national inland fisheries and may not be indicative of an overall national trend.

It might be possible to derive an overall picture of the state of the world's inland fisheries resources by monitoring the state of major inland fisheries at river basin level. Inland fisheries vary notably from year to year because they are influenced not only by fishing pressure but also by often dramatic fluctuations in climatic conditions (rainfall, temperature and seasonal effects), water dynamics (flooding, water flow and connectivity), nutrient availability, water quality and pollution. Tracking such changes in river basins over a five- to ten-year period would help describe and explain trends in inland fisheries.

At the country level, it could be beneficial to monitor the catch and identify key drivers in nationally important inland fisheries – those with high overall production (and thus contribution to national catch) or high participation (e.g. dispersed floodplain fisheries). It could then be possible to determine a national trend and the fisheries (floodplain, riverine, wetland, human-made and natural water bodies) driving it. The tracking of a number of fishery-relevant indicators (e.g. environmental drivers and fisheries production) would also make it possible to identify underlying causes of declines (overexploitation, environmental change). FAO is currently evaluating options of how to establish an approach for inland fishery assessment which would enable member countries to track key fisheries both for global tracking of inland fishery resources and for national policy and management responses. ■

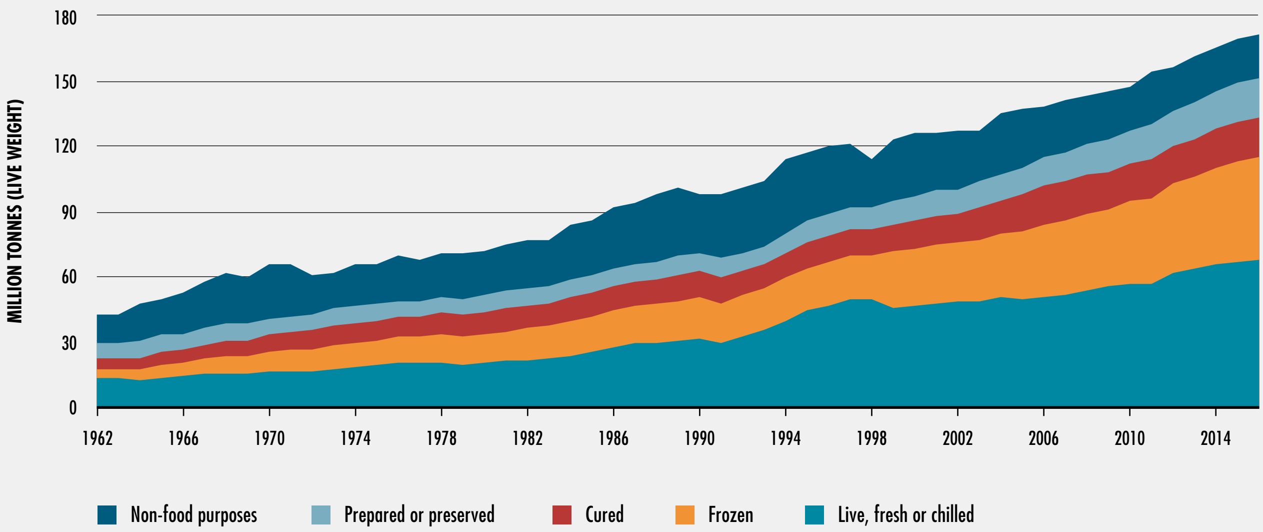
FISH UTILIZATION AND PROCESSING

Fish is a versatile food commodity; the wide variety of species can be prepared in many different ways. As fish can spoil more rapidly than many other foods, post-harvest handling, processing, preservation, packaging, storage and transportation require particular care to maintain its quality and nutritional attributes and avoid waste and losses. Preservation and processing can reduce the rate of spoilage and thus allow fish to be distributed and marketed worldwide in a wide range of product forms destined for food or non-food uses, from live organisms to more complex preparations. Food processing and packaging technology is being developed in many countries, with increases in the efficiency, effectiveness and profitability of the use of raw materials and innovation in product diversification. Moreover, expansion in the consumption and commercialization of fish products in recent decades (see section on consumption later in Part 1) has been accompanied by growing interest in food quality and safety, nutritional aspects and waste reduction. In the interests of food safety and consumer protection, increasingly stringent hygiene measures have been adopted at the national and international trade levels. For example, the Codex Code of Practice for Fish and Fishery Products (Codex Alimentarius Commission, 2016) provides guidance to countries on practical aspects of implementing good hygienic practices and the Hazard Analysis Critical Control Point (HACCP) food safety management system (see also "International trade, sustainable value chains and consumer protection" in Part 3).

In 2016, of the 171 million tonnes of total fish production, about 88 percent or over 151 million tonnes were utilized for direct human consumption (Figure 17). This share has increased significantly in recent decades, as it was 67 percent in the 1960s. In 2016, the greatest part of the 12 percent used for non-food purposes (about 20 million tonnes) was reduced to fishmeal and fish oil (74 percent or 15 million tonnes), while the rest (5 million tonnes) was largely utilized as material for direct feeding in aquaculture and raising of livestock and fur animals, in culture (e.g. fry, fingerlings or small adults for ongrowing), as bait, in pharmaceutical uses and for ornamental purposes.

Live, fresh or chilled is often the most preferred and highly priced form of fish and represents the largest share of fish for direct human consumption, 45 percent in 2016, followed by frozen (31 percent), prepared and preserved (12 percent) and cured (dried, salted, in brine, fermented smoked) (12 percent). Freezing represents the main method of processing fish for human consumption; it accounted for 56 percent of total processed fish for human consumption and 27 percent of total fish production in 2016.

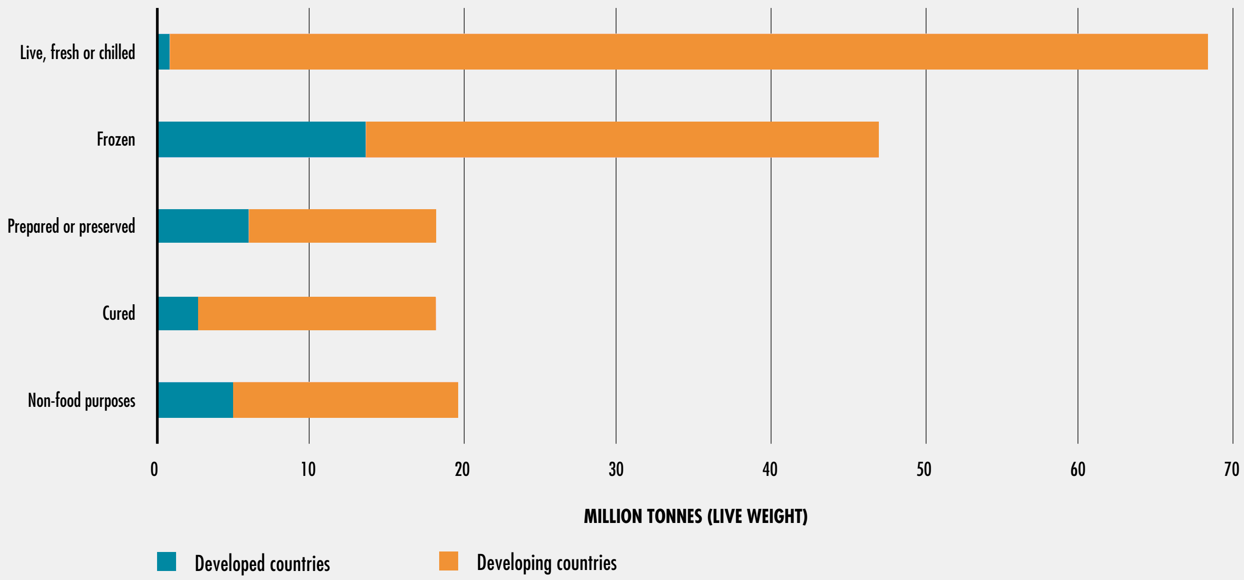
FIGURE 17
UTILIZATION OF WORLD FISHERIES PRODUCTION, 1962–2016



The global averages mask significant differences in the utilization of fish and, more significantly, processing methods among regions and countries and even within countries. Latin American countries produce the highest percentage of fishmeal. In Europe and North America, fish in frozen and prepared and preserved forms represents more than two-thirds of the production of fish used for human consumption. In Africa, the proportion of cured fish is higher than the world average. In Africa and Asia, a large amount of production is commercialized in live or fresh form. Live fish is principally appreciated in eastern and southeastern Asia (especially by the Chinese population) and in niche markets in other countries, mainly among immigrant Asian communities.
Commercialization of live fish has grown in recent years as a result of technological developments, improved logistics and increased demand. Systems for transporting live fish range from simple artisanal systems of plastic bags with an atmosphere supersaturated with oxygen, to specially designed or modified tanks and containers, and on to sophisticated systems installed in trucks and other vehicles that regulate temperature, filter and recycle water, and add oxygen. Nevertheless, marketing and transportation of live fish can be challenging, as they are often subject to stringent health regulations, quality standards and animal welfare requirements (in the European Union, for example). In China and some Southeast Asian countries, live fish have been traded and handled for more than 3 000 years; practices are based on tradition and are not formally regulated.

Major improvements in processing as well as in refrigeration, ice-making and transportation have allowed increasing commercialization and distribution of fish in a greater variety of product forms in the past few decades. For example, in developing countries growth has been seen in the share of production destined for human consumption that is utilized in frozen form (from 3 percent in the 1960s to 8 percent in the 1980s and 26 percent in 2016) and in prepared or preserved form (from 4 percent in the 1960s to 9 percent in 2016) (Figure 18). However, developing countries still mainly use fish in live or fresh

FIGURE 18
UTILIZATION OF WORLD FISHERIES PRODUCTION: DEVELOPED VERSUS DEVELOPING COUNTRIES, 2016



form (53 percent of the fish destined for human consumption in 2016), soon after landing or harvesting from aquaculture. Fish preserved using traditional methods such as salting, fermenting, drying and smoking – particularly customary in Africa and Asia – represented 12 percent of all fish destined for human consumption in developing countries in 2016.

In developed countries, most fish production destined for human consumption is retailed in frozen, prepared or preserved form. In these countries, the share of frozen fish has risen from 27 percent in the 1960s, to 43 percent in the 1980s, to a record high of 58 percent in 2016. Prepared and preserved forms accounted for 26 percent, while cured forms accounted for 12 percent.

In recent decades, the fish food sector has become more heterogeneous and dynamic. In more advanced economies, fish processing has diversified particularly into high-value fresh and processed products and ready and/or portion-controlled, uniform-quality meals. In many developing countries, fish processing has been evolving from traditional methods to more advanced value-adding processes such as breading, cooking and individual quick-freezing, depending on the commodity and market value. Some of these developments are driven by demand in the domestic retail industry, shifts in available species, outsourcing of processing, and producers' increasing linkages with, and coordination by, processors and large firms and retailers, sometimes outside the country. Supermarket chains and large retailers are increasingly the key players in setting product requirements and influencing the expansion of international distribution channels. Processors and producers are working together more closely to enhance the product mix, obtain better yields and respond to evolving quality and safety requirements in importing countries as well as consumers' sustainability concerns (which have led to the emergence of multiple certification systems, discussed under "International trade, sustainable value chains and consumer protection" in Part 3). In addition, the outsourcing of processing activities to other countries and regions is common, although its extent depends on the species, product form, cost of labour and transportation. Further outsourcing of production to developing countries might be constrained by sanitary and hygiene requirements that are difficult to meet, by growing labour costs in some countries (particularly in Asia) and by higher transport costs. All of these factors could lead to changes in distribution and processing practices and to increases in fish prices.

Despite the technical advances and innovations, many countries, especially less developed economies, still lack adequate infrastructure and services for ensuring fish quality, such as hygienic landing centres, electric power supply, potable water, roads, ice, ice plants, cold rooms, refrigerated transport and appropriate processing and storage facilities. This shortcoming, especially when associated with tropical temperatures, can result in high post-harvest losses, as fish can spoil in the boat, at landing, during storage or processing, on the way to market and while awaiting sale. In Africa, some estimates put post-harvest losses at 20 to 25 percent, and even up to 50 percent, and deterioration of quality can account for more than 70 percent of the loss (Akande and Diei-Ouadi, 2010). Throughout the world, post-harvest fish losses are a major concern and occur in most fish distribution chains; an estimated 27 percent of landed fish is lost or wasted between landing and consumption. As noted in the discussion of post-harvest loss and waste in Part 3 (see "International trade, sustainable value chains and consumer protection"), when discards prior to landing are included, 35 percent of global catches are lost or wasted and therefore not utilized (Gustavsson *et al.*, 2011).

A significant, but declining, proportion of world fisheries production is processed into fishmeal and fish oil. This portion contributes indirectly to human food production and consumption when these ingredients are used as feed in aquaculture and livestock raising. Fishmeal is a proteinaceous flour-type material obtained after milling and drying of fish or fish parts, while fish oil is obtained through the pressing of the cooked fish and subsequent centrifugation and separation. These products can be produced from whole fish, fish trimmings or other fish by-products resulting from processing. Many different species are used for fishmeal and fish oil production, small pelagic species predominating. Many of the species used, such as anchoveta (*Engraulis ringens*), have comparatively high oil yields but are rarely used for direct human consumption.

Fishmeal and fish-oil production fluctuate according to changes in the catches of these species. Anchoveta catches, for example, are dominated by the El Niño phenomenon, which affects stock abundance (see section on capture fisheries production). Over time, adoption of good management practices and the implementation of certification schemes have decreased the volumes of catches of species targeted for reduction to fishmeal. Fishmeal production peaked in 1994 at 30 million tonnes (live weight equivalent) and has followed a fluctuating but overall declining trend since then. In 2016, landings from fisheries directed for fishmeal production were down to less than 15 million tonnes (live weight equivalent) because of reduced catches of anchoveta. Owing to the growing demand for fishmeal and fish oil, in particular from the aquaculture industry, and coupled with high prices, a growing share of fishmeal is being produced from fish by-products, which previously were often wasted. It is estimated that by-products account for about 25 to 35 percent of the total volume of fishmeal and fish oil produced, but there are also regional differences. For example, by-product use in Europe is comparatively high at 54 percent (Jackson and Newton, 2016). With no additional raw material expected to come from whole fish caught by reduction-dedicated fisheries (in particular, small pelagics), any increase in fishmeal production will need to come from use of by-products, which can, however, have a negative impact on its nutritional value as feed (see the section on projections in Part 4).

Fish oil represents the richest available source of long-chain polyunsaturated fatty acids (PUFAs), important in human diets for a wide range of critical functions. However, the Marine Ingredients Organisation (IFFO) estimates that approximately 75 percent of annual fish oil production still goes into aquaculture feeds (Auchterlonie, 2018). Because of the variable supply of fishmeal and fish oil production and associated price variation, many researchers are seeking alternative sources of PUFAs, including large marine zooplankton stocks such as Antarctic krill (*Euphausia superba*) and the copepod *Calanus finmarchicus*, although concerns remain over the impacts for marine food webs. However, the cost of zooplankton products is too high for their inclusion as a general oil or protein ingredient in fish feed. Krill oil in particular is destined for products for direct human consumption. Krill meal is finding a niche in production of certain aquafeeds.

Fishmeal and fish oil are still considered the most nutritious and most digestible ingredients for farmed fish feeds, but their inclusion rates in compound feeds for aquaculture have shown a clear downward trend, largely as a result of supply and price variation. They are increasingly used selectively, for example for specific stages of production, particularly for hatchery, broodstock and finishing diets. Their incorporation in grower diets has decreased over time. For example, their share in grower diets for farmed Atlantic salmon is now often less than 10 percent.

Fish silage (Kim and Mendis, 2006), a rich source of protein hydrolysate, is a less expensive alternative to fishmeal and fish oil and is increasingly important as a feed additive, for example in aquaculture and in the pet food industry. Obtained by preserving whole fish or fish by-products with an acid and letting enzymes from the fish hydrolyse the proteins, silage has potential to increase growth and reduce mortality of animals that receive it in their feed.

The expansion of fish processing is creating increasing quantities of offal and other by-products, which may constitute up to 70 percent of fish used in industrial processing (Olsen, Toppe and Karunasagar, 2014). In the past, fish by-products were often thrown away as waste; used directly as feed for aquaculture, livestock, pets or animals reared for fur production; or used in silage and fertilizers. However, other uses of fish by-products have been gaining attention over the past two decades, as they can represent a significant source of nutrition and can now be used more efficiently as a result of improved processing technologies. In some countries, the use of fish by-products has developed into an important industry, with a growing focus on their handling in a controlled, safe and hygienic way. Fish by-products are usually only placed on the market after further processing because of consumer preferences and sanitary regulations, which may also govern their collection, transport, storage, handling, processing, use and disposal.

Fish by-products can serve a wide range of purposes. Heads, frames and fillet cut-offs and skin can be used directly as food or processed into fish sausages, cakes, snacks (crispy snacks, nuggets, biscuits, pies), gelatin, sauces and other products for human consumption. Small fish bones, with a minimum amount of meat, are consumed as snacks in some Asian countries. By-products are also used in the production of feed (not only in the form of fishmeal and fish oil), biodiesel and biogas, dietetic products (chitosan), pharmaceuticals (including oils), natural pigments, cosmetics and constituents in other industrial processes. Some by-products, in particular viscera, are highly perishable and should therefore be processed while still fresh. Fish viscera and frames are a source of potential value-added products such as bioactive peptides for use in food supplements and in biomedical and nutraceutical industries (Senevirathne and Kim, 2012). Shark by-products (cartilage, but also ovaries, brain, skin and stomach) are used in many pharmaceutical preparations and reduced to powder, creams and capsules. Fish collagens are used in cosmetics and in extraction of gelatin.

The internal organs of fish are an excellent source of specialized enzymes. A range of proteolytic fish enzymes are extracted, e.g. pepsin, trypsin, chymotrypsin, collagenases and lipases. Protease, for example, is a digestive enzyme used in the manufacture of cleaning products, in food processing and in biological research. Fish bones, in addition to being a source of collagen and gelatin, are also an excellent source of calcium and other minerals such as phosphorus, which can be used in food, feed or food supplements. Calcium phosphates present in fish bone, such as hydroxyapatite, can help hasten bone repair after major trauma or surgery. Fish skin, in particular from larger fish, provides gelatin as well as leather for use in clothing, shoes, handbags, wallets, belts and other items. Species commonly used for leather include shark, salmon, ling, cod, hagfish, tilapia, Nile perch, carp and seabass. Shark teeth are used in handicrafts.

As the production and processing of crustaceans and bivalves have increased, efficient use of their shells has become important, not only to maximize financial return, but also to address waste disposal problems because of their slow natural degradation rate. Chitosan, produced from shrimp and crab shells, has shown a wide range of applications, for example in water treatments, cosmetics and toiletries, food and beverages, agrochemicals and pharmaceuticals. Crustacean wastes also yield pigments (carotenoids and astaxanthin) for use in the pharmaceutical industry. Mussel shells provide calcium carbonate for industrial use. In some countries, oyster shells are used as a raw material in building construction and in the production of quicklime (calcium oxide). Shells can also be processed into pearl powder, used in medicines and cosmetics, and shell powder, a rich source of calcium in diet supplements for livestock and poultry. Scallop and mussel shells are used in handicrafts and jewellery, and for making buttons.

Research has revealed a number of anticancer agents in marine sponges, bryozoans and cnidarians. However, for conservation reasons, these agents are not extracted directly from the marine organisms but are chemically synthesized. The culture of some sponge species for this purpose is also being investigated. Some marine toxins may have pharmacological applications. Ziconotide, for example, found in cone snails, is a powerful painkiller, and a synthetic version of this molecule has been commercialized (Marine Biotech, 2015).

Seaweeds and other algae are also used as food (traditionally in China, Japan and the Republic of Korea), in animal feed, fertilizers, pharmaceuticals and cosmetics and for other purposes. In medicine, for example, they are used to treat iodine deficiency and as a vermifuge. In 2016, about 31 million tonnes of seaweeds and other algae were harvested globally for direct consumption or further processing. The composition of seaweeds is highly variable, depending on species, collection time and habitat. Seaweeds are industrially processed to extract thickening agents such as alginate, agar and carrageenan or used, generally in dried powder form, as an animal feed additive. Increasing attention is also focusing on the nutritional value of several seaweed species, because of their high content of vitamins, minerals and plant-based protein. Many seaweed-flavoured foods (including ice creams) and drinks are being launched. Their main market is in Asia and the Pacific, but interest is growing in Europe and North America. Several cosmetics have been commercialized from the seaweed *Saccharina latissima*, and other products have been developed from marine macroalgae (Marine Biotech, 2015). Research is also exploring the use of seaweed as a salt substitute and in the industrial preparation of biofuel. ■

FISH TRADE AND COMMODITIES

Trade of fish and fish products plays an essential role in boosting fish consumption and achieving global food security by connecting producers with distant markets for which local supply may otherwise be insufficient. It also provides employment and generates income for millions of people working in a range of industries and activities around the world, particularly in developing countries. Exports of fish and fish products are essential to the economies of many countries and numerous coastal, riverine, insular and lacustrine regions. For example, they exceed 40 percent of the total value of merchandise trade in Cabo Verde, Faroe Islands, Greenland, Iceland, Maldives, Seychelles and Vanuatu. Globally, trade in fish and fish products currently represents above 9 percent of total agricultural exports (excluding forest products) and 1 percent of world merchandise trade in value terms.[6]

Fish and fish products are some of the most traded food items in the world today, and most of

6 Trade data quoted in this section refer to the available information up to mid-March 2018. These figures could differ slightly from those in the FAO fisheries commodities production and trade dataset 1976–2016 and in the Commodities section of the *FAO Yearbook of Fishery and Aquaculture Statistics 2016*, to be released in early summer 2018. The updated data can be accessed through the tools indicated at: www.fao.org/fishery/statistics/global-commodities-production