Aquaculture or fish farming is raising and harvesting fish, shellfish, and aquatic plants in fresh (catfish and trout) or salt or marine (salmon and shrimp) water. Aquaculture is an efficient way to produce protein because farmed fish require less space and feed to reach market weight than chickens, hogs, or cattle.

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Oceans cover 71 percent of the earth’s surface but produce only two percent of the world’s food. Some 92 million tons of wild fish were caught in 2022 for human consumption, while another 130 million tons of fish were farmed. The tonnage of aquaculture fish surpassed wild capture fish in 2012, and the gap continues to grow as aquaculture expands while the wild catch stabilizes. Some wild-caught fish such as anchovies are used to feed farmed fish.

Aquaculture turned salmon and shrimp from luxuries into everyday foods and raised the value of the world’s farmed and caught seafood to $90 billion a year. Proponents of fish farming believe that a blue revolution could benefit the climate by substituting fish for red meat consumption of shrimp and salmon offset declining tuna consumption.

The 15 percent of US salmon that is caught are mostly Pacific salmon, including king, coho, sockeye, pink and chum. Wild salmon is leaner and not as tasty as farmed salmon to many Americans. Most wild-caught Alaska salmon begin in fish hatcheries, and mature salmon are caught as they return to the place where they were born. Alaska salmon is sometimes called salmon ranching, analogous to farmers sending their cattle out to graze. Biologists disagree on whether and how releasing millions of hatchery fish affect the wild salmon that spawn in streams.

Salmon

Norway produces half of the world’s farmed Atlantic salmon, followed by a quarter in Chile and 3 to 7 percent each in the UK (Scotland), Canada, and the Faroe Islands. Norway exports fish, is almost self-sufficient in animal products, and imports many crops, including fruits and vegetables.

Norway is likely to export 1.7 million tons of salmon (laks) in 2024,
55 percent of the world’s 3 million tons (another 600,000 tons of wild salmon are caught). Salmon is the world’s third most consumed fish, after tuna and cod, and is second only to shrimp in seafood exports by value.

Norway salmon farms received NOK 93 ($9.30) per kg of fresh whole salmon in 2023 and NOK 148 per kg for fresh salmon filets ($4.20 and $6.70 per pound). Salmon can be superior, standard, or production. The leading destination for Norwegian whole salmon is Poland, where much of Norway’s superior salmon is processed.

Production salmon must be processed in Norway to preserve jobs and the country’s reputation; production salmon is often smoked. A third of Norway’s salmon is production quality during the winter months, prompting salmon farms to demand a change in policy so that production salmon can be sent to lower-wage areas for processing.

Salmon farming began in the 1970s as a way for coastal farmers and fishers to supplement their incomes, and has evolved into an industry dominated by a handful of multinational firms. The 10 largest Norwegian salmon farms account for three-fourths of Norway’s farmed salmon.

Salmon are anadromous, meaning they live in both fresh and salt water. Eggs hatch into baby salmon called alevin that eat their yolk sacs before becoming fry that eat the food provided to them in fresh water tanks. After a year in fresh water, the salmon are 0.5 kg smolts ready to be transferred to salt water sea cages or pens, where they remain for 18 to 24 months to become adult salmon weighing 4 to 6 kg.

Wild salmon return to the freshwater where they were born to spawn and...
die, leaping over obstacles up to 10 feet high to move upstream. Wild salmon do not eat after they return to freshwater, making the optimal time to catch them the transition from salt to fresh water. Until Alaska became a state in 1959, Seattle-based salmon canners strung nets over rivers in order to capture returning salmon, and one reason Alaska wanted statehood was to outlaw salmon traps over river mouths.

The sea cages for farmed Atlantic salmon are typically 100 feet in diameter, 100 feet deep, and contain 50,000 to 100,000 fish. Nets on top block birds, and nets on the bottom prevent escapes. Floating wharves allow access for feeding and harvesting, and boundary nets keep predators such as seals away.

Feed accounts for half of salmon production costs. Salmon are carnivorous in the wild, eating krill and shrimp that include astaxanthin, which turns their flesh red (astaxanthin explains why flamingos are red or pink). Farmed fish are fed pellets that include both plant material and fish meal, with astaxanthin added. Farmed fish require about 1.2 pounds of feed to produce a pound of biomass, making them among the most efficient converters of feed into protein (more feed is required if the fish food includes a high percentage of plant material).

Wet-well ships move salmon from sea cages to processing plants, where the fish are stunned with electric shocks and their gills slit for bleeding. Fish can be processed near the farm where they were raised or sent to lower-wage countries for processing into filets and other products.

Farmed salmon can get sea lice, parasitic copepods that molt and go through eight stages. Sea lice are in all of the world’s oceans and collectively comprise the largest animal biomass on earth; they are attracted to sea cages with salmon because of the concentrated host population. Sea lice live for up to eight weeks, including five weeks when they are sucking blood from salmon and sometimes killing juvenile salmon. Some farms feed their fish drugs to reduce damage from sea lice, while others add cleaner fish to the fish cages, remove the lice mechanically by brushing the fish, or put the salmon in 30°C water before they are processed.

Norway has a traffic light system to monitor disease and the status of wild salmon. Salmon farming may...
expand in green areas, cannot grow in yellow areas, and must be reduced in red areas.

**Firms**

Bergen-based Mowi (Marine Harvest until 2019) is the world’s largest salmon farmer, followed by Cermaq (owned by Mitsubishi), SalMar, Lerøy, and Cooke (Canada). These multinationals have fish farms in many countries and produce more than salmon.

Mowi says that aquaculture is “working with nature” and produces about 500,000 tons of salmon a year, 20 percent of the world’s farmed salmon. Critics allege that Mowi and other salmon farms rely on anchovies and other fish caught off the coasts of developing countries to feed salmon. Some call salmon farms floating feedlots and want to restrict or ban salmon farming.

Salmon farming is concentrated in Norway, Chile, the United Kingdom, and Canada, and global farmed salmon revenue is $20 billion a year. Mowi and other Norwegian salmon companies helped to establish Chile’s salmon farming industry, which has had several disease outbreaks and relies more on antibiotics than the other salmon-producing countries.

There are two major alternatives to sea cages in coastal ocean waters. First are open ocean salmon farms that place sea cages in areas with waves and currents to ensure that fish waste is removed. Second are land-based recirculating aquaculture systems (RAS) such as Norway’s Salmon Evolution and Homestead, FL-based Atlantic Sapphire, which aims to produce 10,000 tons of farmed salmon sold under the Bluehouse label in 2024 and over 200,000 tons by 2030. Open ocean sea cages are not yet...
proven, and land-based salmon farms are not yet profitable.

**Shrimp**

Shrimp or prawns are the most valuable farmed seafood, worth $60 billion a year globally. The average global price of shrimp is $7.50 per kg, compared with $8.50 per kg of salmon. About 60 percent of global shrimp are farmed and 40 percent are caught wild, often with fine-mesh nets that capture everything in the ocean, so that endangered species such as turtles can be killed by shrimp boats.

Most farmed shrimp, usually Litopenaeus vannamei (L. vannamei), are raised in salt water on the edges of oceans and bays. Ecuador and India are the largest shrimp exporters, each exporting about a quarter of the world’s farmed shrimp, followed by Vietnam, Indonesia, Thailand, China, and Bangladesh.

The Chicago-based Corporate Accountability Lab in spring 2024 charged that shrimp farms in Andhra Pradesh in southeast India contaminated the shrimp they exported with antibiotics and forced women to work in peeling sheds for $3 for 10-hour days. India became the leading shrimp supplier to the US after 2015 due to reports of poor labor conditions in Thailand’s shrimp industry.

Hatcheries breed shrimp to get eggs that produce nauplii after 24 hours that feed on algae and zooplankton to become larvae in 12 days. Larvae develop to withstand more saline water in about three weeks, when they are placed into grow-out ponds for three to six months before being harvested. Yields are often 20,000 kg per hectare of shrimp pond.

Shrimp farms vary in technology and stocking density. Modern inten-
Sive farms feed the shrimp pellets, aerate the water, and exchange the water frequently to remove waste. The feed conversion rate is similar to salmon, about 1.2 to 1.5 pounds of feed yields a pound of shrimp biomass. The farm price of shrimp is $3.50 to $4.50 a pound.

The US was the world’s leading producer of shrimp in the 1970s, catching wild shrimp in the Gulf of Mexico that was relatively expensive for consumers. Producers abroad developed modern shrimp farms and today the US imports 95 percent of its shrimp.

Shrimp farming raises environmental, labor, and health issues. The environmental issue involves destroying mangroves to create shrimp ponds and polluting nearby waters, the labor issue involves migrant workers who are required to work long hours in peeling sheds to remove shrimp heads and tails, and the health issues emanate from the use of antibiotics to keep shrimp healthy.

Seaweed

Seaweed and other aquatic plants can feed humans and animals. Seaweed farming is the fastest-growing sector of aquaculture and includes growing kelp used in sushi, salsas, and salads. Seaweed farmers use the entire water column, so that vertical kelp farms can obtain large harvests from long lines that are suspended below the water’s surface during the winter and harvested in the spring.

China has 130,000 hectares of seaweed farms and produces over half of the world’s farmed seaweed, 20 million of the world’s 35 million tons a year, from farms off the coastal provinces of Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, and Guangdong. Other Asian countries including Japan and Korea also produce seaweed.
Harvesting Sugar Kelp

Seaweed Farms Off China’s Fujian Coast
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