20 Fish and Shellfish

1 Introduction

1.1 Definitions for Fish

At least 1500 species of fish and shellfish are used as food within the United States (US). The FDA defines fish as "*fresh or saltwater finfish, crustaceans, other forms of aquatic animal life (including, but not limited to, alligator, frog, aquatic turtle, jellyfish, sea cucumber, and sea urchin) other than birds or mammals, and all mollusks, where such animal life is intended for human consumption*". Basically, fish is aquatic animal life intended for human consumption other than birds, and mammals (Food and drug Administration 2001).[1] Moreover, "fishery product" was also defined as "any edible human food derived in whole or in part from fish, including fish that has been processed in any manner." Seafood was taken to refer to "fish" and "fishery products" derived from the sea, as outlined above (Federal Register 1995).

The Codex Committee on Fish and Fishery Products (CCFFP) define fish as "*Any of the cold-blooded (ectothermic) aquatic vertebrates. Amphibians and aquatic reptiles are not included*". Codex rules allow for differences in what is considered "fish" in different jurisdictions. Therefore, alligator and frog qualifies as "fish" in the US but might not be so in other countries.

Awareness of the biological classification of aquatic species, including some that are used as foods, is also useful (Table 20.1). Seafood include fish captured from fisheries and those produced from aquaculture, using marine or inland waters. However, "seafood" presumably does not include fresh water fish.

1.2 Naming Fish for Retail: The Seafood List

The US Federal authorities have provided guidance on naming of fish unambiguously for interstate commerce (Food and drug Administration 2016b). The Seafood list (fully online) is a searchable database of over 1800 species of fish. All commercially important fish varieties are assigned four different kinds of names; (i) the acceptable market name – also considered a statement of identity, (ii) common name, (iii) the scientific – Latinized name and (iv) the vernacular name (Food and Drug Administration 2016a).

The accepted market name should be used for labeling. Indeed, seven common names for fish are mandatory for labeling purposes (Table 20.2). For the vast majority of seafood, manufacturers and producers should inspect the seafood lists in

[1] The FDA describe mollusks to include terrestrial gastropods such as, *Achatina fulica* (the African land snail).

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https://doi.org/10.1007/978-3-030-65433-7_20

Table 20.1 Biological classification of aquatic animals

Phylum	Subphylum	Example[a]
Porifera		Sponges
Ctenophore		Comb jellies
Cnidaria		Jelly fish
Arthropoda	Crustacean	Hermit crab, shrimps
Mollusca	Mollusks	Snails, clams, squid
Echinoderms		Starfish, sea cucumber
Chordata	Vertebrates	
	Pisces	Sharks, rays, fish
	Mammals	Seals, whales, dolphins
	Birds	Puffins,
	Reptilians	Turtles, alligators,
	Amphibia	Frogs

[a]Not all are used as foods

Table 20.2 Some legally recognized common names for fish and shellfish[a]

Bonito (21 CFR 102.47),
Canned oysters (21 CFR 161.145),
Canned Pacific salmon (21 CFR 161.170),
Canned tuna (21 CFR 161.190)
Catfish (Federal Food, Drug, and Cosmetic Act (FD&C Act); Sec. 403(t) (21U.S.C. 343(t))
Crabmeat (21 CFR 102.50),
Greenland turbot (21 CFR 102.57),
Pacific whiting (21 CFR 102.46)

[a]*CFR* Code of federal regulations citation

order to determine the most appropriate labeling. Where an acceptable market name is not available, then the common name may be used in a manner that does not mislead (Food and Drug Administration 2016a) (Tables 20.2 and 20.3).

A recent search of the Seafood list using the term "herring" showed 30 different types of fish species that may be labelled as "herring" or else are commonly called herring (Table 20.3)[2]. Interestingly the Seafood data includes basic names and (in some cases) molecular data (e.g. DNA sequences), pictures of the different fishes, and external links to taxonomic information.

[2]A searchable database of acceptable market names for different species of fish that may be important for interstate commerce is available from the Seafood list produced by the FDA and updated every 6 months. Currently the Seafood list contains 1800 species of fish (as defined in Sect. 1.1.) which are either vertebrates, invertebrates and molluscs.

Table 20.3 The Seafood lists showing acceptable market names for herrings

Acceptable market name	Common name	Scientific name
Alewife or river herring	Alewife	*Alosa pseudoharengus*
Cisco or Tullibee	Lake herring	*Coregonus artedi*
Dorab	Dorab wolf-herring	*Chirocentrus dorab*
Herring	Round herring	*Etrumeus teres*
Herring	Flatiron herring	*Harengula thrissina*
Herring	African Ilisha	*Ilisha africana*
Herring	Pugnose Ilisha	*Ilisha elongata*
Herring	Panamanian Ilisha	*Ilisha fuerthii*
Herring	Bigeye Ilisha	*Ilisha megaloptera*
Herring	Indian Ilisha	*Ilisha melastoma*
Herring	Javan Ilisha	*Ilisha pristigastroides*
Herring	Tardoore	*Opisthopterus tardoore*
Herring	Indian Pellona	*Pellona ditchela*
Herring or river herring	Blueback herring	*Alosa aestivalis*
Herring or river herring	Skipjack herring	*Alosa chrysochloris*
Sea herring or Sild	Atlantic herring	*Clupea harengus*
Herring or sea herring or Sild	Pacific herring	*Clupea pallasii*
Herring, thread	Deepbody thread herring	*Opisthonema libertate*
Herring, thread	Atlantic thread herring	*Opisthonema oglinum*
Herrring	Araucanian herring	*Clupea bentincki*
Kahawai	Australian ruff	*Arripis georgianus*
Ladyfish	Ladyfish	*Elops hawaiensis*
Ladyfish	Ladyfish	*Elops saurus*
Mooneye	Mooneye	*Hiodon tergisus*
Mullet	Yelloweye mullet	*Aldrichetta forsteri*
Sardine	Perforated-scale sardine	*Sardinella albella*
Shad	Hickory Shad	*Alosa mediocris*
Shad, gizzard	Western Australian gizzard Shad	*Nematalosa vlaminghi*
Smelt	Great silver smelt	*Argentina silus*
Sprat	Sprat	*Sprattus* spp.

1.3 The United States (US) Seafood Industry at Glance

The seafood industry covers all five Agri-food business activities (Table 20.4): (i) aquaculture or finfish and shellfish farming (NAICS 1125), (ii) finfish and shellfish fishing from capture fisheries (NAICS 1141), (iii) seafood processing and manufacturing (NAICS 3117), (iv) wholesalers (NAICS 4244) and (v) retail of fish & seafood or "fish markets" (NAICS 4452).

Primary production by the US seafood sector (NAICS 1125 & NAICS 1141) amounted to 4.3 million tonnes (US$5.0 billion) in 2012. The top States for commercial fishing by volume were, Alaska > Louisiana > Virginia > Washington > California. However, the value of fish landed were ranked, Alaska> Massachusetts > Maine> Louisiana > Washington. The volume of US seafood export amounted to 3.7 million tonnes (US$ 5.0 billion) with imports of 4.7 million tonnes valued at US$15 billion. Aquaculture accounted for 17% of the seafood production by value whilst 83% was by wild-capture. (National Oceanic and Atmospheric Administration 2012). There are about 170, 000 jobs on 8623 vessels involved in US seafood fishing (OECD 2021).

Table 20.4 NAICS for the fish and aquatic foods

NAICS	Description[a]
112511	Fish farms, finfish
112512	Fish farms, shellfish
114111	Finfish fishing (anchovy, blue fish, cod, croaker, dolphin, eel, flounder, grouper, herring, salmon, seabass, shark, sword fish, whiting)
114112	Shellfish fishing (clam, crab, crayfish, lobster, mussel, octopus, oyster, scallop, sea urchin, shrimp, squid)
114119	Frog fishing, terrapin, turtle,
311710	Fish freezing (e.g., blocks, fillets, ready-to-serve products),
311710	Fish manufacturing, fish meal processing, fish and marine oil processing,
311710	Fish, curing, drying, pickling, salting, and smoking
311710	Seafood manufacturing, chowders, soups, dinners,
424420	Fish, packaged frozen, merchant wholesalers
424460	Merchant wholesalers, fresh, frozen, cured,
424490	Canned foods (e.g., fish, meat, seafood, soups) merchant wholesalers
445220	Fish markets

[a]NAICS = North America Industry Classification Scheme. Abbrided from NAICS Association (https://www.naics.com/search/)

The value for seafood exports (Table 20.5) was estimated at US$5.3 billion in 2014 (USDA Foreign Agricultural Services, 2015). By 2018, seafood production, export and imports were US$ 7.1 billion, US$5.2 billion and US$23.4 billion, respectively (Food and Agriculture Organization 2021; OECD 2021). The US has had a negative trade balance in seafood recently (National Oceanic and Atmospheric Administration 2016a). The major destinations for US seafood exports were the EU (23%), China (22%), Canada (17%), Japan (14%), South Korea (7%) and others (17%). Trade with China increased by 370% over a 5-year period (2009-2014), compared with an overall export growth of 57%. The changes were due to export volume rises, as prices increased only by 4%. Fish and Frozen fish export exceeded shellfish exports (67 vs 33%) but the former grew less strongly (USDA Foreign Agricultural Services, 2015; National Oceanic and Atmospheric Administration 2016a).

The seafood processing, and packaging industry (NAICS 3117) comprised 600 businesses, 32,000 employees and receipts amount-

Table 20.5 US seafood and shellfish receipts (2015)[a]

NAICS	Description	Shipments ($1000)	% Value
311710	Seafood product preparation and packaging	11,463,051	100.0
3117101	Prepared fresh fish and other fresh seafood	2,688,241	23.5
3117102	Prepared frozen fish	3,581,322	31.2
3117103	Prepared frozen shellfish	2,423,672	21.1
3117104	Other prepared fresh and frozen seafood	1,135,300	9.9
3117105	Seafood canning	1,182,317	10.3

[a]Value including domestic consumption. Adapted from (US Census Bureau 2017)

Table 20.6 United States Fish and Seafood Exports (2014)

	FY 2014 (US$million)	5-year increase (%)
Fish (fresh/frozen)	3233	39
Shellfish	1658	65
Other fish products	429	16
Aquaculture exports[a]	1219	
Total exports	5320	44%

Adapted from (USDA Foreign Agricultural Services 2015)

[a]Aquaculture products across all fish categories

ing to US$11.5 billion for 2015 (US Census Bureau 2017, p.10). About 92 businesses (2100 employees) were involved in seafood canning (NAICS 311711), whilst 552 businesses (29,158 employees) dealt with fresh and frozen seafood (cf. Chapter 2; Sect. 2.5). Approximately, 24%, 31% and 10% of earnings were for fresh, frozen or canned finfish respectively (Table 20.5).

1.4 Global Seafood Industry

The world production of seafood was 167 million tonnes (US$300 billion) live-weight in 2014. Remarkably, the value of fish produced by aquaculture (73.8 million tonnes; US$160.2 billion) exceeded the value seafood captured from the wild, for the first time (Food and Agriculture Organization of the United Nations 2018).

Most of the global seafood yield (63%) is consumed domestically whilst 37% (US$148 billion) is used for export. The main importers for seafood products were the US, Japan, China and Spain. From 2009 to 2014, fish consumption per capita increased from 16 kg to 20kg per person (Food and Agriculture Organization of the United Nations 2018). The "GLOBEFISH" website contains updated information on the status of the global fishing industry (Food and Agriculture Organization 2021).

1.5 Hygiene and Safety of Fish Products

1.5.1 Fish Handling

The general principles of food hygiene apply to fish (Borgstrom 2012). Some issues that are important for safety handling of fish in a domestic of foodservice setting are highlighted below. International guidelines for health and safety related to fish and fishery products are also briefly outlined. The fish flesh is readily digested, and is subjected to highly active bacterial enzymes. Therefore, fish can deteriorate rapidly and cannot be held at temperatures above freezing for long periods.

A simple principle that applies to all fresh food, and especially to fish, is the 3/H rule: Rule 1. Handle the product under strict sanitary conditions (to keep the microbial contamination at a minimum). Rule 2. Handle the product at a cool temperature (microbes multiply rapidly and spoilage reactions proceed rapidly at warm temperatures but both proceed slowly at cool temperatures). Rule 3. Handle the product quickly (fish deteriorate as a function of time as well as temperature).

To explain the importance of temperature, fresh-caught fish will generally last about 12 days if held in ice (temperature at about 32 °F or 0 °C) whereas they will last only about 4 days at 46 °F (7.8 °C), a temperature commonly found in domestic refrigerators. There are at least three reasons why fish spoil so rapidly at refrigerator temperatures: first, because they are readily digestible; second, because muscle glycogen is nearly depleted during harvesting, leaving little to be converted to lactic acid, which would act as a preservative; finally, because the bacteria found on fish are psychrophiles (they can grow well at low temperatures), and their enzymes are functional at low temperatures. Even among psychrophiles, there is a range of optimum growth temperatures for individual species, and it is known that some of the psychrophilic bacteria found naturally on fish grow at such low temperatures that they are not reliably detected by standard bacteriological plating techniques that incubate at elevated (warm) temperatures (Huss 1994a; Ghaly et al. 2010).

1.5.2 Safety Codes for Fish and Fishery Products

International guidelines exist to deal with health and safety aspects of fish and fishery products – covering production, storage, handling, transportation, import / export, and processing. The guidelines produced by the Codex Committee on Fish and Fishery Products (CCFFP) address safe production of fish and fishery products in order to facilitate trade and avoid international disputes. The CCFFP require that various stakeholders employ sound food safety management systems, based on two approaches: (a) the so-called pre-requite safety program similar to GMP that addresses (i) fishing and harvest vessels, (ii) facilities and processing plants, (iii) Utensils and fittings, (iv) An ongoing hygiene program, (iv) Personnel hygiene and (v) staff straining. The GMP pre-requisite program is expected to be followed with a formal HACCP program that focusses on processing methods relevant for the specific food manufacturer (Codex Committee on Fish and Fishery Products (CCFFP) 2003).

1.5.3 Common Hazards Associated with Eating Fish

Fish are in large part carnivorous. Those predatory fish higher up in the food chain may accumulate significant levels of environmental pollutants (heavy metals, organo-mercuric pesticides can be a concern). Another particular hazard frequently discussed in relation to fish are biotoxins produced by algal blooms.

Disease outbreaks associated with seafood were grouped into several categories (Lipp & Rose 1997; Todd 1997). Firstly, norovirus is a frequent cause of seafood-linked outbreaks. The second group of outbreaks are due to toxic algal blooms (tiny microalgae that produce toxins, which accumulate in marine lifeforms). Algal toxins are linked with a cluster of life threatening conditions, e.g. amnesic, diarrheic, neurotoxic, and paralytic shellfish poisoning (Munday and Reeve 2013). Thirdly, scromboid poisoning is due histamine produced from the amino acid histidine during spoilage. Scomboid poisoning is associated often with tuna, skipjack and related fishes (Attaran and Probst 2002; Lavon et al. 2008). Finally, many salt-water bacteria pathogens are associated with seafood (e.g. vibrio and Clostridium spp) either directly or due to environmental contamination (Huss 1994b) as discussed in Chap. 2.

2 Commercial Species of Fish

2.1 Fish Capture

Seafood taken directly from the wild (wild-capture or capture fisheries) levelled out at 91.2 million tonnes annually for a decade (2009-2019). As the total fish production volume increased from 145.9 million tonnes (2009) to 177.8 million tonnes (2019), the proportion from wild-capture as part of the total declined from 60% (2009) to 51% (Food and Agriculture Organization of the United Nations 2018). Nevertheless, capture fisheries (worth US$140.0 billion) remain an important industry.

Of the variety of methods employed for commercial fishing, line fishing is one of the simplest (National Oceanic And Atmospheric Administration 2021; Australian Fisheries Management 2021). Examples of hand lines and long lines are shown in Fig. 20.1. Fish such as halibut, cod, and haddock are caught using these methods. Troll lines are used to catch certain species of salmon and other fish found near the ocean surface (Fig. 20.2).

Nets are used to catch popular species such as cod, haddock, flounder, and other bottom fish. (Fig. 20.3). Gill nets are used to catch salmon and shad, and sometimes herring, mackerel, cod, and haddock. Otter trawls are used to catch the bottom fish. A purse seines net is used to wall off large areas of the sea, to catch pelagic fish that swim together in large groups such as menhaden, tuna, salmon, herring, and mackerel. The relative ease of capture of pelagic fish leads to their being used not only for human food but also for fish feed in the aquaculture industry (Alder et al.

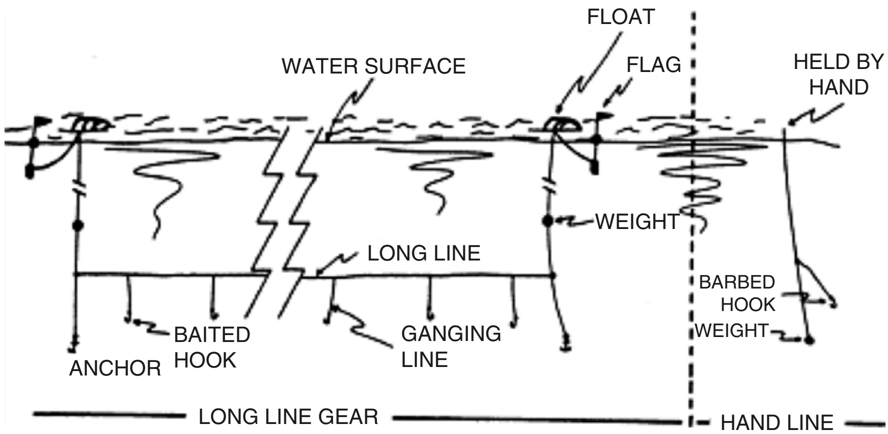


Fig. 20.1 Line fishing

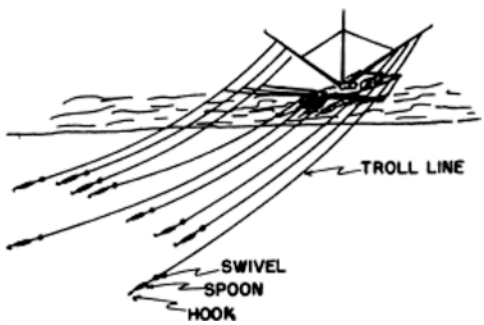


Fig. 20.2 Troll line fishing

2008). Crustaceans such as crabs and lobsters and some freshwater fish are caught in pots. Examples of these are shown in Fig. 20.4. Shellfish such as scallops, clams, and oysters are harvested by the use of dredges, tongs, rakes, or forks (Fig. 20.5). After fin fish are caught, ice is added to the catch to reduce deterioration. Different commercial fishing gear have their own advantages and disadvantages (National Oceanic And Atmospheric Administration 2021; Australian Fisheries Management 2021).

2.2 Aquaculture, Fish Farming

The value of seafood produced by aquaculture (US$160.2 billion) exceeded the value of seafood extracted from the wild from 2014 onwards (Food and Agriculture Organization of the United Nations 2018). Over the period 2017-2019, fish production by aquaculture increased by +3.9% compared to a 3.4% decline in fish production by wild-capture (Food and Agriculture Organization 2021). The growth of fish farming was faster than anticipated 20 years ago (Tidwell & Allan 2001).

Aquaculture covers more than 500 species including, finfishes (362 species), mollusks (104 species), crustaceans (62 species), aquatic invertebrates (9 species) and aquatic plants (37species). The rise in fish farming is partly because of the high feed / conversion ratio for fish where every 1 lb. (454 g) of feed yields about 0.67 lb. (300 g) of live weight. Fish also require less space than other livestock (Tidwell & Allan, 2001; FAO 2016).

Food scientists are getting involved in aquaculture in terms of adding quality attributes to the finished products (Fig. 20.6). Both color and flavor can be altered by additives to the fish feed. The Atlantic salmon aquaculture industry has found that the addition of carotenoid (astaxanthin) to the fish feed imparts a pinkish appearance to the fish flesh and this seems to be a positive quality factor to consumers. Taste can also be improved by the addition of bromophenols to the feed of aquaculture freshwater fish. This adds shrimp like flavor that is preferred by the consumer (Boyle et al. 1993; Anderson 2001).

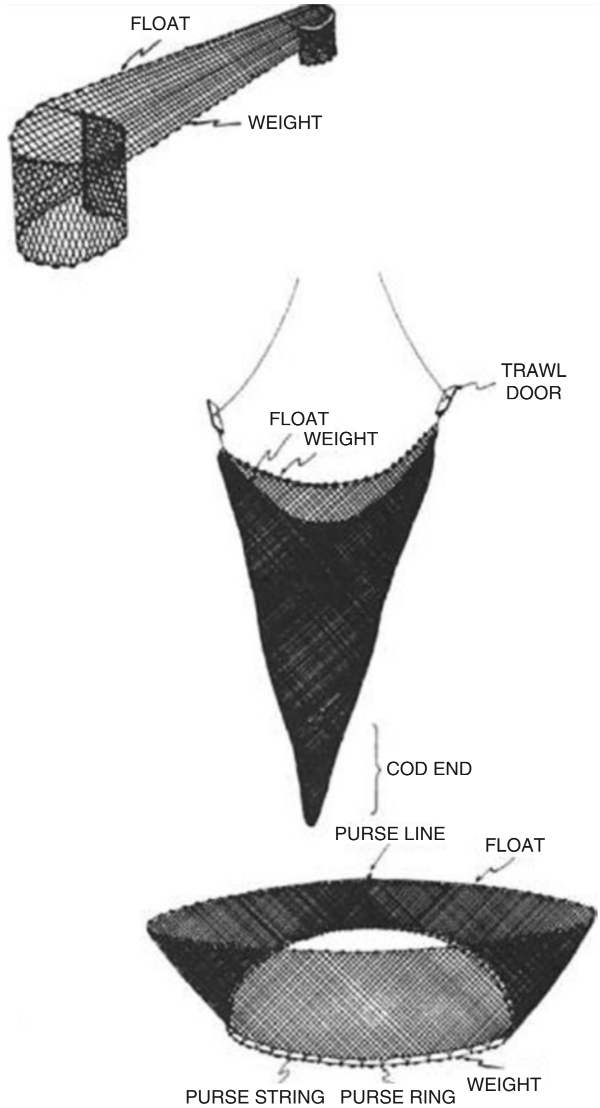


Fig. 20.3 Shows (top to bottom) the drift gill net, otter trawl net, and purse seine net

2.3 The Herring Family (Clupeidae)

2.3.1 Sea Herring

Sea herring (see Fig. 20.7) are found in ocean waters from Alaska to the State of Washington on the West Coast, and from Labrador to Cape Hatteras on the East Coast. Most sea herring are caught with purse seines, but some are caught with pound traps or weirs (similar to pound traps but constructed with poles and brush). Gill nets are sometimes used to catch these fish.

The larger fish may be exported, as there is a foreign market for this species where it is used for human food. The smaller herring, which are canned as sardines, must be held in the purse

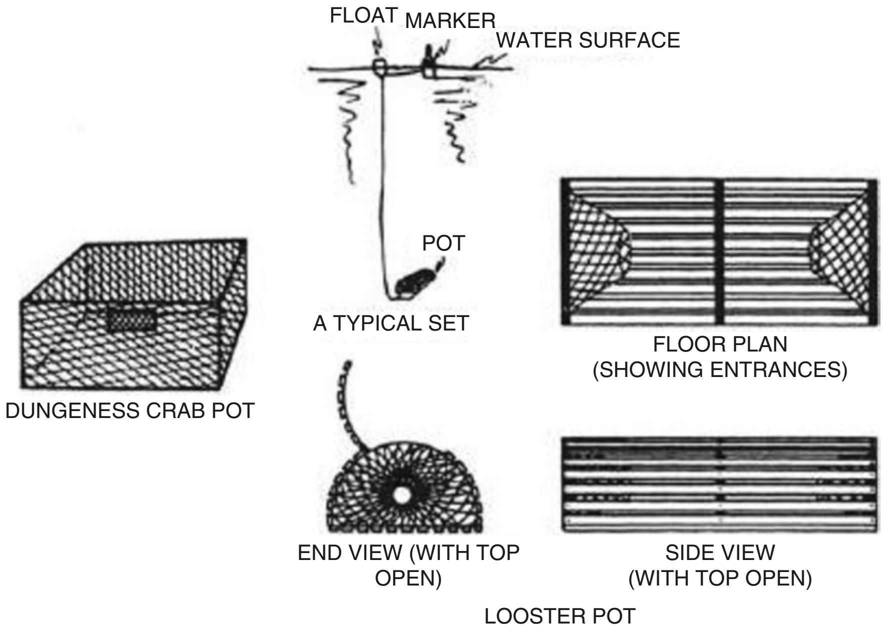
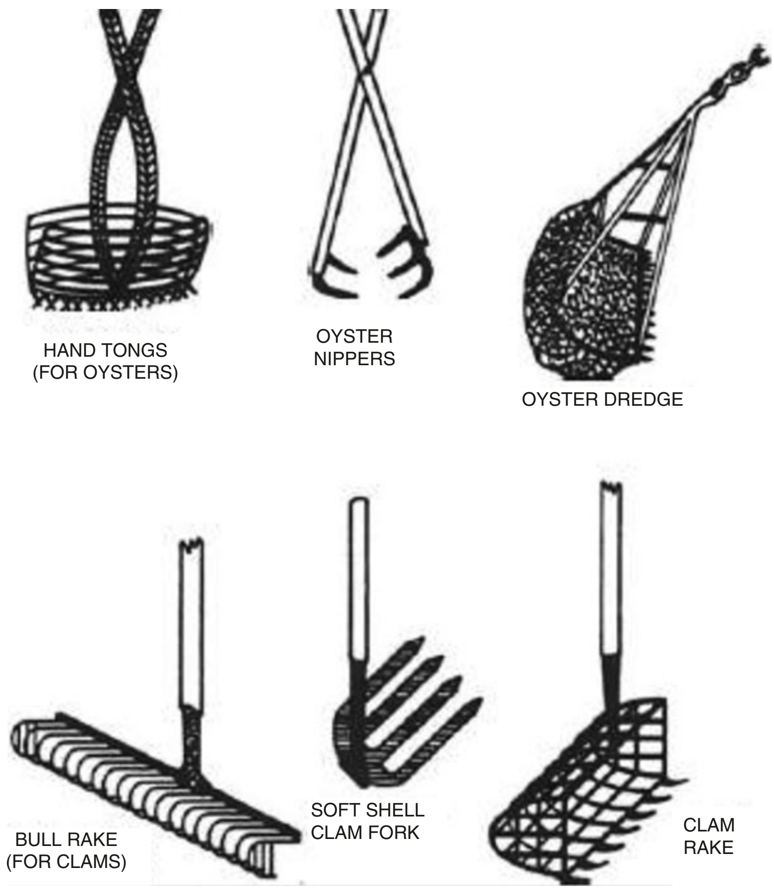


Fig. 20.4 Entrapment devices

Fig. 20.5 Shellfish harvesting devices



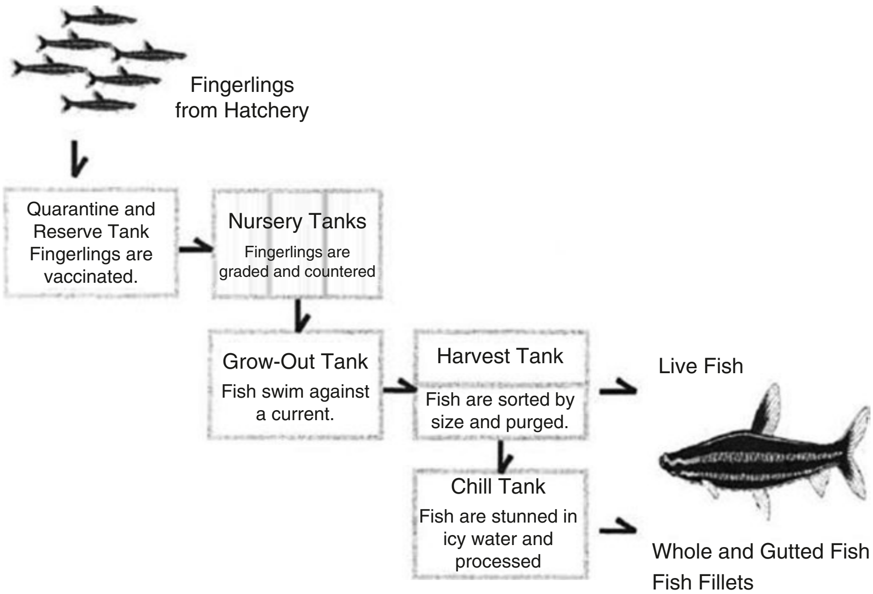


Fig. 20.6 Aquaculture of striped bass

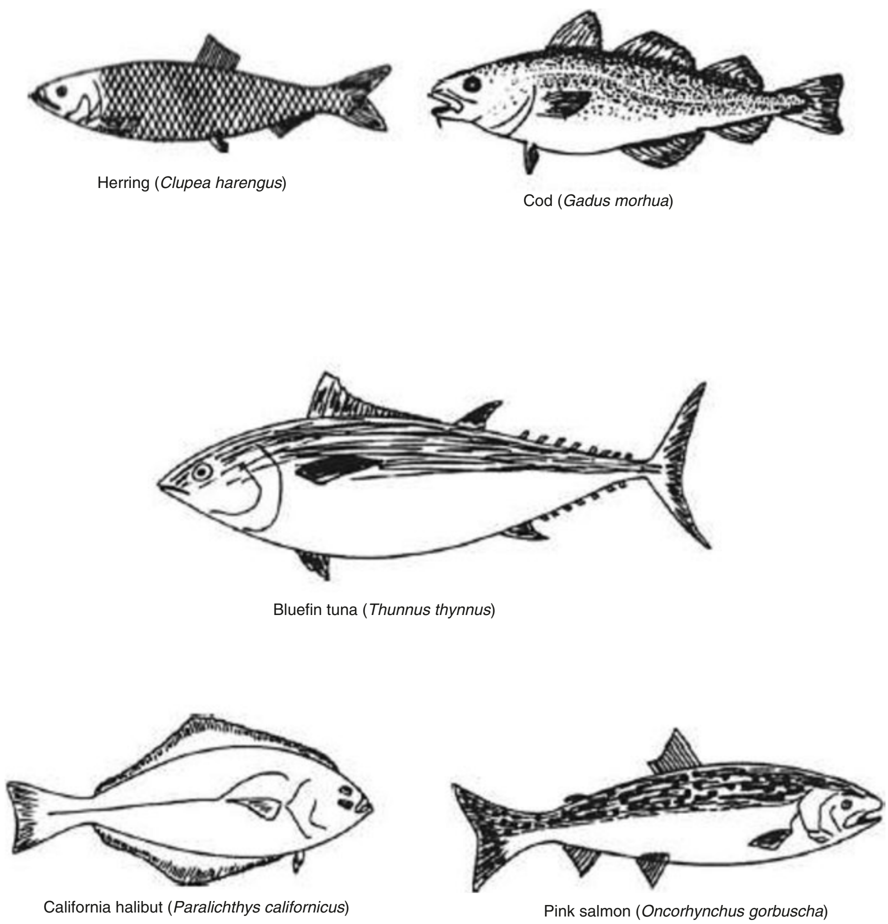


Fig. 20.7 Some important finfish species

seine alive (sometimes for longer than 24 h) until the stomach is free from feed. This is done to prevent enzyme action, which would reduce the quality of the fish. Fish from the nets are loaded on the boat with a large vacuum pump and are salted. More salt is added at the processing plant after the fish are beheaded and eviscerated. The small herring are then preheated, placed in small rectangular cans, and subjected to steam for 18–20 min. The liquid in the cans is drained and replaced with vegetable oil, tomato sauce, or mustard sauce and the cans are sealed, heat-processed and cooled. The resulting product is shelf-stable.

Herring is also processed "whole" but in larger oval cans, usually in tomato sauce. Some large herring are cut transversely into bite-sized pieces and packed in small cans in tomato sauce. This product is also shelf-stable. Some herring are pickled (salt, vinegar, sugar, and spices) and packed in glass jars. Sour cream, onions, or other flavoring ingredients may be added before sealing the jars. Other pickled products include rollmops (pickled herring strips wrapped around a piece of pickle or onion) and kippered herring (salted and lightly smoked). These products must be refrigerated. Some herring are highly salted and heavily smoked, and this product is shelf-stable.

In Alaska, and to some extent in eastern US, the roe (eggs) is taken from herring approaching the spawning stage, salted, packaged in containers, and sold at high prices to certain Asian countries.

Some herring is converted into fishmeal, which is used as a protein supplement for cattle and poultry; the availability of fishmeal is an important consideration for aquaculture (Olsen and Hasan 2012). When used for this purpose, some fish are brought to port in unrefrigerated vessels. At the processing plant, the fish is first cooked in live steam in a continuous cooker, and then pressed in a screw-type continuous press. The press cake is dried with hot gases from oil-produced flames in a rotary drier, to a moisture content of 5–8%. The liquid from the pressed product is not discarded. It is first centrifuged to remove oil, which is collected and sold for industrial uses. The remaining liquid (stick water), which contains proteins, peptides, and amino acids, is then vacuum concentrated to a solids content of 50% and acidified to prevent spoilage. This product may be sold as a protein supplement or it may be added back to the press cake before the latter is dried (Chadd et al. 2002).

2.3.2 Shad

Shad are anadromous fish (ascend rivers to spawn) that spend the greater part of their lives in ocean waters as far as 50 miles (80.5 km) from shore. Shad are used almost entirely as the fresh product, with only small amounts being frozen. They contain many small bones, but can be filleted to eliminate most of them from the flesh. The roe (unfertilized eggs), which prior to spawning is held together by a thin membrane, is highly prized. It is sold fresh, or packaged in moisture vapor proof material and frozen to be sold to the restaurant trade and, in this state, may be stored at 0 °F (−17.8 °C) for 6–8 months. Longer storage under these conditions usually results in a rancid product resulting from oxidation of the fat contained therein.

2.3.3 Menhaden

Four species of menhaden, sometimes called "pogy," "bunker," or "mossbunker," are found in the Western Atlantic. They range from Nova Scotia to Brazil. Menhaden are not used for human food. They are processed to produce fishmeal and oil in the manner described for herring. In the US, larger quantities of menhaden are caught (several hundred thousand metric tons) than that of any other fish or shellfish.

2.3.4 The Anchovy

The anchovy (family Engraulidae) is a small herring-like fish found off the coasts of California and Mexico (California Department of Fish and Game 2006). It is caught in purse seines, and at one time was used as line bait for tuna fishing and later mostly in the production of fishmeal and fish oil. However, a growing amount is used for human consumption in appetizers, garnishes, sauces, relishes, and especially in toppings for pizzas. It is packed in 2-oz (56-g) tins in oil for domestic use and in large tins for industrial use.

2.3.5 Other Clupeidae

Pilchards are members of the herring family, and at one time were plentiful off the coast of California, where they were caught with purse seines. They were used for canning as sardines and to produce fishmeal and oil.

2.4 The Cod Family (Gadidae)

2.4.1 The Cod

Cod (see Fig. 20.7) are found on both sides of the Atlantic and are most plentiful around Norway, Iceland, Newfoundland, Nova Scotia, and on Georges Bank off Cape Cod. In the Western Atlantic, they range from Greenland to North Carolina. Mollusks (clams, oysters, scallops, etc.) are said to make up an important part of the diet of the cod, but cod also eat small fish.

By far the largest quantities of cod are caught with otter trawls in waters ranging from 300 to 1500 ft. (91–457 m) in depth. Small quantities of this species are caught with long lines, hand lines, or gill nets. When caught with otter trawls, the fish are gutted and washed on the deck of the boat. During summer months, the gills must be removed, but the head is left intact. The fish are stored in boxes or pens, in either case layered with ice.

At the processing plant, the fish are washed and filleted, skinless. The fillets are then candled (observed over a bright light) to locate and remove parasites such as worms. Fillets to be sold as fresh are precooled, placed in metal tins of 10, 20, or 30 lb. (4.5, 9.1, or 13.6 kg), and the tins are refrigerated (mechanically or in ice) until they reach their destination. Some fillets are precooled, packed in small trays, overwrapped with a transparent plastic, and shipped to their destination in insulated containers.

Fillets that are to be frozen for the retail trade are packed in 1-lb (454-g) waxed cartons with or without being first wrapped in moisture-vapor-proof plastic. Some cod fillets are frozen, usually in a plate freezer into 16-lb (7.26-kg) blocks and then cut into fish sticks or fish portions that are then breaded in a batter and deep fried. Some battered and breaded product is not fried but frozen raw. This product is used by fast food restaurants and other food service facilities where it is deep-fried to order.

Cod may be salted. To produce salted cod, the fish are beheaded and split longitudinally; the backbone and the abdominal cavity lining are removed, and the fish is washed and layer-salted in closed casks (brine salting).

Fish cakes are prepared from salt cod by first cooking and freshening the fish to remove most of the salt, then mixing it with mashed cooked potatoes and small portions of oil, onions, and pepper. A proportion of about 40% shredded cooked fish and 60% of cooked potatoes is used. This product may be canned without forming or it may be formed into small cakes, deep fat fried to brown the surface, and frozen, or sold in the refrigerated state.

2.4.2 Haddock

The haddock is the second most important member of the cod family. The haddock is found on both sides of the Atlantic from Norway to New Jersey but are most plentiful in waters off Nova Scotia and Cape Cod (Georges Bank). In recent years, the stocks of haddock have been greatly depleted because of overfishing. Haddock are processed to produce fillets, fish blocks, and fish sticks in the same manner as that described for cod. Haddock is not salted and dried although some are lightly salted and lightly smoked, without heat, to produce a product called “finnan haddie.”

2.4.3 Pollock

Pollock are found on both sides of the Atlantic from Norway to the Chesapeake Bay but are most plentiful in waters off Nova Scotia, Cape Cod (Georges Bank), and in the Gulf of Maine. Pollock are caught in waters at levels between the surface and a depth of 450 ft. (137 m). They are caught, handled aboard the boat, and processed in much the same manner as that described for cod. Small quantities of pollock are salted and dried.

2.4.4 Hake

There are several species of hake, the most important of which is the silver hake or whiting.

The whiting is most abundant in waters off Nova Scotia. It is caught and handled in much the same manner as are cod. Some whiting are headed, gutted, washed, and frozen in blocks without further cutting, for utilization as food.

2.4.5 Small Fish Species

Small fish, species not especially prized as food (red hake, etc.), and fish frames (the portion remaining after the fillet has been cut away) may be passed through mechanical meat/bone separators (machines that separate the flesh portion from bones and skin). This provides a significant yield of edible, ground fish flesh (resembling hamburger in texture) that may be used to produce frozen fish blocks to be further processed into products such as fish portions and fish sticks.

Handled in conventional fashion, such products are not stable in frozen storage because the fat oxidizes and becomes rancid, and the tissues get tough at a faster rate than that of the corresponding fillets held under the same conditions. The faster oxidation of fats is due to the exposure to oxygen because of the great increase in surface area. The increased rate of toughening may be due to a wider distribution of the enzyme that decomposes trimethylamine oxide to form dimethyl amine and formaldehyde (Sotelo et al. 1995). The latter compound is known to denature proteins. The spoilage reactions may be slowed considerably by storing at lower temperatures, for example, −20 °F (−28.9 °C). Rancidity can be prevented altogether by protecting the product with a wrapper of gas-impermeable plastic film, for example, polyester, polyvinyl chloride, nylon-II or aluminum laminate.

2.5 The Mackerel Family (Scombridae)

The mackerel family include various tuna, the Atlantic mackerel, the jack mackerel, and the Spanish mackerel. Tuna are torpedo-shaped fish tapering to a pointed nose and a slender caudal peduncle (the portion near the tail). Globally the more important species of tuna include the skipjack tuna, yellow fin tuna and big eye tuna that make up, 50.7%, 31% and 10% of catches, respectively (Miyake et al. 2010). The blue fin can attain a weight of 1000 lb. (454 kg), but average size of the tuna caught is about 30 lb. (13.6 kg). Mackerel is much smaller than tuna, but is similarly shaped.

2.5.1 Tuna

Yellowfin tuna is found on the West Coast from southern California to southern Chile. Bluefin tuna range from Nova Scotia to Brazil on the East Coast and from southern California to northern Mexico on the West Coast. The skipjack is found in the Pacific Ocean from southern California to Central and South America. The albacore ranges from Puget Sound (State of Washington) to lower California. The yellowtail is found in Pacific waters from southern California to the coast of Mexico (California Department of Fish and Game 2006). Several other species of tuna are found elsewhere, especially in the Eastern Pacific Ocean.

Tuna are caught mainly with purse seines, which, owing to the size of the fish, are made with heavy twine. Most tuna fishing boats make trips lasting for several months, and for this reason, the fish are frozen aboard the boat. In freezing, the whole fish are cooled in a large well with refrigerated seawater at 28 °F (−2.2 °C). Later the RSW is replaced with refrigerated brine at 10 °F (−12.2 °C). The fish are kept frozen by circulating mechanically refrigerated air.

Traditional fresh tuna steaks (sashimi) and dried skipjack sticks (katsuobushi), originally sold at Japanese auctions, were followed by the canning of tuna in the 1960s; interestingly the trade for sashimi is now a global phenomenon with supply chains shifting to involve supermarkets (Miyake et al. 2010).

Canned tuna are produced at fish processing plants, where the fish is first thawed with running water, eviscerated and washed (Fig. 20.8). They are then cooked in steam, under pressure, and then cooled. When cooled, the heads and

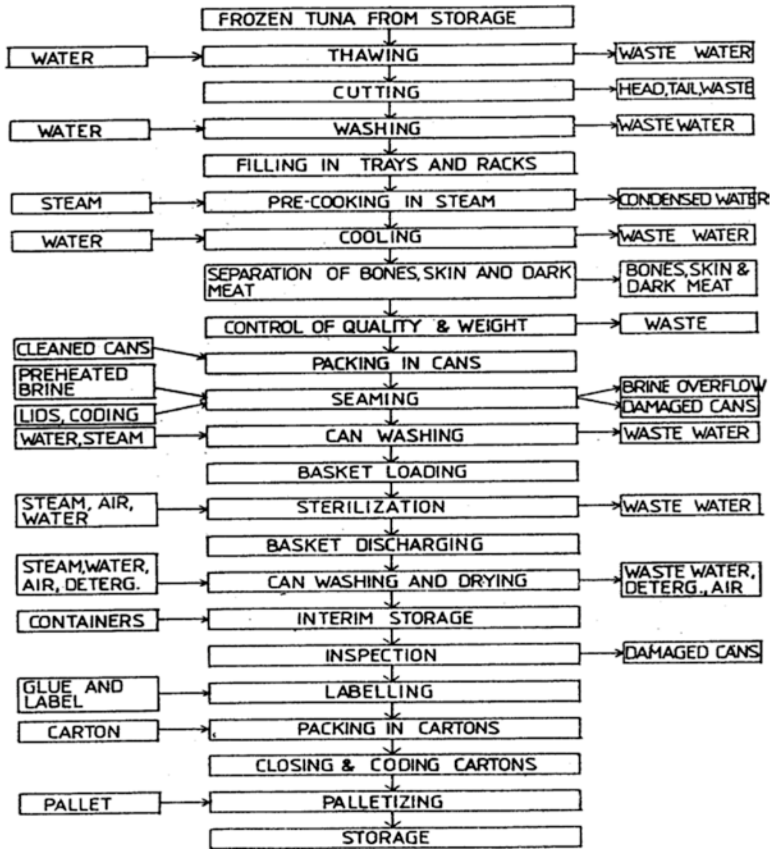


Fig. 20.8 Flow chart for processing tuna. Source: Food and Agriculture organization of the United Nations (1985), reproduced with permission

skins are removed. The fish are then cut longitudinally, after which all bones are removed. If all white meat varieties are being produced, the dark meat is also removed. The white meat is then shaped, mechanically, into a cylinder, fed to cans, and cut to length. To pack chunk-style tuna, pieces are filled into cans with an adjustable filler. Vegetable oil or a broth containing hydrolyzed vegetable protein in water is metered into the cans, which are then heated in steam, sealed, heat-processed, cooled, labeled, and stored (Dewberry 1969).

2.5.2 Mackerel

Atlantic mackerel are found from the Gulf of St. Lawrence to Cape Hatteras in America, and from Norway to Spain in the Eastern Atlantic. Spanish mackerel range from Maine to Brazil in the Western Atlantic but are mostly caught in waters off the Carolinas and southward. The jack mackerel ranges from British Columbia to Mexico in the Pacific Ocean.

Mackerel may be taken in pound traps or with gill nets, but by far the greatest quantities are taken with purse seines. If the boat is to remain out of port after the fish are caught, they are held in ice in the round, un-eviscerated state. Atlantic and Spanish mackerel are sold to retailers as the fresh product, either as fillets or as the round uncut fish. Some are frozen and sprayed with water for purposes of glazing to prevent dehydration until defrosted for sale to restaurants or retail outlets.

Jack mackerel are canned in 1-lb (454-g) tall containers. During the first pass on the conveyor belt the fish passes under circular knives. This cuts off the heads and tails whilst cutting the fish to can-size lengths. The entrails are then removed, after which the fish are washed and flumed to a container feeding the packing table, where they are filled into cans by hand. The open cans are then heated in a steam box to raise the product temperature to 145 °F (62.8 °C), after which they are inverted to drain off liquid formed during heating. Oil, brine, tomato sauce, or mustard sauce is then added to cover the fish, and the cans are then sealed and heat-processed.

2.6 The Salmon Family (Salmonidae)

2.6.1 Pacific Salmon

A number of commercially important species of the salmon family are found throughout the world. Some of the most important species of salmon are listed in Table (20.7). There are five types of Pacific salmon important in the US: pink, chum, Coho or silver, the sockeye or red salmon and Chinook or king salmon (Fig. 20.7). Chinook salmon is the largest salmon with a high oil content. Chum salmon, which has lowest oil content, is least desirable. Silver salmon has similar flavor to Chinook. The sockeye or red salmon is highly regarded for both its flavor and texture (Jensen 1976, p.10). The enormous salmon cannery businesses on the Pacific Northwest reached their peak in the 1900s (Newell 1989).

2.6.2 Atlantic Salmon

Wild populations of the North American Atlantic salmon (*Salmo salar*) have been in decline since the late nineteenth century. The decline of the Atlantic salmon may be partly due to overfishing, habitat loss and interruptions in the migratory routes. Catches of Atlantic salmon rose to their peak in the 1970s and diminished exponentially to present very low levels in about 2010. Currently, the Atlantic salmon is designated as" extinct or endangered" in many areas of West Coast. Indeed commercial fishing for Atlantic salmon is prohibited in US federal waters (NASCO 2016; National Oceanic and Atmospheric Administration 2021).

Commercial farming of Atlantic salmon is credited to systems developed in Norway from the 1960s. From 1980 to 2010, the global production increased from 5000 metric tons to 2.5 million metric tons or ~ 4% of global aquaculture production. About 50% of farmed Atlantic salmon is used in world trade. The main producer nations are Norway, the USA, Scotland, Chile, Australia and New Zealand (FAO Fisheries and Aquaculture Department 2016) (Fig. 20.9).

Salmon farming "has long" been controversial due to concerns with the possible negative impact on the environment, inadvertent interactions between farmed and wild fisheries, welfare of farmed salmons and the need to promote responsible aquaculture practices (FAO Fisheries and Aquaculture Department 2016). The FDA approved a fast-growing genetically modified Atlantic salmon as safe to eat as a non-genetically modified salmon. Manufacturers may adopt voluntary labeling to distinguish their products as "not bioengineered" (Food and Drug Administration, 2015). The status of US salmon fisheries has been discussed recently (Fay et al. 2006).

Table 20.7 Seafood listing for some commercially important salmon

Accepted market name	Vernacular name	Scientific name
Salmon, Pink, Humpback	Pink Salmon	*Oncorhynchus gorbuscha*
Salmon, Danube salmon	Danube salmon	*Hucho hucho*
Salmon, Chum, Keta	Chum Salmon	*Oncorhynchus keta*
Salmon, Coho, Silver Medium Red Salmon	Coho Salmon	*Oncorhynchus kisutch*
Salmon, Cherry salmon	Cherry Salmon	*Oncorhynchus masou*
Trout, Rainbow or Steelhead	Rainbow trout	*Oncorhynchus mykiss*
Salmon, Sockeye, Red Blueback	Sockeye Salmon	*Oncorhynchus nerka*
Salmon, Chinook, King	Chinook salmon	*Oncorhynchus tshawytscha*
Salmon, Atlantic salmon	Atlantic salmon	*Salmo salar*
Trout	Brown trout	*Salmo trutta*

Adapted from the seafood list of acceptable market names. (Food and drug Administration 2016b)

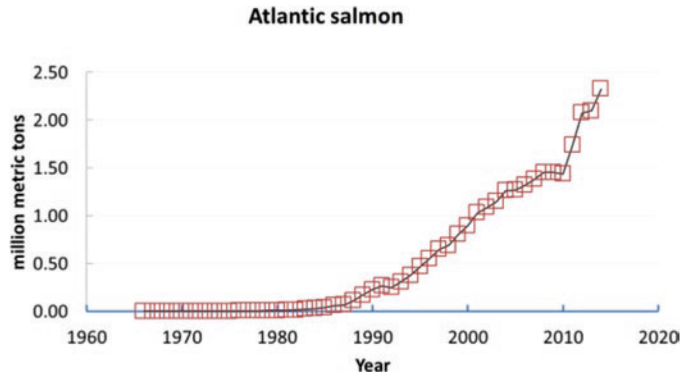


Fig. 20.9 World production of Atlantic salmon by aquaculture. (Drawn using data from (FAO Fisheries and Aquaculture Department 2016)

2.6.3 Salmon Processing

The salmon processing industry located at the Pacific Northwest was impacted greatly by the introduction of a powered iron-butchering machine for salmon invented by Edmond A. Smith in 1901/ 2 (Jones 2006). Salmon could be prepared more quickly for canning using the iron butcher, as compared to manual butchering. The iron butcher removed the head, tail, fins, and viscera from fish after which the salmon is trimmed by hand to remove extraneous material and then washed. The fish next passes under rotary blades on a slotted conveyor, where they are cut into can-sized lengths. The cut salmon pieces then pass on to a volumetric filling machine where salt is added to the can (about 1.25% by weight), and the cans are filled with fish. After filling, the covers are clinched on the cans, which are then sealed under vacuum, or they may be sealed without first clinching, a steam jet being used to remove air from the headspace in the can. After sealing, the cans are washed, heat-processed to provide commercial sterility, and then cooled in the retort. The cans are then labeled, if not lithographed, packed in cases, and stored in a warehouse until shipped out. Heat-processing times and temperatures are applied according to the weight of the product in the can.

Some coho and spring salmon are sold fresh as steaks; some are frozen, in gas-impermeable containers. Spring salmon are sometimes preserved by salting in casks, and held at 35 to 40 °F (1.7 to 4.4 °C) for 30 days. This product is usually shipped to processors who smoke the fish. In smoking, the salted fish is first soaked in water to remove salt, then smoked at temperatures below 90 °F (32.2 °C) or hot smoked at a temperature of about 175 °F (79.4 °C).

2.7 The Flatfish Family (Pleuronectidae)

Many species of flatfish are utilized as food. On the East Coast of the US, the halibut, the turbot, the sand dab, the fluke, the yellowtail flounder, the black back flounder, the lemon sole, the plaice, and other species are edible. On the West Coast, the halibut, petrale sole, English sole, rex flounder, arrowtooth flounder or turbot, Dover sole, starry flounder, rock sole, and other types are caught as edible fish. All the above are flounder; none are true sole. In shape, flounder are flat, comparatively thin fish.

Flatfish vary in size. Although halibut can grow to a very large size, the average weight of those caught today is about 40 lb. (18.2 kg); the average size of turbot is about 7 lb. (3.2 kg); plaice are about 10 lb. (4.54 kg); other species are smaller.

Small flounder are caught with otter trawls. Aboard fishing boats, they are held in pens or boxes in ice, as are cod, but these fish are not eviscerated prior to icing. On the West Coast, halibut are caught with long lines. The fish are eviscerated, the gills are removed, and they are placed in hold pens in ice much in the same manner as described for cod, but in this case, the "poke" (belly cavity) is also filled with ice. Small flounders, to be sold either fresh or frozen, are handled, packed, and distributed similarly to cod fillets.

Halibut are handled in both the fresh and frozen state. As the fresh product, the fish are beheaded, washed, and packed in ice in boxes. Then they are shipped from the West Coast to the Midwest or the East Coast under refrigeration. If the fish are small, they may be sold by distributors to retailers as received. If the fish are large, they may be sold to retailers as portions. Frozen halibut are decapitated, washed, and placed on racks in freezer rooms at 0 °F (−17.8 °C) or below until shipped to distributors in the frozen state. Small halibut, after freezing, may be sawed into steaks, trimmed, and packaged in moisture-vapor-proof plastic film as 12, 14, or 16-oz (340-, 397-, or 454-g) portions.

2.8 Other Fish

Many species of fish are not discussed to any extent in this chapter, for example, bluefish, butterfish, croaker, red and black drum, eels, groupers, mullet, ocean perch (fairly important fish of small size, caught with otter trawls handled aboard boats in the iced un-eviscerated state, and processed as fresh or frozen fillets), pompano, rockfish, sablefish, sea trout, red and other snappers, spot, striped bass, swordfish and other marine species, as well as freshwater fish, such as buffalo fish, carp, catfish, chubs, cisco, trout, and whitefish.

Currently, there is a considerable fish farming industry in the US in which catfish and trout are grown in freshwater ponds. In many countries, carp and tilapia are grown in freshwater ponds and harvested as food for humans (Sect. 2.2).

3 Shellfish

3.1 Bivalve Mollusks (Class Pelyopoda)

There are other mollusks, besides bivalves, that are used as food for humans; squid is among them. In the US, the mollusks used chiefly for food are oysters, a number of clam varieties, and scallops (Cheng and Capps Jr. 1988). As noted above the market for shellfish products is about half of the value for fin fish (Sect. 1.3).

Oysters and other bivalves may be eaten raw or without cooking. Therefore, great care must be taken to make sure that bivalve growing areas are not polluted with even traces of human excrement. Control of bivalve harvesting areas is supervised by a division of the Food and Drug Administration but must be effected by state authorities. Another safety issue, arises because clams and mussels that feed mainly on algae may at times become toxic to humans (shellfish poisoning). This happens when bivalves feed on certain algae (dinoflagellates) containing substances that are toxic to humans but not to mollusks. Public health officials periodically test bivalves for toxin and close the shellfish beds when there is danger of shellfish poisoning outbreaks (Lipp & Rose 1997; Sobel and Painter 2005; James et al. 2010).

3.1.1 Oysters

There are five species of oysters in the US, three on the East Coast, and two on the West Coast, one of which was introduced from Japan (Lavoie 2005; Vilanova 2014). Oysters are harvested with rakes, tongs, dredges, or with water-jet vacuum dredges (Fig. 20.5). The boat used to harvest bivalves should be outfitted with a chemical toilet so that oyster-growing areas will not be polluted with human discharges.

At the processing plant, oysters in the shell are washed with cold seawater (with or without sanitizer), packed in sacks or barrels, and shipped to restaurants at temperatures between 32 °F and 40 °F (0 °C and 4.4 °C). Most oysters are shucked (meats removed from the shell) by hand with the aid of a knife. The meat is washed with fresh potable water, graded for size, and packed in jars or metal containers and shipped to market in crushed ice at a temperature about 33 to 34 °F (0.6–1.1 °C). Some shucked oysters are frozen and stored at 0 °F (−17.8 °C) or below until shipped to market. Finally, oysters is also breaded, packed in waxed paperboard cartons holding 10–14 oz. (284–397 g) of product, then frozen. Oysters may be eaten raw from the half shell or in stews (lightly heated in milk with some butter), or breaded and deep-fat fried. In addition, there is available canned smoked oyster, canned boiled oyster, dried oyster, salt-fermented oyster and oyster juice (Park et al. 1988).

3.1.2 The Hard-Shell Clam

The hard-shell clam is similar to the oyster in its internal structure. The shell is rounded, symmetrical, and relatively smooth on the outside, coming to a gradual peak near the hinge. The shell is quite hard and thick.

Hard-shell clams may be harvested by hand (feeling for them with the hands or feet and removing them by hand). They may also be removed from shallow water with clam rakes. The largest quantities of this clam are harvested with scratch rakes, with tongs similar to those used to remove oysters, or with dredges. Dredges are used in comparatively deep water and may be of the basket or water-jet type. Aboard boats, hard-shell clams should be handled in the manner described for oysters.

In preparing them for market, hard-shell clams are washed with seawater, graded for size, and cooled. Some clams may be taken from semi polluted waters, provided they are depurated.

In the shell, hard-shell clams are marketed according to size. The different sizes are “chowders” (large size), which are used to prepare chowders, fritters, or stuffed clams; “cherrystones” (medium size), which are used for baking; and “littlenecks” (small size), which are used as steamed clams or for eating raw on the half shell. Hard-shell clams are neither canned nor frozen in significant quantities.

3.1.3 The Soft-Shell Clam

The soft-shell clam is found in the Western Atlantic as far north as the Arctic regions and as far south as Virginia, being most plentiful off the coasts of New England, New Jersey, and Virginia. In New England, soft-shell clams are harvested when the tide is low by digging into the mud with the short-handled clam hoe and removing them by hand. In the Chesapeake Bay area, clams are harvested from boats using water-jet dredges and an escalator.

They are placed in bags or baskets and brought to the processing plant, where they are washed with seawater and sorted according to size. Specimens 3 in. (7.6 cm) in length or smaller are usually cooked by steaming. The larger-sized clams are removed from the shell by hand and placed in metal containers, after which the containers are refrigerated by being surrounded with crushed ice. In this form, they are shipped to restaurants to be served as a breaded, deep-fat-fried product. Soft shell clams may be removed from restricted areas and depurated.

3.1.4 Surf Clams

The surf clam or “skimmer” is large, reaching a length of 8 in. (20.3 cm). It is found just below the surface of sandy bottoms in waters 30–100 ft. (9–30 m) deep off Atlantic Coast states from Massachusetts to Virginia. Most of the harvesting of this species is done off New Jersey with water-jet dredges having V-shaped scoops. Aboard the boats, the clams are placed in baskets or jute bags and brought to the processing plant without refrigeration.

Surf clams are used primarily for canning. The viscera are not utilized as food. At the canning plant, the clams are washed, then steamed lightly to cook the meat partially and so the shell will open. The meat is then removed by hand, the nectar (liquid left in the shell) being saved. The lower part of the neck (syphon), the mantle, the adductor muscle, and the foot (muscular portion that allows the clam to anchor itself in the mud) are then removed with scissors and diced into pieces about 3/8 in. (1 cm) wide. The diced portions are then filled into cans together with some hot nectar and salt, after which the cans are sealed and heat-processed.

3.1.5 Other Clams

Other species of clams used as human food include the butter clam and pismo clam harvested off the West Coast and the ocean quahog harvested off the East Coast. The latter is not as large, nor as much in demand, as the surf clam, but is used to help fill the demand for surf clam, which exceeds its supply.

Mussels that resemble soft-shell clams, except for the color of the shell and other minor differences, are used to some extent to help fill the demand for soft-shell clams, of which there is an insufficient supply.

3.1.6 Scallops

There are several types of scallops, of which the sea scallop and the bay scallop are best known. The internal anatomy of the scallop is similar to that of the oyster, but the adductor muscle, the only part of the scallop that is eaten, is much larger than those of oysters are and clams are. Once beyond the larval stage, the scallop may attach itself temporarily to some object, but the adult scallop is quite mobile. By closing the opened shell with its adductor muscle, thus forcing water through two holes in the top shell, the scallop becomes jet propelled. These bivalves cannot be held out of water in the live state, as can clams and oysters, since the water drains from the shell, which cannot be tightly closed.

The bay scallop is generally circular in shape with a grooved upper and lower shell and a rectangular projection at the back near the ligament (the bay scallop is the logo that can be seen in any Shell Gasoline sign). The bay scallop reaches several inches (1 in. = 2.54 cm) in diameter, and the adductor muscle may be as large as 1 in. (2.54 cm) in diameter. Bay scallops are harvested with basket rakes in shallow water and with dredges in deeper water.

The sea scallop is much larger than the bay type. It may reach a size of 8 in. (20.3 cm) in diameter, and the adductor muscle may be as large as 3 in. (7.6 cm) or more in diameter. Unlike the bay scallop, the shell of the sea scallop is not grooved. Sea scallops are found in ocean waters 60 ft. (18.3 m) or more in depth. While this bivalve ranges from Labrador to New Jersey, it is most plentiful on Georges Bank off Cape Cod. Sea scallops are harvested with dredges. Aboard the boat, the "eyes" or adductor muscles are removed from the bivalves with the aid of a knife, placed in muslin bags, and iced and brought this way to port. The remaining portions are discarded at sea. Sea scallops are sold in the fresh or frozen form. If frozen for purposes of selling after defrosting, they are placed in freezer rooms in muslin bags and held until shipped to retailers. Some sea scallops are breaded and may be deep-fat-fried prior to packaging and freezing. At 0 °F (−17.8 °C), the storage life of scallops is longer than 1 year. Other species of scallops include the calico scallop, found off the coast of Florida, and bay-type scallops, found off the coasts of Alaska and Australia and in the Irish sea.

3.2 Crustaceans(Class Decapoda)

Several types of crustaceans are used as food for humans, most of which are prized as delicacies. Included among these are shrimp (several species); lobsters (American, European, and Norwegian species); crabs (several species); and crayfish (several marine species and the freshwater species). Although the shells of Crustacea vary in color, they all turn pink when cooked.

Crustaceans have a hardened external skeleton made up of a calcified polymer of glucosamine (a six-carbon sugar containing an amine [NH2] group) called chitin.

The external anatomy of crustaceans consists of the mouth parts, the eyes, the antennae (varying greatly in size), the body or cephalothorax to which five pairs of legs are attached, and the abdomen or tail consisting of a number of jointed segments adjoined to the body. In some crustaceans, the first pair of legs is chelate or enlarged and developed into biting and crushing appendages called "claws." The end section of the tail has several parts, including the fan-shaped telson. In some species, the tail may be contracted or flexed to provide for movement in the water. On the underside of the tail, there are a number of attachments called pleopods or "swimmerets," which species are the main appendages providing for movement in the water. Some crustaceans will shed an injured claw, then generate and grow a new one.

Crustaceans grow by shedding the old shell (molting) to become soft-shelled for a short period (the new larger shell soon becomes hard) and filling up the new larger shell, which allows more room for growth; molting occurs most frequently in the early years of growth. Mating takes place when the female is in the soft shell stage. The fertilized eggs are attached to the swimmerets, are eventually hatched, and after several larvae stages the small crustaceans sink to the bottom and assume the general habits of the adult.

3.2.1 Lobsters

Lobsters have either a well-developed first pair of walking legs or biting claws. The European lobster is found around certain parts of the British Isles and mainland Europe. The Norwegian lobster is found mainly around the coast of Norway and the west coast of Sweden. The American lobster ranges from Labrador to the coast of North Carolina in an area that extends seaward for a distance of 50 miles (80 km). However, there are deep-sea lobsters found more than 200 miles (322 km) from the coast. The depth of water where lobsters are taken is usually 30–150 ft. (9–46 m), but deep sea lobsters live at a depth up to 1200 ft. (366 m). The American lobster is most abundant off the coasts of Maine and the maritime provinces of Canada. The average American lobster caught measures 9–10 in. (23–25 cm), weighs 1to 2 lb. (454–908 g), and is 4–7 years old. However, deep-sea lobsters are larger, and specimens weighing more than 40 lb. (18 kg) have been caught that are believed to be more than 50 years of age. The food of lobsters include fish, clams, and other mollusks.

Lobsters are caught in pots (Fig. 20.5) and are held in the live state aboard boats without refrigeration, because they are brought to port shortly after harvesting. Lobsters may be held in the live state, out of water at low temperatures above freezing, for more than 1 week, if given sufficient air space, because they are able to obtain oxygen from what dissolves in the water on their gills (the gills must be kept moist). They may also be held in the live state for a month or more in ocean pounds, which allow the free flow of water, or in tanks in which seawater is filtered, aerated, and circulated. When lobsters are held in tanks, the biting claws may be immobilized by the insertion of a wooden plug into the flesh above the thumb or by an elastic band encircling the thumb and claw.

Lobsters are sold mostly to restaurants or to the consumer, in the live state. Lobsters should be cooked from the live state or killed and cooked immediately. The reason for this is that lobsters have a very active proteolytic enzyme system that soon digests part of the tissue of the dead lobster, partially liquefying the meat or causing it to become soft and crumbly (a condition known as "short meated"). Some cooked lobster meat is sold as a canned or frozen product but does not make up a significant part of the catch. The storage life of cooked frozen lobster meat at 0 °F (−17.8 °C) is at least 8 months. Whole lobsters in the raw, cooked, or partially cooked state cannot be frozen successfully, because when frozen in the cooked state, the tomalley (liver) becomes rancid and affects the flavor of the meat, and, when frozen raw or in a partially cooked state, the flesh undergoes proteolysis.

3.2.2 Shrimp

There are numerous species of shrimp used as food for humans. The edible types vary in size from very small, about 2 in. (approximately 5 cm), to more than 10 in. (25 cm). The larger shrimp are called prawns. The overall size of Gulf shrimp as caught is 7–8 in. (17–20 cm). Most shrimp caught by U.S. fishermen are taken from the Gulf of Mexico, and these consist of three main types: white, brown, and pink. Some shrimp are taken from Atlantic waters off the Carolinas, Georgia, and Florida, and some are taken off Alaska, Maine, and Massachusetts. Shrimp are imported from Mexico, India, Panama, Venezuela, Brazil, Guiana, Ecuador, Nicaragua, Colombia, El Salvador, Honduras, Thailand, Surinam, Malaysia, and other countries.

Shrimp are caught with otter trawls that are somewhat modified from those used to catch cod and haddock. In some instances, two boats may be used to tow the trawl attached to an outrigger. Aboard the boat, all but the tails of the shrimps are discarded. The tails are washed and stored in boxes or pens in ice.

At the processing plant, the shrimps may be peeled and deveined (the intestinal tract is removed), and they are washed. In some cases, shrimps are dipped in a solution of sodium tripolyphosphate to prevent softening of the texture and loss of water during storage. However, if excess amounts of this salt are absorbed, the cooked product will appear and have the texture of raw shrimp.

Shrimps may be frozen in a plate freezer where boxes of the product are frozen into shrimp blocks or the shrimps may be frozen individually using a liquid freezant (e.g., liquid nitrogen). Prior to freezing, some shrimps are butterflied (split longitudinally), and some may be cooked. Some frozen shrimp may be tempered (partially thawed) in order to coat them with a breading, and then refrozen.

Raw shrimp in the shell, when protected against dehydration, have a high-quality storage life of at least 2 years at 0 °F (−17.8 °C) or below. Cooked shrimp, especially those cooked in hot oil, have a storage life of 3–5 months at 0 °F (−17.8 °C). Uncooked shrimp, prepared and frozen in the butterfly form, are subject to storage changes. There is so much air space in the package that dehydration occurs through a continuing two-step process: (1) moisture from the product vaporizes and fills the voids and (2) moisture from the voids condenses on the inner surface of those parts of the package that are adjacent to the voids.

Frozen shrimp imported from other countries must be defrosted before they can be processed. This may be done by tempering the product at about 40 °F (4.4 °C) for 24 h, then completing defrosting by holding the unpackaged shrimp in running water. A more sanitary defrosting method-employing microwave heating is also used.

Considerable quantities of shrimp are canned. For this purpose, they may be delivered to the cannery with the heads on. The shrimp are first washed and separated from the ice. The tails are then removed from the heads. The shell is removed and the vein taken. Individual specimens are then inspected, and broken and decomposed shrimp are discarded and may be used for pet foods or fertilizers. The product is then blanched or heated in boiling saturated salt solution (25%) for a period of 45 s to 3 min. After blanching, the shrimp are graded for size and filled by machine into one of several can sizes. Hot, dilute salt solution is added to the product in the cans, and the cans are sealed immediately. Heat-processing to provide commercial sterility is carried out at 250 °F (121.1 °C) for various times depending on the size of the container.

In the Pacific Northwest and Alaska, very small shrimp may be canned without deveining. Shorter blanching times are used for this product and small amounts of citric acid are added to the brine used to cover the shrimp. The brine is added cold, and the cans are vacuum-sealed prior to the heat processing.

3.2.3 Blue Crabs

Crabs have the general anatomy of other crustaceans, but the body is oval-shaped or disc-like instead of cylindrical, as in lobsters, shrimp, and crawfish. Also, the abdomen (tail) is comparatively small, flattened, and permanently flexed under the body. Several species of crab are used as food by humans.

The blue crab is found from Nova Scotia to Mexico, including the Gulf of Mexico, and is especially abundant in the Chesapeake Bay region. It is commercially important only south of New Jersey. The semi oval body of the blue crab has spiked peaks near the back end. The first walking legs are well developed into biting claws and the last pair of legs (called back fins) is flattened and used to propel the crab in the water. When fully grown, these crustaceans measure 7 in. (15 cm) or more across the body. Crabs are caught with crab pots or traps or with trot lines.

Blue crabs are brought to the processing plant in the live state. They are then cooked in boiling seawater, or in steam. After cooking, the back shell, viscera, claws, and legs are removed; then the meat may be removed from the shell with the aid of a small, sharp knife. In hand picking, the body meat adjoining the back fin is separated from the finer body meat, as it is considered to be of better quality and of higher value. Certain machines are now available for removing crab meat from the shell. This may be done by impact, or a roller process may be applied to the cooked or partially cooked "debacked" body, legs, and claws. Somewhat better yields of meat are obtained by machine picking and much less labor is required to do the job, but machine picking does not provide for the separation of back fin lump meat from the other body meat, unless it is done by hand before the crabs are machine-processed.

After the meat has been picked, it is packed in metal cans that are then closed and heated in boiling water until an internal temperature (at the center) of 185 °F (85 °C) is reached. This temperature is maintained for 1 min. The product is then cooled and held at 33–38°F (0.6–3.3 °C) prior to distribution.

Blue crab meat is neither frozen nor heated-processed to the point of commercial sterility, because either treatment results in a product of poor quality. If blue crabs, when caught, are nearing the molting stage, they may be held in seawater pounds, until they shed their shells. They are then soft-shell crabs, and they are sold in the live state at a premium price, as soft-shell crabs are considered to be a delicacy. High mortality rates are usually encountered during the holding of crabs for molting.

3.2.4 Dungeness Crab

The Dungeness crab is found from the Alaskan peninsula to southern California but is most abundant in the area between San Francisco and southeast Alaska (California Department of Fish and Game 2000). It may attain a size of 9 in. (23 cm) across the back. It has well developed biting claws. Dungeness crabs are caught in water 12–120 ft. (3.7–36.6 m) deep. The circular pot is used in deep water, the rectangular pot in shallow water. Ring nets may also be used. Dungeness crabs are brought to port in the live state aboard the boat, held in wells of seawater, and may thereafter be held in tanks of seawater until sold to restaurants in the live state.

In processing, to obtain meat from Dungeness crabs, the back shell of the live crab is first removed, the viscera and gills are then torn away, and the body is broken in half with the legs attached. The sections are then cooked in boiling seawater for 10–12 min; then the meat is removed by hand by shaking or by affecting against a metal container or it may be removed by running the body and legs between mechanized rollers. Pieces of shell may then be separated by floating the meat in a salt solution of the appropriate specific gravity for the meat to float and the shell to sink. Fresh meat is packed in cans, the cans are sealed, and the product is held at 32–40 °F (0–4.4 °C) for purposes of distribution.

Some whole or eviscerated Dungeness crab is frozen in brine at 5 to 0 °F (−15 to −17.8°C), packaged or glazed, and stored at 0 °F (−17.8°C) for distribution in the frozen state. A larger amount of this type of crab meat is packed in hermetically sealed cans and frozen in moving air at 0 to −10 °F (−17.8 to −23 °C). This type of crabmeat is not especially stable in frozen storage but may be held for as long as 6 months at −10 °F (−23 °C) with good results.

Dungeness crab meat is also canned and heat-processed. The meat is packed in cans holding 6.5 oz. (185 g) of product. A weak solution of salt and citric acid (pH 6.6–6.8) is then added, covering the meat to prevent discoloration. The cans are then sealed and heat-processed at 240 °F (115.6 °C) for 60 min, then cooled in the retort. The quality of this product is inferior to that of the fresh meat.

3.2.5 King Crab

This species is not a true crab but is similar to crabs in structure and habits. It is much larger than other crabs, attaining a spread of about 5 ft. (1.5 m) and a weight of about 24 lb. (10.9 kg).

King crabs are caught off central Alaska to the Aleutian Islands and off the islands of northern Japan. They are harvested with large rectangular pots. Aboard boats, the crabs are held in the live state in wells of circulating seawater.

King crab meat is either canned or frozen. In canning, the whole crab is cooked in boiling water, after which the meat is squeezed out between rubber rollers. The meat is then washed, packed in cans in a weak brine, and the cans are sealed, heat-processed, cooled, and stored.

The meat may be frozen in large blocks for the restaurant trade. The legs and claws are also frozen for retail outlets and restaurants. If properly packaged, and frozen to a temperature of 0 °F (−17.8 °C) or below and held at this temperature, King crab meat has a high-quality storage life of at least 12 months. Lower storage temperatures provide for an even longer storage life.

3.2.6 Snow or Tanner Crab

This species is relatively large, reaching a size of 5–6 in. (12.7–15.2 cm) across the back and 2.5 ft. (76.2 cm) between the tips of the outstretched legs. The snow crab is taken in deep water off central and eastern Alaska and in the Bering Sea and some is taken off Nova Scotia and Newfoundland. Itis caught in large, baited pots, as is the King crab.

Snow crabs are handled and processed in much the same manner as are King crabs, but most of the meat is canned and heat-processed. The meat of the snow crab is inferior to that of the King crab.

3.2.7 Red Crab

The red crab is found from Nova Scotia to South America but is taken almost entirely in deep waters off southern New England. Red crabmeat is removed mechanically from the debacked, partially cooked specimens with machinery employing the roller process. Red crabmeat is sold mostly as the fresh cooked refrigerated product but some is sold as frozen.

3.2.8 Jonah Crab

The Jonah crab is found in waters from Nova Scotia to North Carolina and is caught in lobster pots. The meat of this crab is difficult to remove from the shell, and the product is sold mostly as cooked refrigerated or frozen whole crabs or claws.

3.2.9 Marine Crayfish

The crayfish or spiny lobster has become a popular food in the US. There are a number of different species of marine crayfish ranging from Florida and the Gulf of Mexico to Central and South America. They are also found off Australia, New Zealand, South Africa, and other countries. These species have the general anatomies of lobsters, but the first pair of walking legs is not developed into biting claws.

Because only the tail portion is eaten, this is removed from the live specimen, packaged, with shell on, in moisture-vapor-proof material, and frozen, for sale to restaurants or for the retail trade.

3.2.10 Freshwater Crayfish

Freshwater crayfish are grown in ponds. Although they have the general anatomy of the true lobster, with well-developed biting claws, they are much smaller, the maximum weight being about 8 oz. (227 g). There is at present a small industry in which the small crayfish are placed in rice fields after the rice has been harvested. Here, they eat the rice roots and also serve to fertilize the fields. By planting time, the fields can be drained and the crayfish harvested. Generally, these specimens are handled in the fresh, refrigerated state and are processed only by cooking.

4 Surimi

Japanese fisherman found nearly 900 years ago that if they minced and washed the fish and mixed it with salt and spices, ground it to a paste, then cooked it by steaming or broiling, it would last much longer than fresh fish (Nicklason 1993). The product is called surimi. Surimi is not itself a foodstuff but is an intermediate raw material from which the traditional Japanese kneaded foods called “kamaboko” are made (Park 2013).

The word “surimi” literally means “minced meat.” Surimi is more than minced meat, as it has gel-forming capacity and has long-term stability in frozen storage. It gains these qualities from the addition of sugars as cryoprotectants. When fish muscle is separated from bones, skin, and entrails, and then comminuted, it is called minced meat (Park 2013).

Minced fish becomes raw or unfrozen surimi after it has been washed to remove fat and water-soluble constituents. The raw surimi is quite bland in flavor and the washing removes water-soluble components, thus isolating the meat's myofibrillar protein. This protein is water insoluble and gives the surimi the excellent gel-forming capacity.

When raw surimi is mixed with anti-denaturants and frozen, the product is called frozen surimi. Sugar compounds such as sucrose and sorbitol are often added as anti-denaturants or cryoprotectants. The production of frozen surimi is shown in Fig. 20.10. Surimi-based products have other ingredients added to give the product desired flavor, color, and texture. An example of the formulation of a crab leg-type product is shown in Figs. 20.11 and 20.12.

Surimi has been made from Alaska Pollock but other fish such as sardine and mackerel have been used and some very high quality surimi and surimi-based products have been produced. Some examples of different surimi-based products are shown in Figure 20.12.

5 Further Reading

About 75% of the earth's surface is covered with water, which provides a large and apparently limitless supply of seafood, except that it is not inexhaustible. Amongst the many interesting topics not covered in this short discussion, the sustainability of future fish stocks is amongst the most important (Jennings et al. 2016). The production of fish protein concentrates from fish waste and underutilized parts has also received considerable attention in the past (Ariyawansa 2000; Kristinsson and Rasco 2000). The potential for various sea foods to contain toxins such as heavy metals and organophosphorus compounds is one reason why expectant mothers are advised to reduce fish consumption (Pompa et al. 2003). Another interesting aspect worth further reading is in the area of fish and seafood allergy (Moonesinghe et al. 2016; Pedrosa et al. 2015).

Some of the main types of shellfish used for human food and the manner of their production, preparation and processing were described. However, the focus was on mollusks (oysters, clams and scallops) and crustaceans (lobsters, shrimps, crabs and crayfish) which are most important in the US. Other shellfish groups that are also deserving of further discussion include the, gastropods (e.g. snails and whelk) and cephalopods e.g. squid, octopus and cuttlefishes (Duncan 2003; Granata et al. 2012; Vilanova 2014).

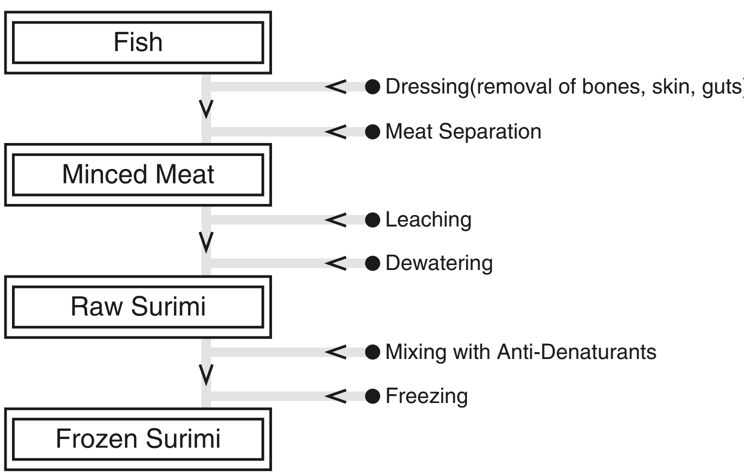


Fig. 20.10 Production of surimi

Fig. 20.11 Manufacturing of a crab-leg type product

Manufacturing Process

Alaskan Pollock Surimi (frozen)
♦
Thawing in De-Freezing Machine with Hot Water
♦
Cutting in Silent Cutter
♦
Blend in Blender [Silent Cutter] with Salt and Starch
♦
Knead in Mixing and Kneading Machine [Silent Cutter] with Additives [flavor, sugar, etc.]
♦
Meat Conveying Pump
♦
Sheet Forming in Sheet Farming Machine
♦
Setting in Baking and Steaming Machine
♦
Cooling in Cooling Machine
♦
Cutting into Strings in Cutting Machine
♦
Color Paste Film in the Color Hopper
Wrapping and Forming Crab Leg-Type in Coloring Hopper
♦
Packing in Vacuum Packing Machine
♦
Fixation of Gel and Sterilization in Boil Style Sterilizer
♦
Cooling in Cooling Tank
♦
Drying in De-Watering Conveyor

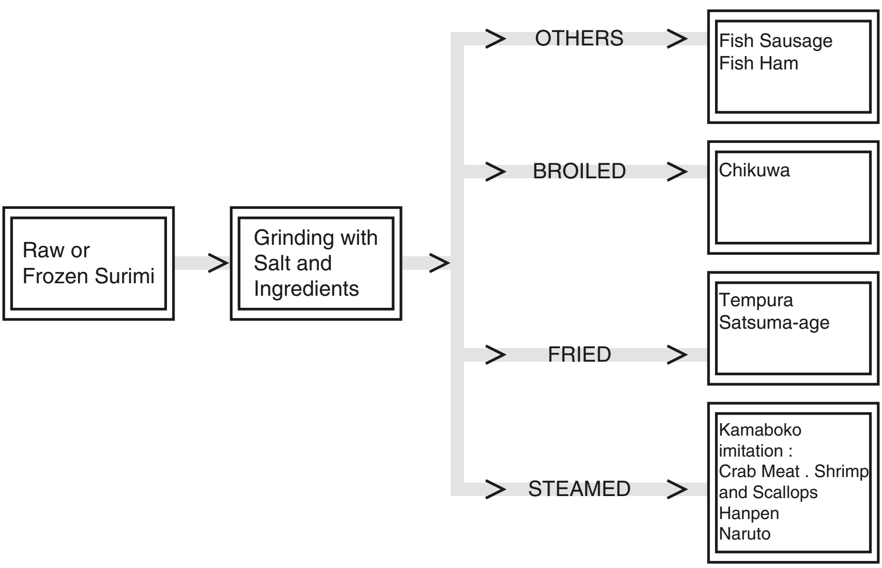


Fig. 20.12 Different surimi-based products

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