water or in an airtight container. Scrub shells with a stiff brush just prior to shucking or cooking.

Mussels live in the shell should be used within two to three days; clams and oysters in the shell, within seven to ten days. If some shells open during storage, tap them. They will close if alive; if not, discard them.

Store shrimp, squid, and shucked shellfish in a leak-proof bag or container. Squid and freshly shucked clams have a shelf life of one to two days. Shrimp and scallops have a shelf life of about two to three days. And freshly shucked oysters have a shelf life of five to seven days.

Live lobsters and crabs should be cooked the day they are purchased. Store cooked, whole lobsters or crabs in a rigid airtight container and use them within two to three days. Cooked, picked lobster or crab meat may be stored in a sealed moisture-proof container or bag for three to four days. Pasteurized crab meat can be refrigerated for up to six months before opening; use it within three to five days after opening. Follow the "use by" dates on the package.

Keeping Hawaii Seafood

SAFE TO EAT

Fresh *island seafood*

Fresh island seafood is one of the things that makes living in Hawaii so special.

It is vital to the people of Hawaii for a healthy nutritious diet. It is also important to the island economy, because seafood is a key ingredient of the tourism "product" that Hawaii has to share with the world. Being in the middle of the Pacific Ocean means that Hawaii's fishermen can supply the islands with a variety of fresh, high quality, open ocean fish like *ahi* (bigeye and yellowfin tuna), *mahimahi*, and exotic deepwater snappers like *opakapaka* and *onaga*. Simply put, local seafood greatly enhances the visitor experience and the quality of life in the islands.

Hawaii Seafood is a premium product.

Hawaii has become a recognized source of premium fresh seafood that is presently featured in some of the best restaurants in the islands and across the country. This reputation has been earned through the combined efforts of Hawaii's hardworking fishermen, fresh fish auction, wholesalers and innovative chefs, and through generic seafood promotion efforts that have helped to introduce the country to fresh Hawaii seafood. High-profile Hawaii chefs have spearheaded the development of Pacific Rim or Hawaii Regional cuisine by featuring Hawaii seafood and other local products.

Cover: Fresh Hawaii longline-caught bigeye tuna sashimi *(chu toro)* prepared by Taketoshi Gibo, Take's Fish Market, Honolulu, Hawaii. (Photo by John Kaneko)

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Keeping Hawaii Seafood safe.

Preventing seafood-borne illness is vital to preserving the reputation of Hawaii seafood. Understanding the potential public health problems associated with some of our seafood products is the first line of defense. Establishing appropriate and effective control measures to prevent seafood-related illnesses is the next step. Finally, seafood safety is achieved when all of the people involved from the fishermen to the final consumer are aware of the potential hazards and their responsibilities in keeping Hawaii seafood safe to eat.

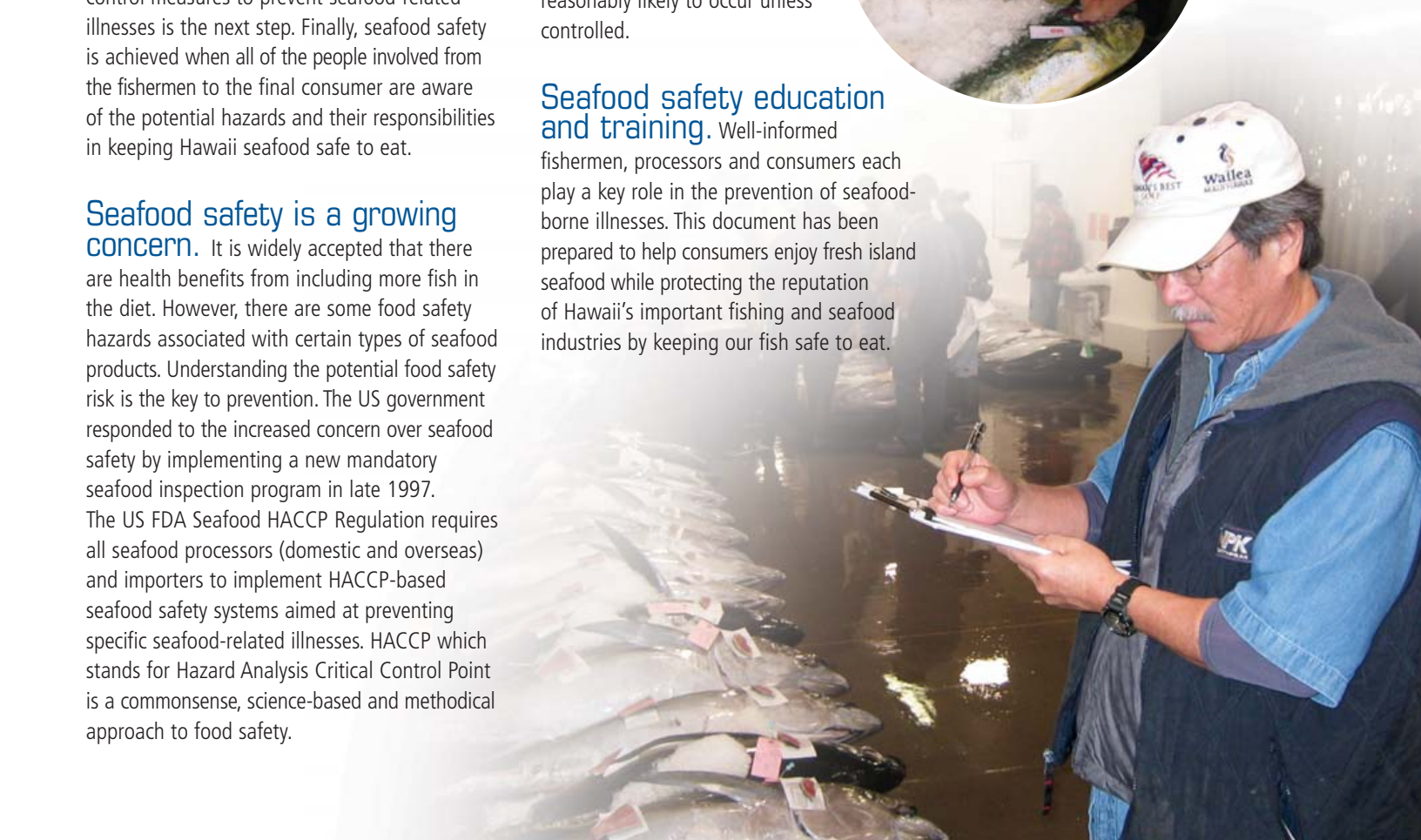
Seafood safety is a growing concern.

It is widely accepted that there are health benefits from including more fish in the diet. However, there are some food safety hazards associated with certain types of seafood products. Understanding the potential food safety risk is the key to prevention. The US government responded to the increased concern over seafood safety by implementing a new mandatory seafood inspection program in late 1997. The US FDA Seafood HACCP Regulation requires all seafood processors (domestic and overseas) and importers to implement HACCP-based seafood safety systems aimed at preventing specific seafood-related illnesses. HACCP which stands for Hazard Analysis Critical Control Point is a commonsense, science-based and methodical approach to food safety.

The HACCP approach depends on understanding the potential hazards, devising effective control measures, and monitoring critical steps in the harvesting and processing of seafood to control the hazard. HACCP is not a zero-risk system, but instead aims to minimize the risk of seafood safety hazards that are reasonably likely to occur unless controlled.

Seafood safety education and training.

Well-informed fishermen, processors and consumers each play a key role in the prevention of seafood-borne illnesses. This document has been prepared to help consumers enjoy fresh island seafood while protecting the reputation of Hawaii's important fishing and seafood industries by keeping our fish safe to eat.



Seafood Quality and Safety

Deciding whether or not a seafood product is safe to eat is based on an understanding of the factors that have the potential to increase the risk of illness. These factors include the species of fish, where the fish were harvested, how they were caught, how they were handled on the fishing vessel and how the catch was handled on shore.

Seafood SAFETY ISSUES

of special importance to Hawaii.

SEAFOOD-BORNE ILLNESS	BRIEF DESCRIPTION	FISH SPECIES IMPORTANT TO HAWAII
SCOMBROID FISH POISONING	A.k.a. histamine poisoning. Pseudo-allergic reactions caused by histamine and possibly other biogenic amines in spoiled fish.	*Mahimahi*, tuna, marlin, *akule* and others.
CIGUATERA FISH POISONING	Ciguatoxin is a marine biotoxin. Causes mild to severe neurologic symptoms, reversal of hot and cold temperature sensation.	Tropical reef fish: *roi, kole, ulua, papio* and many others.
HALLUCINOGENIC REEF FISH POISONING	Unknown marine biotoxin. Causes severe nightmares and hallucinations. Source of toxin is unknown.	Nightmare *weke* (*Upeneus arge*), other *weke* (*Mulloidichthyes* spp) and striped mullet (*Mugil cephalus*).
MERCURY	An unavoidable natural contaminant in open ocean fish. No cases of poisoning reported from open ocean fish. Neurotoxic effects of high mercury concentrations are known in cases of industrial pollution or accidental poisoning.	Large tuna, marlin, swordfish and sharks contain mercury but at much lower levels compared with fish from polluted waters.
HERRING AND COD WORM INFECTION	A.k.a. *anisakiasis* caused by accidental herring and cod round-worm infection (*Anisakis simplex* or *Pseudoterranova decipiens*).	Fresh, raw wild Pacific salmon (*Onchorhynchus* spp), squid (all species), Pacific rockfish (*Sebastes* spp).
BROAD FISH TAPEWORM INFECTION	A.k.a. *diphyllobothriasis* caused by broad fish tapeworm infection (*Diphyllobothrium latum*).	Fresh, raw wild Pacific salmon (*Onchorhynchus* spp).
SALMON FLUKE INFECTION	A.k.a. *nanophyetiasis,* caused by accidental salmon fluke infection. This parasite (*Nanophyetus salmonicola*) causes salmon poisoning in dogs.	Fresh, raw wild Pacific salmon (*Onchorhynchus* spp).
ANGIOSTRONGYLIASIS	A.k.a. *eosinophilic meningitis* caused by accidental larval rat lungworm infection (*Angiostrongylus cantonensis*) of the central nervous system.	Fresh, raw freshwater prawn (*Macrobrachium* spp), slugs and snails.
INTESTINAL HETEROPHYSIASIS	Accidental intestinal fluke infection (*Stellantchasmus falcatus*).	Fresh, raw mullet (*Mugil cephalus*).

Seafood SAFETY HAZARDS

and potential control approaches.

There are a variety of methods to detect indicators of an unsafe product. These methods include sensory examination, temperature measurements, and laboratory tests.

Sensory examination.

We naturally judge the quality of food using our senses to evaluate the visual appearance, smell and texture of the product. Seafood is highly perishable and off-odors are the main indicators of spoilage. While sensory experts apply a highly-evolved descriptive language to the range of odors that may be found in seafood, the ability to judge spoiled from non-spoiled food can be easily taught and this skill is largely instinctive.

Main seafood safety problems of importance to Hawaii include

Scombroid Fish Poisoning

Ciguatera Fish Poisoning

Hallucinogenic Reef Fish Poisoning

Mercury

Parasites

When in doubt, throw it out.

SEAFOOD SAFETY PROBLEM	CHILLING AND REFRIGERATION	FREEZING	COOKING	SPECIES AVOIDANCE
HISTAMINE	Effective only if chilling begins immediately after harvest and is rapid enough to prevent bacterial growth and enzyme action that form histamine.	Effective only if freezing is rapid enough to prevent histamine formation. Ineffective if histamine is allowed to form before freezing.	Ineffective if histamine is allowed to form before cooking. Toxin is not affected by cooking temperatures.	Unnecessary if histamine-forming fish are properly chilled and stored at <40°F and do not show signs of spoilage or mishandling.
CIGUATERA	Ineffective. Toxin is not affected by refrigeration temperatures.	Ineffective. Toxin is not affected by freezing temperatures.	Ineffective. Toxin is not affected by cooking temperatures.	Necessary precautions for fish species and fishing areas known to produce ciguatera.
MERCURY	Ineffective. Mercury content is not affected by refrigeration temperatures.	Ineffective. Mercury content is not affected by freezing temperatures.	Ineffective. Mercury content is not affected by cooking temperatures.	Necessary to reduce mercury exposure from the diet. But the known health benefits of eating fish should be carefully weighed against the undocumented health affects of low-levels of mercury in open ocean fish. Women of child bearing age and young children should follow their doctors' advice.
PARASITES	Ineffective. Parasites survive refrigeration temperatures.	Effective. Parasites are killed by deep freezing temperatures.	Effective. Parasites are killed by cooking temperatures.	Necessary precautions for species known to contain infective larvae only if fish are not frozen before being eaten raw.

Hawaii Fisheries

Open Ocean (pelagic) Fishery

Ahi (bigeye and yellowfin tuna), *tombo ahi* (albacore tuna), *aku* (skipjack), swordfish, *kajiki* (Pacific blue marlin), *nairagi* (striped marlin), *hebi* (spearfish), *mahimahi* (dolphinfish), *ono* (wahoo), *opah* (moonfish), *walu* (escolar and oilfish), *monchong* (bigscale pomfret). Landed in Hawaii primarily by the pelagic longline fleet with some fish also caught by pole and line vessels (*aku* boats), trolling and handline boats.

Coral Reef Fishery

Ulua/papio (jacks), surgeonfish, *uhu* (parrotfish), *weke* and other goatfishes, *kaku* (barracuda), and assorted fish, shellfish and seaweed species. Hawaii has introduced species of shallow-water snappers and groupers. Small coastal schooling pelagic fish including *akule* (big eyed scad) and *opelu* (mackerel scad) are also extremely important food fish. Caught by net, hook and line and spearing methods.

Deep-slope Bottomfish Fishery

Onaga (long-tailed red snapper), *opakapaka* (pink snapper), *ulua* (jacks), *uku* (grey snapper), *hapu'upu'u* (seabass). Caught by bottomfishing boats using hook and line methods.

Histamine Poisoning

a.k.a. *Scombroid Fish Poisoning*

What is histamine poisoning?

Histamine poisoning is also known as *Scombroid Fish Poisoning*. It is caused when seafood containing high levels of histamine is eaten. Histamine levels in fish are naturally very low, but can increase to toxic levels in certain types of fish like *mahimahi* and tuna if they are not properly chilled. Histamine is generated in susceptible types of fish (histamine-formers) that are exposed to elevated temperatures for a prolonged period that allows bacterial growth and enzyme action. Certain types of bacteria are very efficient at converting *histidine* (a naturally occurring amino acid) to histamine (the toxin) in fish muscle. The conditions that allow spoilage also promote histamine production. Histamine can accumulate when fish are held on fishing vessels and while being handled by seafood processors, distributors, retailers and restaurants and finally in the hands of seafood consumers.

Is histamine poisoning a problem in Hawaii?

Histamine poisoning occurs, but cases are infrequent. However, it is one of the most common seafood-related illnesses reported in Hawaii and across the country. Hawaii people eat more seafood per capita than the rest of the US, and especially fish like *mahimahi*, tuna and other open ocean fish that are histamine-formers. The Hawaii Department of Health summarized the number of histamine poisoning cases reported between 1999 and 2003. During this 5-year period about 60 cases (illnesses) were reported each year for a resident population of roughly 1.2 million people. By comparison, the average number of cases of *campylobacteriosis* (a serious food-borne illness) mainly from chicken contaminated with the bacteria *Campylobacter jejuni*, was just over 800 per year. The risk of histamine poisoning in Hawaii is about 5 cases per 100,000 people per year, compared with 67 cases of *campylobacteriosis* per 100,000 people per year. The risk estimate is much lower if the large visitor population present in the islands is included.

What fish cause histamine poisoning in Hawaii?

Many of the important Hawaii fish species are potential histamine-formers including *mahimahi*, tuna (bigeye, yellowfin, albacore and skipjack) and other related open ocean fish species. In Hawaii, *mahimahi* caused 51% of the total number of reported cases of histamine poisoning followed by *ahi* (mostly yellowfin tuna and possibly bigeye) (32%), *kajiki* (blue marlin) (4%), *akule* (big eye scad) (4%), *ono* (wahoo) (3%) and the remaining species each at less than 1% of the total.

What are the symptoms of histamine poisoning?

Fish allergy or fish poisoning? Histamine poisoning occurs when people eat fish containing high concentrations of histamine and possibly other related biogenic amines generated during spoilage. Histamine poisoning can be misdiagnosed as a *"fish allergy"* because histamine causes *pseudo-allergic reactions*. Histamine is a mediator of the immune system. It is partly responsible for the reactions (swelling, itching and redness) people have to mosquito bites or symptoms people with allergies might have to dust or pollen.

The onset of symptoms is rapid, within minutes of exposure and symptoms usually subside in 8 to 12 hours. Over the counter anti-histamines can help alleviate symptoms. There are no reported fatalities associated with histamine poisoning.

The body reacts with some or all of the following symptoms:

- ITCHING ON THE FACE AND AROUND THE MOUTH
- BURNING SENSATION IN THE THROAT
- DRYNESS OF THE MOUTH
- DIFFICULTY SWALLOWING
- NAUSEA AND VOMITING
- WEAKNESS
- FLUSHING (REDNESS) OF THE FACE AND OTHERS PARTS OF THE BODY
- SEVERE THROBBING HEADACHE
- RAPID, STRONG HEART BEAT
- ABDOMINAL CRAMPS AND DIARRHEA

Top 10 fish species involved in reported cases of **histamine poisoning** in Hawaii during the 14-year period between September 1989 and October 2003.

RANKING	**FISH** (Hawaiian name and common name)	**OUTBREAKS** % and (n)	**ILLNESSES** % and (n)
No. 1	***mahimahi*** (dorado)	28.0% (81)	51.1% (353)
No. 2	***ahi*** (yellowfin & bigeye tuna)	45.3% (131)	31.5% (218)
No. 3	***kajiki & nairagi*** (blue & striped marlin)	5.9% (17)	3.8% (26)
No. 4	***akule*** (bigeye scad)	6.2% (18)	3.6% (25)
No. 5	***ono*** (wahoo)	3.8% (11)	2.6% (18)
No. 6	***walu*** (escolar & oilfish)	0.7% (2)	0.6% (4)
No. 7	***aku*** (skipjack tuna)	0.7% (2)	0.4% (3)
No. 8	***tombo ahi*** (albacore tuna)	0.4% (1)	0.3% (2)
No. 9	***hebi*** (shortnose spearfish)	0.4% (1)	0.3% (2)
No. 10	***opelu*** (mackerel scad)	0.4% (1)	0.1% (1)
TOTAL	***All fish implicated in reported cases of histamine poisoning.***	100% (289)	100% (691)

How can fish with high histamine content be detected?

Some victims of histamine poisoning have reported that they detected a sharp peppery or metallic taste in the fish. Others report that the fish had a strong taste, while some did not detect anything unusual about the fish they ate before becoming ill.

The detection of spoilage odors can be a useful indicator of mishandling, the risk of elevated histamine concentration and the relative safety of the product. Careful inspection of fish for spoilage odors is an extremely important and practical control measure because histamine is formed by a special type of bacterial spoilage.

Histamine does not by itself have a distinctive odor. However the conditions that allow spoilage also allow histamine to form. When bacteria grow, they give off odors characteristic of spoilage. These odors are useful practical clues about the possibility that fish were mishandled, that the fish are spoiled and may also contain an elevated concentration of histamine.

THE NOSE KNOWS. Studies in Hawaii have demonstrated the effectiveness of sensory examination to detect odors and visual cues of spoilage in preventing fish with high histamine levels from entering the market from commercial fishing vessels. A total of 1,065 histamine-forming fish delivered to the Honolulu fish auction were first inspected for spoilage, accepted or rejected when spoilage odors were present and then tested for histamine content. Only 15 fish exceeded the government limit for histamine and each of these fish was first rejected from the market because of spoilage. It is highly unlikely that representative sampling and testing could have been effective in culling 15 out of 1,065 fish with elevated histamine content. These studies demonstrated the value of careful screening of histamine-forming fish for odors and visual indicators of spoilage as an effective and practical histamine control measure in Hawaii. Sensory judgments are quick and for the Hawaii fishery products, have been validated for effectiveness as a practical histamine control measure.

Testing methods exist. The federal government has established a maximum histamine concentration of 50 ppm (parts per million) allowed in seafood. This limit has a built-in safety margin and is set well below the concentration that causes poisoning. Studies in Hawaii have shown that most fish contain much less than 1 ppm histamine. Histamine concentration in fish can be determined using laboratory tests. These laboratory methods are used routinely by canneries receiving frozen tuna to screen fish before canning. These tests take time and because the tuna can be stored in the freezer, canners have the time needed to utilize testing methods as an initial screening method. Loads of frozen tuna delivered by purse seine vessels to canneries often exceed 1,500 tons, and are broken into lots that can reach 100 tons containing thousands of individual fish. Handling high quality fresh seafood in much smaller lots is an entirely different situation. A typical Hawaii longliner delivers 7 to 8 tons of fish per trip and local trollers might deliver a single fish to the market. Fresh seafood is highly perishable and shelf life is limited. The routine use of histamine testing is not easily integrated into a fishery that catches, receives, processes and distributes the fresh high quality fish rapidly while maintaining cold temperatures.

How can histamine poisoning be prevented?

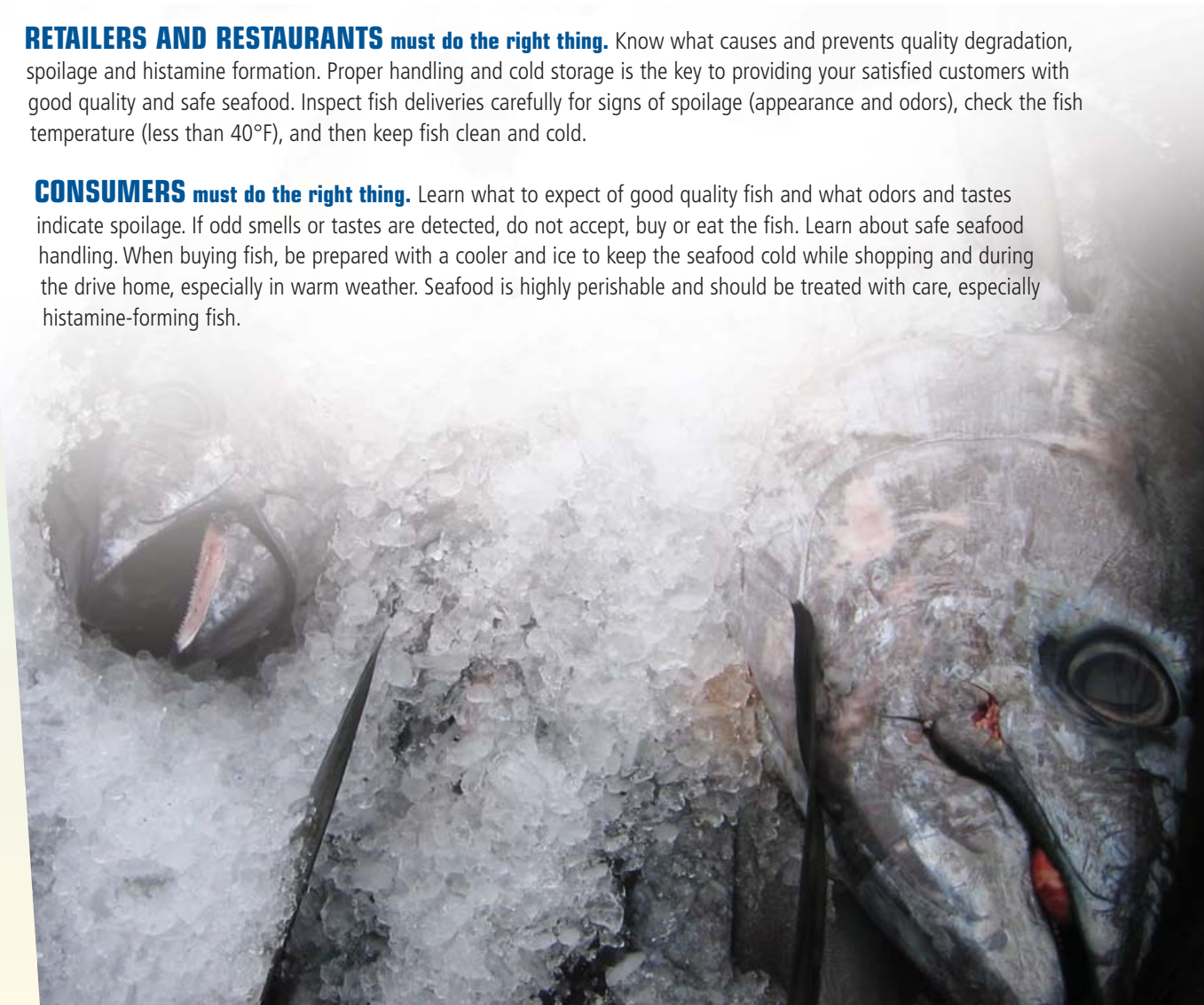
IT'S SIMPLE, keep fish cold and clean. Prevention relies on consumer and industry education and proper fish handling practices. Temperature control is the key to prevention of histamine poisoning. This is because bacterial growth and histamine production can be greatly reduced by rapid chilling and proper cold storage temperatures thereafter. Preventing the conditions that promote bacterial spoilage involve both temperature control and sanitary practices. All people involved in the harvesting, processing, distribution, preparation and consumption of susceptible fish play a role in the prevention of histamine poisoning. However, fishermen have the most important role because it is the initial cooling period after harvest that determines whether or not fish will be likely to form toxic levels of histamine. If fishermen understand the problem and consistently apply proper fish handling and icing of the catch, histamine control thereafter is achieved by maintaining proper storage temperatures. However, if the fishermen delay icing and do not properly store fish in ice or under 40°F, histamine control will be difficult.

FISHERMEN must do the right thing. Know what causes and prevents quality degradation, spoilage and histamine formation. Catching fish is only part of the job. Delivering a well-handled, top quality and safe product is the key to getting paid for all the hard work. Recreational and subsistence fishermen should also handle their fish carefully to preserve quality and make sure no one gets sick, including friends and family. Fish should be iced without delay, using enough ice to chill the fish quickly to below 40°F and then to near 32°F while stored in ice during the rest of the trip. Only new clean ice should be used on the fish. Sanitation is also important and the fish hold, brine tanks and fish boxes should be cleaned and sanitized between trips to keep the bacterial load to a minimum and to extend the shelf life and quality of the catch.

PROCESSORS must do the right thing. Know what causes and prevents quality degradation, spoilage and histamine formation. Proper handling and cold storage is the key to selling and getting paid for the processed seafood. Make sure fishermen ice the fish on the boat, then check the fish temperature to be sure the fish was well iced (less than 40°F), check carefully for signs of spoilage (appearance and odors) and then keep fish clean and cold (less than 40°F).

RETAILERS AND RESTAURANTS must do the right thing. Know what causes and prevents quality degradation, spoilage and histamine formation. Proper handling and cold storage is the key to providing your satisfied customers with good quality and safe seafood. Inspect fish deliveries carefully for signs of spoilage (appearance and odors), check the fish temperature (less than 40°F), and then keep fish clean and cold.

CONSUMERS must do the right thing. Learn what to expect of good quality fish and what odors and tastes indicate spoilage. If odd smells or tastes are detected, do not accept, buy or eat the fish. Learn about safe seafood handling. When buying fish, be prepared with a cooler and ice to keep the seafood cold while shopping and during the drive home, especially in warm weather. Seafood is highly perishable and should be treated with care, especially histamine-forming fish.



Marine Biotoxins: Ciguatera Fish Poisoning

What is ciguatera fish poisoning?

Ciguatera fish poisoning occurs when tropical reef fish containing *ciguatoxin* are consumed. Ciguatoxin is actually a complex of related marine biotoxins that have powerful neurotoxic effects. Ciguatoxin is formed by *Gambierodiscus toxicus*, and possibly other related single cell organisms known as dinoflagellates that adhere to marine algae and produce the toxin. Fish that eat the algae (herbivores) inadvertently ingest and accumulate the toxin. Fish that eat other reef fish (carnivores) further concentrate the toxin. This process is known as *bioaccumulation*. Fish do not appear to be affected by ciguatoxin, but people who eat fish containing ciguatoxin can suffer greatly.

Is ciguatera fish poisoning a problem in Hawaii?

Ciguatera is one of the most common seafood-borne illnesses in the US with the majority of the cases occurring in states and US associated regions that contain coral reef fisheries. These include Hawaii, Florida, Guam, American Samoa, Puerto Rico and US Virgin Islands. The people at greatest risk of ciguatera poisoning in Hawaii are recreational and subsistence fishermen that catch and eat susceptible reef fish.

Ciguatera cases are reported to the Hawaii Department of Health at about the same rate as histamine poisoning cases. A 5-year summary of ciguatera cases reported to the Hawaii Department of Health indicates that between 1999 and 2003 there was an average of 53 cases (illnesses) per year. By comparison, during this same period there were just over 800 cases of *campylobacteriosis* per year, mostly associated with eating contaminated chicken. The risk of ciguatera fish poisoning in Hawaii is about 4 cases per 100,000 people per year compared with the risk of *campylobacteriosis* of about 67 cases per 100,000 people per year.

What fish cause ciguatera fish poisoning in Hawaii?

There is a long list of reef fish that have been implicated in cases of ciguatera in Hawaii over the years. The ten most common species implicated in cases reported in Hawaii between 1999 and 2003 are presented on the following page.

What are the symptoms of ciguatera fish poisoning?

The onset of symptoms may occur within 10 minutes to 12 hours after exposure and symptoms can last from days to months.

Some or all of the following symptoms may occur:

- CHILLS
- ITCHING
- DIZZINESS
- SWEATING
- HEADACHE
- METALLIC TASTE IN MOUTH
- NAUSEA
- VOMITING
- DIARRHEA
- GENERALIZED WEAKNESS
- DECREASED SENSATION TO PAIN OR TOUCH
- TINGLING OR BURNING SENSATION IN AROUND MOUTH, HANDS AND LEGS
- PAINFUL MUSCLES
- REVERSAL OF TEMPERATURE SENSATION, COLD THINGS FEEL HOT, ETC.

Top 10 fish species involved in reported cases of **ciguatera fish poisoning** in Hawaii during the 5-year period between September 1999 and 2003.

RANKING	**FISH** (Hawaiian name and common name)	**OUTBREAKS** % and (n)	**ILLNESSES** % and (n)
No. 1	***roi*** (peacock grouper)	18.5% (23)	22.5% (56)
No. 2	***kole*** (gold ring surgeonfish)	15.3% (19)	15.7% (39)
No. 3	***ulua*** (large jacks mixed spp)	9.6% (12)	7.6% (19)
No. 4	***papio*** (small jacks mixed spp)	7.3% (9)	7.2% (18)
No. 5	***seabass*** (spp uncertain)	5.6% (7)	8.0% (20)
No. 6	***palani*** (eyestripe surgeonfish)	5.6% (7)	8.0% (20)
No. 7	***uku*** (green jobfish)	5.6% (7)	4.8% (12)
No. 8	***weke*** (goatfish)	5.6% (7)	4.8% (12)
No. 9	***wahanui*** (smalltoothed jobfish)	4.0% (5)	2.8% (7)
No. 10	***uhu*** (parrotfish)	1.6% (2)	1.2% (3)
TOTAL	***All fish implicated in reported cases of ciguatera poisoning.***	100% (124)	100% (249)

William Walsh/DAR/DLNR

Roi (*Cephalopholis argus*) was implicated in 18.5% of the total number of ciguatera outbreaks and 22.5% of the ciguatera poisonings (illnesses) reported during this 5-year period. The *roi* is a type of grouper, a shallow-water reef predator.

Kole (*Ctenochaetus strigosus*) caused 15.3% of the outbreaks and 15.7% of the illnesses. The *kole* is a type of surgeonfish and is an herbivore.

Ulua (large jacks) and **papio** (small jacks) combined caused 16.9% of the outbreaks and 14.8% of the illnesses. Jacks (*Caranx* spp) are reef predators and these two categories are only differentiated by the size and age of fish within the same group of species. Larger sized predators are commonly thought to be more likely to be ciguatoxic. It is important to note that in the case of jacks (*ulua* and *papio*) and apparently with *roi*, that smaller-sized individuals are not always free of ciguatera toxin and larger individuals are not always ciguatera toxin positive.

Seabass (grouper) caused 5.6% of outbreaks and 8.0% of illnesses. "Seabass" and "grouper" are common market names for fish implicated in cases of ciguatera poisoning, but are non-specific to the species of fish. *Hapu'upu'u*, the deep-sea grouper (*Epinephelus quernus*) is listed as one of the groupers that cause ciguatera poisoning in Hawaii. The implication of *hapu'upu'u* is questionable because this fish is caught at great depths, well below 300 ft, although younger individuals may on occasion be found in much shallower water. Ciguatera toxic species in Hawaii are thought to range from the ocean surface down to about 200 ft (60 meters). Species substitution in the market occurs and may explain why this fish has been identified in cases of ciguatera poisoning in the past.

Uku (*Aprion virescens*) is another important bottomfish in Hawaii. This species has been implicated in 5.6% of the outbreaks and 4.8% of the cases of ciguatera poisoning. *Uku* are more likely to accumulate ciguatera toxin because they tend to have a shallower distribution than the other deep-slope bottomfish. The skinless fillet of this fish is similar in appearance to the higher priced *opakapaka* and *onaga* and species substitution in the market in the past may account for concerns about ciguatera in these deepwater snappers.

It is notable that during the five-year period between 1999 and 2003 that no cases of ciguatera poisoning were reported involving deepwater snappers, including *opakapaka* (*Pristipomoides filamentosus*) and *onaga* (*Etelis coruscans*). These fish are very important Hawaii market species and concerns have been raised about related species being potentially ciguatoxic. The reason that these fish are not implicated in cases of ciguatera poisoning is because these fish inhabit the deep waters between approximately 320 to 980 ft (100 and 300 meters) below the surface, well beyond the depths in which ciguatoxic fish occur.

How can fish containing high levels of ciguatera toxin be detected?

You can't smell ciguatera. Ciguatoxic fish cannot be detected by visual appearance or odors. Testing methods exist, but there are no validated, rapid methods that are suitable for commercial testing of fish lots for ciguatoxin. The FDA has not established an action level for ciguatoxin. Laboratory methods for detection of ciguatoxin in fish are used mainly for research and during disease outbreak investigations. A mouse bioassay is a generally accepted method for confirming the toxicity of fish samples.

A rapid enzyme-linked immunoassay ("stick test") for ciguatera toxin was developed in Hawaii by Dr. Y. Hokama of the University of Hawaii. This technology is now available to the public for the detection of ciguatoxin in reef fish (Cigua-Check® Fish Poisoning Test Kit by Toxi-Tec, Inc., Honolulu, Hawaii). It is useful especially for recreational fishermen, to screen individual fish prior to consumption.

There are other marine biotoxins generated in reef areas in Hawaii that can accumulate in reef fish and cause symptoms that can resemble ciguatera. These include *palytoxin*, *maitotoxin* and *scaritoxin*. These toxins appear to be related to ciguatoxin but may be generated by different organisms. Palytoxin and maitotoxin are the most powerful marine biotoxins and are toxic at much lower concentrations than ciguatoxin. Palytoxin was found to be the cause of an extremely rare and unfortunate seafood-borne fatality from the consumption of just three Marquesan sardines (*Sardinella marquesensis*) in Hawaii in 1978. These fish and the Goldspot sardine (*Herklotsichthys quadrimaculatus*) are introduced species, they are rarely eaten in Hawaii and consumers should be warned about the unpredictable potential palytoxin hazard.

How can ciguatera fish poisoning be prevented?

Know where your fish is coming from. Prevention essentially relies on consumer and industry education, varying levels of species avoidance and knowledge of reef areas that have produced ciguatoxic fish. Representative sampling and testing is of questionable value because some fish from a group of fish caught on the same reef may be safe to eat while others are not. Ciguatera problems may also be seasonal. These factors together with differences in individual susceptibility to the toxin make prevention of ciguatera difficult. People who are more frequent consumers of reef fish may have a much lower threshold for a ciguatoxic dose, while first-time consumers may tolerate higher initial doses of the toxin without symptoms. In commercial settings, most Hawaii seafood retailers and wholesalers refrain from selling potentially ciguatoxic fish species. Companies that supply the reef fish market niche must carefully select fish from reliable fishermen, make sure fishing is not in areas known to be producing ciguatera poisoning and keep abreast of state health advisories.

The majority of cases of ciguatera fish poisoning reported in Hawaii have come from recreational fishing, but some cases do occur from commercial sources of fish. Fishermen should be aware of the potential for ciguatera in Hawaii's reef fish and which species are frequently implicated. The risk of ciguatera toxin in reef fish is associated with not only the species, but conditions in individual reef areas. Therefore, it is important for fishermen to pay close attention to state health advisories regarding ciguatera and local knowledge of any cases that might have occurred in a particular reef area.

Marine Biotoxins:
Hallucinogenic Reef Fish Poisoning

What is hallucinogenic reef fish poisoning?

Hallucinogenic reef fish poisoning occurs when people eat certain types of reef fish containing the toxin. This toxin is unknown chemically and its origin remains undetermined.

What are the symptoms of hallucinogenic reef fish poisoning?

Symptoms are limited to severe nightmares and hallucinations.

Is hallucinogenic reef fish poisoning a problem in Hawaii?

Yes, but cases are very rare. A 5-year summary of cases reported to the Hawaii Department of Health between 1998 and 2002 indicates an average of 2 cases (illnesses) per year for a resident population of roughly 1.2 million people. The risk is less than 1 case (0.33 cases) per 100,000 people per year. This rate estimate is for the general population and the people at greatest risk are consumers of reef fish, especially the species implicated in cases of hallucinogenic fish poisoning.

What fish cause hallucinogenic reef fish poisoning in Hawaii?

A type of goatfish known as the nightmare *weke* (*Upeneus arge*), other types of *weke* (*Mulloidichthyes* spp) and the striped mullet (*Mugil cephalus*) have been implicated in cases of hallucinogenic fish poisoning.

How can fish containing high levels of hallucinogenic reef fish toxin be detected?

No testing methods exist. The nightmare *weke* is easily identified by the sharp black and white striped color pattern of the tail fin. These fish should be avoided. Mullet and *weke*, however are food fish in Hawaii.

How can hallucinogenic reef fish poisoning be prevented?

Prevention relies on consumer and industry education and species avoidance. Nightmare *weke* should not be eaten. For mullet and other species of *weke*, local knowledge and avoidance of reef areas that have caused hallucinogenic fish poisoning are the primary means of prevention.

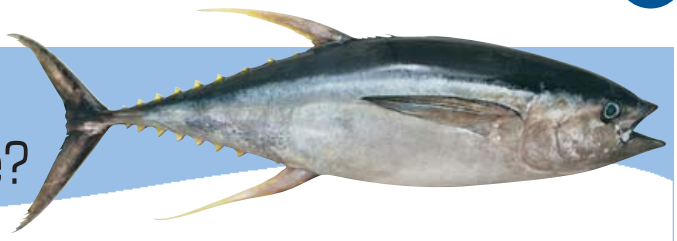
William Walsh/DAR/DLNR

Mercury

What is mercury poisoning?

Mercury poisoning can occur from exposure to mercury, a toxic metal. The most important toxic form of mercury in seafood is *methylmercury*. Mercury poisoning from eating fish is also known as *Minamata Disease*. This is in reference to the severe poisoning of people that ate seafood grossly contaminated with methylmercury originating from industrial pollution in Minamata Bay Japan in the 1950's. Another serious mercury poisoning event occurred in Iraq during the 1970's when mercury treated grain seeds meant to be planted were instead used to make bread and consumed directly. Much of what is known about the toxic effects of mercury is from studies of these two tragic accidental poisoning events. However, extrapolating the potential for methylmercury poisoning to open ocean fish like tuna, swordfish, and marlins remains highly controversial.

What about *ahi*, is it safe?



Yes. There are no reported cases of mercury poisoning associated with Hawaii's open ocean fish, including tuna, marlin and swordfish.

No adverse health effects were found in children born to mothers that ate 12 meals of fish (like Hawaii's fish) in the Seychelle Islands.

The known health benefits of fish in the diet appear to outweigh any potential adverse health effects of low-level mercury exposure from a diet of open ocean fish.

Is mercury poisoning a problem in Hawaii?

No single case of mercury poisoning from the consumption of Hawaii fish has been reported. Also, no cases have ever been reported that specifically implicated open ocean fish like swordfish, tuna or marlin anywhere in the world.

What fish cause mercury poisoning in Hawaii?

No Hawaii fish species are known to have caused mercury poisoning.

Where does mercury come from?

Mercury in the environment comes from two basic sources, those that are natural and those that result from human activity (pollution). The ocean is a natural mercury sink. Volcanic activity and the leaching of soil by rainfall deposit mercury into the ocean. Mercury vapors emitted into the atmosphere from coal fired power plants and incinerators, and mercury contained in industrial effluents are significant sources of manmade mercury pollution. Mercury enters the water from industrial discharge and from contaminated rain.

Mercury is transformed into the toxic form, methylmercury through the action of bacteria in the sediments. This is especially important in small, shallow bodies of freshwater exposed to significant amounts of mercury pollution. Fish from polluted water can quickly accumulate high levels of methylmercury from the aquatic life they feed on. The mercury cycle in the deep ocean is quite different from the relatively small volume, inland and nearshore waters.

What are the symptoms of mercury poisoning?

Mercury acts as a powerful neurotoxin. At high concentrations it kills nerve cells and can cause problems with vision, coordination, speech and in some cases death. Mercury at high doses during pregnancy can cause blindness, cerebral palsy, delayed development and other birth defects in children. By contrast, the effects of low-level mercury exposure from open ocean fish in the diet continue to be debated by scientists.

The following symptoms are described from cases of mercury poisoning from severely contaminated nearshore fish from polluted water and the accidental poisoning involving mercury treated grain, and not from open ocean fish like tuna, swordfish or marlin.

Symptoms of mercury poisoning at high concentrations may include:

- STUMBLING GAIT
- DIFFICULTY SPEAKING
- TUNNEL VISION
- IMPAIRED HEARING
- MUSCLE WEAKNESS
- FATIGUE
- HEADACHE
- IRRITABILITY
- TREMORS
- COMA
- DEATH

The potential for toxic effects of mercury on the developing fetus and young children is a major concern.

Studies of children born to Iraqi women in the early 1970's exposed to mercury from the consumption of mercury treated wheat seeds have drawn attention to the vulnerability of the fetus to mercury exposure.

Additional studies have been done on populations that eat fish to determine if lower levels of mercury exposure can also impact the fetus. One study followed women and their children who were exposed to mercury through the diet of fish in the Faroe Islands. This study found a statistical correlation between umbilical cord blood mercury and diminished scores on standardized tests of children. However, the "fish" source of methylmercury was primarily pilot whale, a marine mammal. These women periodically feasted on pilot whale meat and exposed their children to elevated levels of methylmercury as well as other toxic substances including cadmium and PCBs.

Pilot whales are not fish.

A more appropriate study of health effects from fish consumption involved a population of mothers in the Seychelle Islands that ate an average of 12 meals of fish per week. The general population in the Seychelles has one of the highest fish consumption rates in the world estimated at between 175 and 220 lbs per person per year. The Seychelle Island diet of fish includes yellowfin tuna, skipjack, bonito, wahoo, jacks and other fish similar to those found in Hawaii. Whale meat is not part of the diet. No adverse health effects from the high fish consumption levels and low-level mercury exposure were found in children during the 9 year study. It is quite possible that the known health benefits of eating fish outweighed the possible adverse effects of the low levels of mercury contained in the fish.

Why was the situation in Minamata Japan different?

The nearshore fish that caused mercury poisoning in Minamata Japan in the 1950's were contaminated with extremely high levels of mercury from industrial pollution. Average mercury concentrations in Minamata Bay seafood ranged from 9 to 24 ppm (parts per million), with some fish reaching 40 ppm. These values far exceed the US government methylmercury limit of 1 ppm and the levels found in Hawaii fish. In addition, the fish consumption rate in Japan (over 160 lbs per year) is estimated to be 10 times that of the average US consumer (16 lbs per year).

What about open ocean fish?

Open ocean fish like sharks, swordfish, marlins and tunas accumulate methylmercury from their diet. The larger, older individuals of these species have greater potential to build up higher levels of methylmercury. The source of the mercury in Hawaii's open ocean fish appears to be from natural sources and not directly from atmospheric mercury pollution from manmade sources. A Princeton University study found that between 1971 and 1998, while emissions from industry were estimated to have increased atmospheric mercury pollution by 10 to 25%, there was no change in the low levels of methylmercury (average 0.22 ppm in 1971 and 0.21 ppm in 1998) in the yellowfin tuna caught in Hawaii during the same period.

This study provides evidence that the mercury found in yellowfin tuna caught in the middle of the Pacific Ocean near Hawaii is not directly from atmospheric pollution, but more likely through the natural marine food web originating from deep ocean sediments. The mercury cycle in the ocean is distinct from shallow nearshore areas, lakes and rivers that are more rapidly and directly affected by mercury pollution because of the proximity to point sources and the much smaller volume and shallow nature of the water systems in which contaminated fish are found.

By contrast, the mercury cycle in the deep ocean may be a much longer process involving methylation of mercury in the deep ocean sediments followed by a prolonged period of time for mercury to be accumulated through the food web. The mercury accumulated by open ocean fish far from significant sources of mercury pollution is more likely to reflect naturally occurring environmental background levels of methylmercury.

Should the Iraqi mercury poisoning incident be used to derive recommendations on fish consumption?

This was a case of severe mercury poisoning and not a situation of low level mercury exposure. The people were poisoned by eating mercury contaminated grain and not fish. The data from the Iraqi incident that are being used to extrapolate the estimate of tolerable mercury exposure are very limited in numbers. The University of Rochester scientists that conducted the Iraqi studies have cautioned about the limitations of using the Iraqi poisoning event to determine the effects of mercury exposure from fish. As a result, they conducted the Seychelle Island study to focus on a more appropriate sentinel fish eating population and the children exposed to low mercury levels from ocean fish in their mother's diet during pregnancy.

How can fish containing high levels of mercury be detected?

Fish containing mercury do not have a characteristic appearance or odor.

Laboratory testing methods exist and are used in some settings to screen fish for mercury content. The US FDA has established a 1 ppm defect action limit for methylmercury in fish.

How can mercury poisoning be prevented?

There is no evidence that species of fish from Hawaii fisheries have ever caused mercury poisoning, or ever will at the concentrations that have been reported. The evidence is weak that the low levels of mercury contained in Hawaii open ocean fish pose a health risk.

Protecting the developing fetus and young children from mercury exposure from fish can be done by limiting mothers' and infants' consumption of contaminated fish, especially those caught in recreational inland fisheries where mercury may build up to unnaturally high levels. There are many watersheds and lakes across the country contaminated with mercury at levels that have prompted health advisories for specific bodies of water.

Is there consensus of what constitutes a safe daily intake of mercury?

No. Several organizations that issue health advisories and have conducted studies on methylmercury have drawn quite different conclusions about safe daily intake of mercury. Some of the differences result from the targeted population of consumers and the type of seafood that led to methylmercury exposure in studies of populations at risk. For example, in the Seychelle Islands study population, women ate a variety of nearshore and open ocean fish and are thought be more representative of fish eating populations. The joint EPA-FDA advisory is stricter because of the reliance on the results of studies of the Faroe Islands population that was exposed to methylmercury from periodic feasts on pilot whale, a marine mammal.

Guidance for pregnant women for safe fish (ex. yellowfin tuna steaks) **consumption aimed at reducing prenatal mercury exposure of their children.**

AGENCY OR SOURCE	GUIDANCE*
EPA-FDA Joint Advisory 2004	1 meal/week
World Health Organization (WHO)	2.3 meals/week
Agency for Toxic Substance and Disease Registry (ATSDR)	3 meals/week
Seychelle Island Child Development Study (Univ. Rochester)	12 meals/week**

** A "meal" is a 6 oz. portion of fish. **Average fish consumption without any adverse health effects.*

There are continuing efforts to weigh and compare the known health benefits of fish in the diet with the uncertain toxic effects of low levels of mercury intake associated with eating fish. It is clear that at much higher consumption rates of fish with much greater mercury concentrations (from polluted water) that poisoning can occur. However, it does not appear to be a significant risk when considering the naturally occurring background levels of mercury found in open ocean fish like tuna. A quantitative risk assessment that considers the risk and the benefits of eating fish is needed. Another mother and child cohort study is underway in the Seychelle Islands, thought to be the best sentinel population to study the effects of mercury from a true marine fish diet.

The World Health Organization (WHO) provides guidance of 5 ppm hair mercury concentration as the safe upper limit of mercury exposure. This value has a 10-fold safety factor built in. It is based on the finding of health effects at a minimum of 50 ppm hair mercury in studies of patients exposed to high levels of mercury contaminated food. University of Rochester scientists, studying the Seychelle Islanders found the average hair mercury concentration in young children was 7 ppm about 10 times higher than the US average. No harmful effects in children (the most sensitive population) were detected, even at 15 ppm methylmercury in hair, nearly 20 times the US average. While further studies are being completed, women should follow their doctor's advice.

Safe raw fish consumption

The consumption of raw fish is a traditional practice in Hawaiian, Pacific Island and Japanese cultures. Today, Hawaii consumers enjoy a variety of fresh, high quality fish that are eaten as *poke*, *sashimi*, *sushi* and a variety of other raw fish preparations. Seared tuna (cooked only on the surface and raw in the center) is a form of raw fish preparation with roots in the traditional Japanese preparation called *tataki*. A popular *tataki* preparation is made using raw *aku* (*katsuo* or skipjack).

The most popular fish species eaten raw in Hawaii include bigeye tuna, yellowfin tuna, skipjack, albacore tuna, blue marlin, striped marlin, *opakapaka* and *onaga*. These fish are **safe to eat raw.**

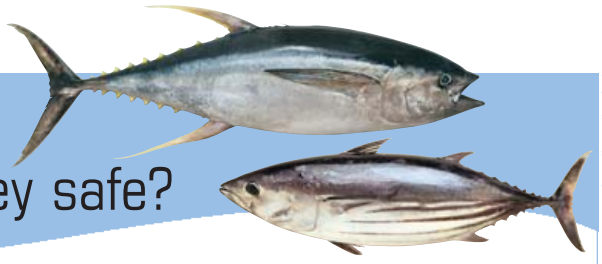
Parasites

All animals including fish can have parasites, but only a few species of important food fish contain parasites that are potentially harmful to people. Most parasites seen inside some types of fish fillets are an aesthetic quality problem and not a health risk. Unsightly worms can destroy the value of fish fillets, but are only of public health importance if they are alive (viable), are infective (transmissible) to humans and if the fish are eaten raw. For example, the small white worms found in the muscle near the belly of *aku* (skipjack) are larvae of a species of shark tapeworm. These are not infective to people, but it is common practice to avoid eating the parasites for aesthetic reasons.

There are some fish that should not be eaten raw. Determining the fish species that are unsafe to eat raw requires an understanding of the biology of the parasite. Parasite-host fish relationships are highly-evolved and highly-specific. **As a general rule, freshwater fish should not be eaten raw** because of the greater potential for parasites harmful to people. Generally, it is the parasites that naturally occur in marine and land mammals and birds that have the greatest potential for parasites harmful to people. Certain marine fish should not be eaten raw because of the risk of parasite infections, while other species are free of parasites of public health importance and are safe to eat raw.

Most parasite life cycles involve multiple hosts coinciding with different life stages of the parasite. Only some of the stages are infective to humans. When people encounter infective parasite larvae in raw fish, they may become accidental hosts and suffer from parasitic infections. Knowing which fish are safe and which are unsafe to eat raw is the key to preventing fish-borne parasitic infections.

Fully frozen and fully cooked fish of any species are free of harmful parasites, because the two temperature extremes kill the parasite larvae, making them harmless. Freezing fish to kill parasite larvae requires holding fish at -4°F for at least 7 days or at -31°F for at least 15 hours. Cooking should be to an internal temperature of 140°F or greater (until it loses its translucent "raw" appearance). The trend towards undercooking fish is safe only if the fish species is free of harmful parasites or the fish was adequately frozen prior to cooking.



What about *ahi* and *aku*, are they safe?

YES. The fish commonly eaten raw as *sashimi* or *poke* in Hawaii are safe to eat.

There have been no reported cases of parasite infections from *ahi* (bigeye, yellowfin or albacore tuna) or *aku* (skipjack) in Hawaii.

There are no reported cases of parasite infections from other fish eaten as *sashimi* or *poke* including *kajiki* (blue marlin), *nairagi* (striped marlin), *onaga* (long tailed red snapper) or *opakapaka* (pink snapper).

State of Hawaii, Hawaii Seafood Promotions Committee

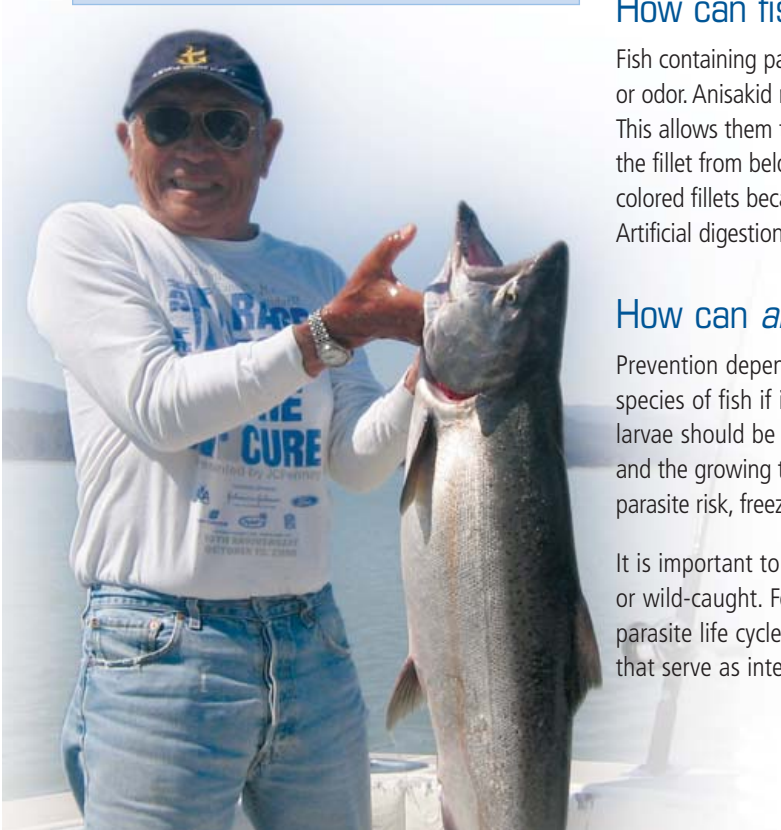
Parasites: Herring and cod roundworms

What are herring and cod roundworm infections?

Infection by larvae of the roundworms, *Anisakis simplex* (herring worms) or *Pseudoterranova decipiens* (cod worms) is known as *anisakiasis*.

What are the symptoms of herring and cod roundworm infections?

In many cases, the patient feels a tingling sensation in the back of the throat and coughs up a worm. In more severe cases, the patient feels abdominal discomfort, which has led to the misdiagnosis of appendicitis.



Are herring and cod worm infections a problem in Hawaii?

Cases are extremely rare. In the late 1980's, it was estimated that a little more than 50 cases had ever been reported in the US. In Hawaii, where residents consume more fish per capita than other states with much of that fish eaten raw, there does not appear to be a problem with parasites from fish consumption. The only cases of anisakiasis in Hawaii in which the type of fish was confirmed involved wild Pacific salmon from Alaska or the Pacific Northwest and imported squid.

What fish can cause herring and cod roundworm infections when eaten raw?

Important species to Hawaii consumers include,

- Wild Pacific salmon (king, silver, sockeye, pink and chum)
- Pacific rockfish (*Sebastes* spp)
- Squid (all species)

Of particular concern is the use of salted salmon in the Hawaiian dish called *lomilomi* salmon. Salt does not kill the worm larvae. If the fish are not properly frozen to kill parasite larvae, consumers may become infected. The popularity of sashimi and cold smoked salmon made from farm-raised Atlantic and Pacific salmon may also be a factor leading to greater risk, if consumers do not make the distinction between farm-raised and wild-caught salmon. **Cultured salmon is known to be free of harmful parasites and can be eaten raw.** Wild-caught salmon should never be eaten raw unless it is first frozen to kill the parasite larvae.

How can fish with herring and cod worm larvae be detected?

Fish containing parasites of public health concern do not have a characteristic outer appearance or odor. Anisakid roundworm larvae can be seen with the un-aided eye in pale colored fish fillets. This allows them to be detected using a technique called *candling* in which a light is passed through the fillet from below, illuminating the parasites inside the muscle. Candling is not effective in dark colored fillets because larval parasites are more easily concealed than in less pigmented fillets. Artificial digestion and screening methods can be used to survey for anisakis-type roundworm larvae.

How can *anisakiasis* be prevented?

Prevention depends on consumer and industry education, species avoidance, and freezing certain species of fish if intended to be eaten raw or undercooked. Fish known to carry harmful parasite larvae should be completely cooked if not previously frozen. The tendency to cook seafood lightly and the growing trend to undercook fish may present new parasite concerns. When in doubt about parasite risk, freeze the fish before eating it raw or undercooked.

It is important to know the fish species and the associated risk and whether it was farm-raised or wild-caught. For example, cultured Atlantic salmon can be eaten fresh and raw because the parasite life cycle is broken by the use of artificial feeds in place of natural forage prey species that serve as intermediate hosts for parasites.

Parasites: Broad fish tapeworm

What is broad fish tapeworm infection?

Fish-borne infections by tapeworms of the genus *Diphyllobothrium* are known as *diphyllobothriasis*. The broad fish tapeworm, *Diphyllobothrium latum* is the largest human tapeworm (reaching 30 ft in length) and most common species of the 8 *Diphyllobothrium* species that can parasitize people. The main (definitive) host is man, but other mammals can also serve as hosts including dogs, cats and swine. Adult tapeworms reside in the small intestine and shed eggs through the feces. Several larval stages occur in the complex life cycle, leading to the infective stage that is found embedded in the muscle of some types of freshwater and *anadromous* fish like salmon that hatch in freshwater, grow to adults in seawater and return to freshwater to spawn. People become infected by ingesting the larval tapeworms contained inside raw or undercooked fish.

Is broad fish tapeworm infection a problem in Hawaii?

Broad fish tapeworm infection are rare and not associated with fish from Hawaii.

What fish cause broad fish tapeworm infection when eaten raw?

Wild-caught Pacific salmon of the genus *Onchorhynchus* are the most important species of Pacific Northwest fish for Hawaii consumers. Other species including wild-caught trout, pike and perch are also important, but these fish are not normally eaten raw in Hawaii and are not generally available.

Pacific salmon are important in Hawaii because the popularity of *lomilomi* salmon made with salted wild-caught salmon. Pacific salmon can be infected with broad fish tapeworm larvae in addition to the larvae of herring worms that cause *anisakiasis*.

How can fish with broad fish tapeworm larvae be detected?

Infected fish cannot be identified by outward appearance or odors. Knowledge of the species and source of fish that have the potential to harbor broad fish tapeworm larvae is the best and most practical approach. It is not common to inspect fish for the presence of broad fish tapeworm larvae. Examination of thin slices of fish muscle under a microscope can be done to detect parasite larvae. Artificial digestion methods can also be used to screen for parasite larvae.

How can broad fish tapeworm infection be prevented?

Prevention relies on consumer and industry education and species avoidance. **Wild-caught and fresh (never frozen) Pacific salmon and other susceptible fish species should never be eaten raw or undercooked.** If fish that are known to be potential hosts of broad fish tapeworm larvae are to be eaten raw, they should be properly frozen first to less than -4°F for at least 7 days or to below -31°F for at least 15 hours.

What are the symptoms of broad fish tapeworm infection?

Infection can be prolonged and without symptoms other than weight loss, because the parasite is well adapted to man. Patients may first be alerted to the presence of the broad fish tapeworm when infective pieces of the tapeworm are seen in the stool.

Some clinical symptoms include:

- ABDOMINAL DISCOMFORT AND DISTENTION
- INTERMITTENT ABDOMINAL CRAMPING
- FLATULENCE
- DIARRHEA
- VOMITING
- WEIGHT LOSS
- ANEMIA

Parasites: Salmon fluke infection

What is salmon fluke infection?

Salmon disease in dogs is caused by the parasitic fluke (trematode), *Nanophyetus salmonicola* that can be present in some freshwater fish like trout (*Salmo* spp) and *anadromous* fish like Pacific salmon (*Onchorhynchus* spp). This organism carries *Neorickettsia helminthoeca*, the *rickettsial* agent (a type of microbial pathogen) that causes salmon "poisoning" in dogs. Dogs should never be fed raw wild salmon for this reason. People are also vulnerable to accidental infection with the salmon fluke (*nanophyetiasis*), but do not appear to be susceptible to the *rickettsial* pathogen.

What are the symptoms of salmon fluke infection?

- NAUSEA
- ABDOMINAL DISCOMFORT
- DIARRHEA
- FATIGUE
- WEIGHT LOSS
- SOME CASES ARE ASYMPTOMATIC

Is salmon fluke infection a problem in Hawaii?

This disease is extremely rare in the US. Twenty cases of infection in people have been reported in Oregon. Cases in the US have involved raw, undercooked and inadequately processed smoked salmon and steelhead. The potential for Hawaii consumers to become infected is mainly related to the consumption of raw, fresh (never frozen) wild-caught Pacific salmon.

What fish cause salmon fluke infection when eaten raw?

Consumers should be aware that there is the potential for parasitic infection if wild-caught Pacific salmon or trout are eaten raw without first freezing the fish to kill the parasite larvae.

How can fish with salmon fluke larvae be detected?

No detection methods have been developed for the larvae of this fluke in fish. Artificial digestion and screening methods are probably useful in detecting larvae.

How can salmon fluke infection be prevented?

Prevention relies on consumer and industry education and species avoidance. Wild-caught, fresh (never frozen) Pacific salmon or trout should never be eaten raw or undercooked.

Parasites: Angiostrongyliasis

What is angiostrongyliasis?

Angiostrongyliasis is a rare accidental parasitic infection of people by larval rat lungworms, a type of roundworm. *Angiostronglysus cantonens*is is the species known to be present in Hawaii. The larval worms invade the central nervous system in man and cause *eosinophilic meningitis* and *meningoencephalitis*. The definitive hosts are rodents, the intermediate hosts are mollusks (snails and slugs) and crustaceans (prawns), and man is an accidental host.

What are the symptoms of angiostrongyliasis?

The body reacts with some or all of the following symptoms:

- SUDDEN ONSET OF SYMPTOMS
- SEVERE HEADACHES
- NAUSEA
- VOMITING
- NECK STIFFNESS
- SEIZURES
- MODERATE BUT PROLONGED FEVER
- ABDOMINAL PAIN
- ANOREXIA

Is *angiostrongyliasis* a problem in Hawaii?

Cases in Hawaii are extremely rare. However, *eosinophilic meningitis* caused by *A. cantonensis* infection has recently become a reportable disease in Hawaii. Physicians are now required to report cases to the Hawaii Department of Health because of several recent cases and the possible increase in the prevalence of this disease in Hawaii.

What fish cause *angiostrongyliasis* in Hawaii?

The most likely route of this infection is through the consumption of inadequately washed fresh vegetables and fruits, either containing infected slugs or snails, or contaminated with their slime that may also contain infective larvae. Freshwater snails should not be eaten raw because of the parasite potential. African snails, *Anchatina fulica* are known carry *A. cantonensis* larvae. Accidental infections have occurred in American Samoa where raw and undercooked African snails were consumed. Another case was reported in Australia in which the patient confessed to eating live slugs on a dare and suffered greatly. Susceptible aquatic foods in Hawaii include freshwater prawn *Macrobrachium* spp which are eaten raw in some areas of the Pacific Islands (Tahiti) and in Southeast Asia. **Eating raw freshwater prawns is not a common practice in Hawaii.**

How can prawns with *Angiostronglysus cantonensis* larvae be detected?

Uncertain, but microscopic examination of prawn muscle should be able to detect encysted larvae.

How can *angiostrongyliasis* be prevented?

Prevention relies on consumer and industry education and species avoidance. **Freshwater prawns and snails should never be eaten raw or undercooked.** Also thoroughly wash and carefully inspect fresh fruits and vegetables, especially leafy greens, for slugs, snails or their slime. Never eat slugs or snails raw.

Parasites: Intestinal Heterophysiasis

What is intestinal *heterophysiasis*?

Intestinal infection with the larvae of the trematode (fluke), *Stellantchasmus falcatus* that can be present in mullet (*Mugil cephalus*).

What are the symptoms of intestinal heterophysiasis?

The body reacts with some or all of the following symptoms:

MOST CASES OF HUMAN INFECTION ARE BENIGN AND ASYMPTOMATIC

SEVERE CHRONIC DIARRHEA

WEIGHT LOSS

IRRITATION OF THE INTESTINE

COLIC

NAUSEA

Is intestinal *heterophysiasis* a problem in Hawaii?

This disease is extremely rare but a few cases have been reported in the past. Mullet is not commonly eaten raw in Hawaii but may account for the rare occurrence of this infection. Consumers should be aware that the potential for parasitic infection is high if mullet are eaten raw because there is a high rate of infection of mullet by *S. falcatus* larvae in Hawaii.

What fish cause intestinal *heterophysiasis* when eaten raw?

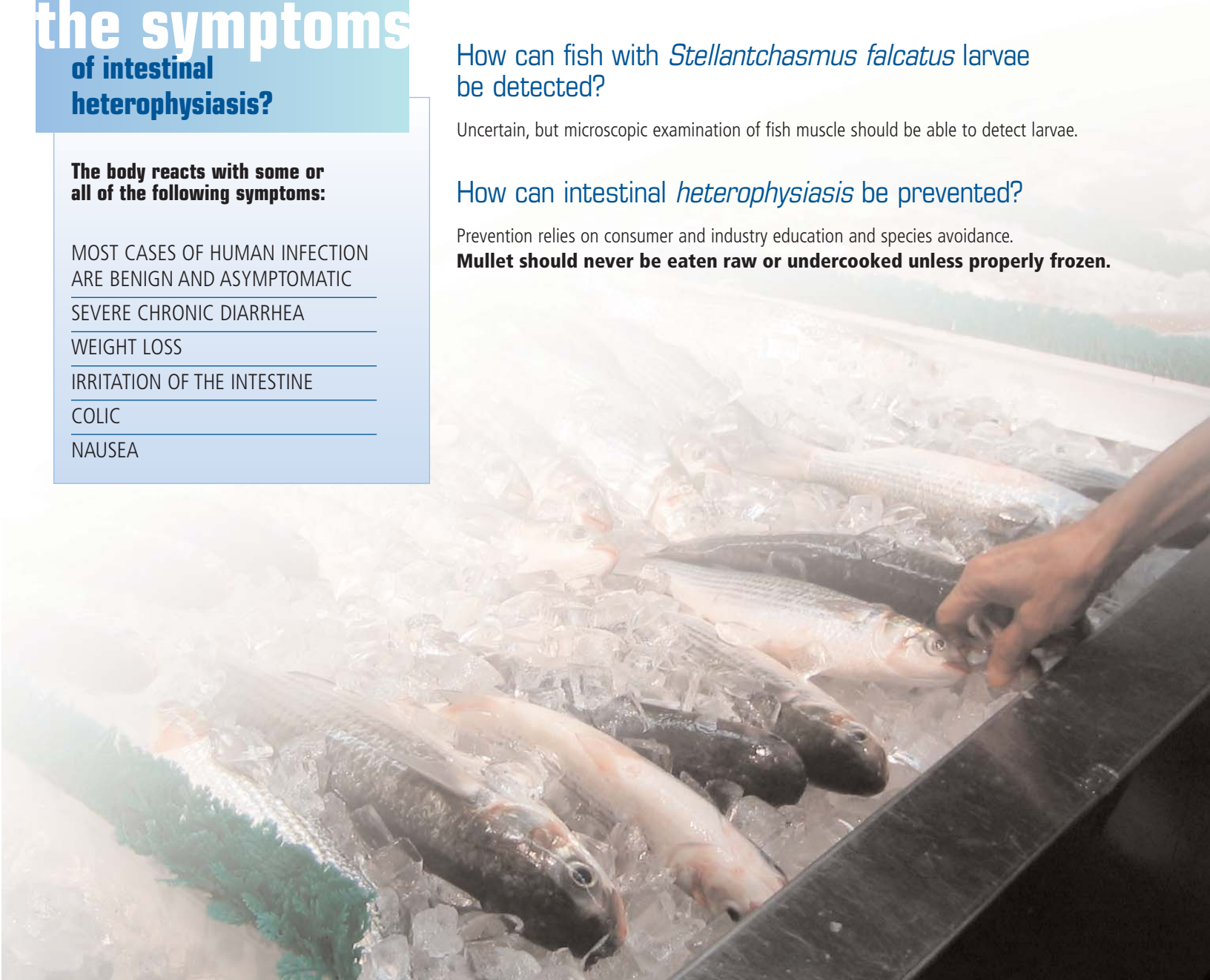
Mullet are the only marine fish of public health importance in Hawaii in the transmission of *S. falcatus* larvae to humans.

How can fish with *Stellantchasmus falcatus* larvae be detected?

Uncertain, but microscopic examination of fish muscle should be able to detect larvae.

How can intestinal *heterophysiasis* be prevented?

Prevention relies on consumer and industry education and species avoidance.
Mullet should never be eaten raw or undercooked unless properly frozen.



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