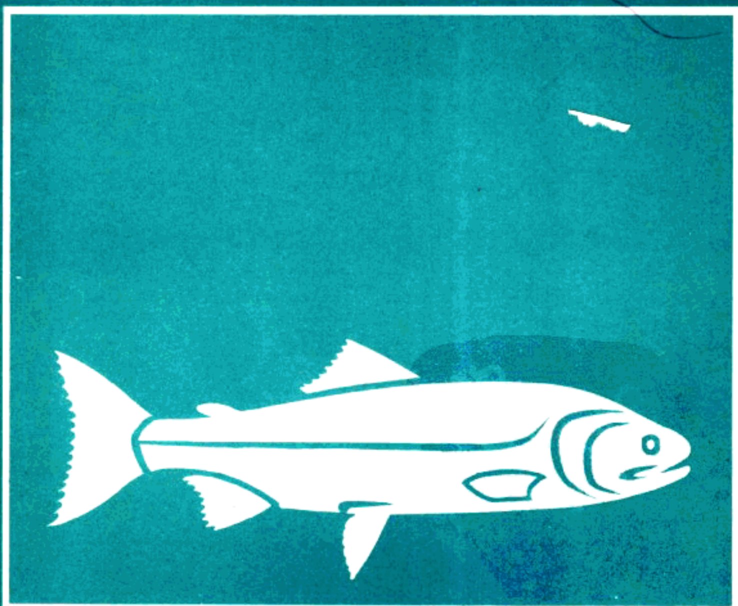
Fresh fish

quality and quality changes



DANIDA

FAO FIAT PANIS

FRESH FISH — QUALITY AND QUALITY CHANGES

Preface

Fresh fish — quality and quality changes is designed primarily for courses in fish technology. It was published first in Danish in 1983 under the title *Fersk fisk — kvalitet og holdbarhed* and constitutes part of the teaching material used by the Technical Laboratory, Ministry of Fisheries at the Technical University, Denmark.

The present issue in English is in part a translation of the Danish publication but it has been expanded with data relevant to tropical fisheries and tropical fish species. In this form it is intended as a basic text on the subject of fish technology for those who are undergoing training at the workshops run by FAO and financed by the Danish International Development Agency (DANIDA). DANIDA also agreed to fund the preparation of this publication.

Some of the material in this manual has already been used at a number of FAO/DANIDA workshops, and it is intended that this and future updated issues will be widely used for years to come. French and Spanish versions are now in preparation.

The Food and Agriculture Organization acknowledges the valuable assistance so generously given to the author by many collaborators in the preparation of this document.

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Contents

1. Aquatic resources and their utilization

More than two-thirds of the world's surface is covered by water. The oceans alone account for 71 percent. Tiny microscopic plants, the phytoplankton, are the primary producers of organic material using the energy supplied by the sun as shown in Figure 1.1.

This enormous primary production is the first link in the food chain and forms the basis for all life in the sea. How much harvestable fish results from this primary production has been the subject of much

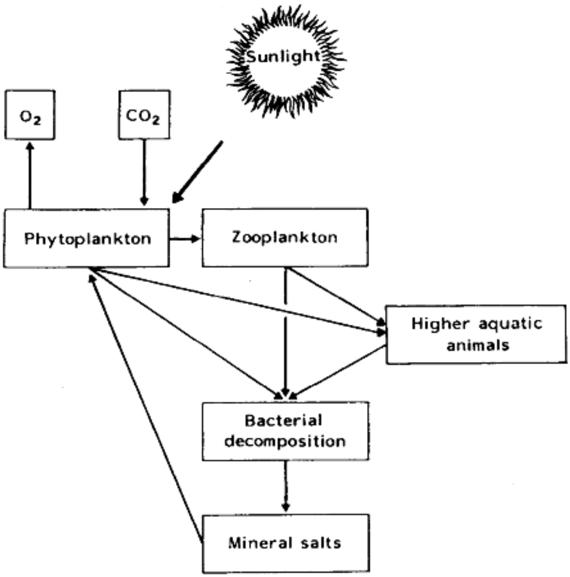

Figure 1.1. The annual aquatic production of organic material is estimated at 40 000 million tonnes (Møller Christensen, 1968)

speculation. However, there are great difficulties in estimating the ecological efficiency, i.e. the ratio of total production at each successive trophic level. Gulland (1971) reports a range from 10 to 25 percent but suggests 25 percent as the absolute upper limit of ecological efficiency; for example, not all of the production at one trophic level is consumed by the next. Ecological efficiency also varies between levels,

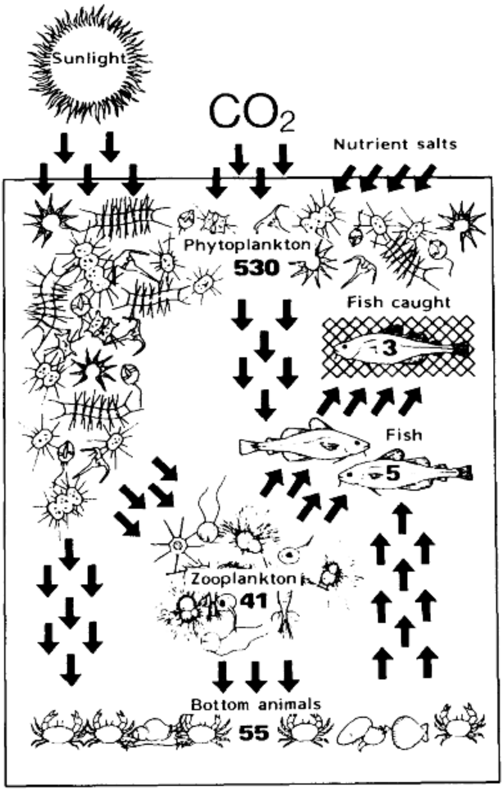

Figure 1.2. Annual production (in million tonnes) in the North Sea, one of the richest fishing waters in the world

being higher at the lower levels of the food chain with smaller organisms using proportionally more of their food intake for growth rather than for maintenance. Diseases, mortality, pollution, etc. may also influence ecological efficiency. The conditions in the North Sea, with very rich fishing waters, are shown in Figure 1.2 as an example.

Since production is greater in the early stages of the food chain, the potential catch is also greater if harvesting is carried out at these stages. If progress in catch handling, technology and marketing makes harvesting at the early trophic levels feasible, then the potential catch may increase accordingly (see Table).

The world catch stagnated in the 1970s at around 70 million tonnes but has now increased to 75 million tonnes (1984), including 9 million tonnes from freshwater sources. About 70 percent of this amount is used for food.

FAO sources estimate that the conventional catch of marine species could be increased by 20-30 million tonnes, much of which (50 percent) depends on improved management. Reduction of post-harvest losses and recovery of by-catches could add another 10-20 million

Summary of current and potential global aquatic resources

	World harvest 1981 (million tonnes)					Potential harvest increase	
	Used for food	Post-harvest losses	Indus-trial use	Total harvest landed	Dis-cards at sea	Short term	Long term
Conventional							
Freshwater	7.9	0.2		8.1		4.5	[1]30
Marine: demersal	13.5	1.5	7.0	22.0	4-5	5	
small pelagic	15.6	3.2	14.6	33.4		5	15
others	3.1	0.1	+	3.2		2	
shellfish	5.9	0.2		6.1		0.7	[1]?
Unconventional							
Cephalopods	1.3	+	0.1	1.4		4	150+
Mesopelagic (Lantern fish)	?	+	+	+		+	100+
Euphausids (Krill)	+		0.4	0.4		+	50+
Seaweeds	1.8		1.2	3.0		8	[1]?
Total	**49.1**	**5.2**	**23.3**	**77.6**	**4-5**	**29.2**	**345+**

[1] Magnitude depends on culture.
Source: Whittle, 1984.

tonnes. The freshwater aquaculture potential is not known but could possibly yield up to 30 million tonnes in the future. However, to meet the demand, it is essential to reduce the proportion of catch used for industrial purposes and develop unconventional resources such as those shown in the Table. The use of food fish is shown in Figure 1.3.

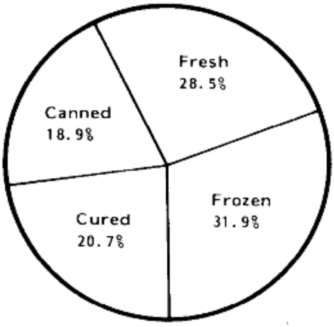

Figure 1.3. Food fish usage, 1982 (James, 1984)

It has been estimated by James (1984) that about 8 percent of the food fish never reaches the market, which means that, in 1982, 4.25 million tonnes were wasted. These post-harvest losses are most significant in the fresh and cured fish sectors. The important thing is that the technology for limiting or preventing these losses is available but needs to be put into effect, as pointed out by James (1984).

2. Classification, anatomy and physiology of fish

Classification

Fish are the most numerous of the vertebrates with 20 000 species known and probably many more unknown (Lagler *et al.*, 1977).

Fish are usually divided into three classes: Cephalaspidomorphi, jawless fish like lampreys and slime-eels; Chondrichthyes, cartilaginous fish like sharks and rays; and Osteichthyes, lungfish and all other bony fish, which include most of the commercially important species. These classes represent numerous genera, which are then further subdivided into different species.

The use of common or local names often creates confusion since the same species may have different names in different regions or, conversely, the same name is ascribed to several different species, sometimes with different technological properties. As a point of reference the scientific name should, therefore, be given in any kind of publication or report the first time a particular species is referred to by its common name. It is normally written in italics (or underlined). For further information see the ICES "List of Names of Fish and Shellfish", *Bulletin statistique*, vol. 49, September 1966; the Torry Advisory Note No. 55, *Fish Names in the Common Market*; and the *Multilingual Dictionary of Fish and Fish Products* prepared by OECD and published by Fishing News Books Ltd, United Kingdom.

The classification of fish into cartilaginous and bony (the jawless fish are of minor importance) is important from a practical viewpoint, since these groups of fish spoil differently (Chapter 4) and vary with regard to chemical composition (Chapter 3). Most non-taxonomists refer to these groups as teleosts (bony fish) and elasmobranchs (cartilaginous fish).

Furthermore, fish can be divided into fatty and lean species, but this type of classification is based purely on some technological characteristics.

Anatomy and physiology

The skeleton

Being vertebrates, fish have a vertebral column — the backbone — and a cranium covering the brain. The backbone runs from the head to the tail fin and is composed of segments (vertebrae). These vertebrae are extended dorsally to form neural spines and in the trunk region they have lateral processes that bear ribs (Fig. 2.1). The ribs are cartilaginous or bony structures in the connective tissue (myocommata) between the muscle segments (myotomes) (see also Fig. 2.2). Usually, there is also a corresponding number of false ribs or "pin bones" extending more or less horizontally into the muscle tissue. These bones cause a great deal of trouble when fish are being filleted or otherwise prepared for food.

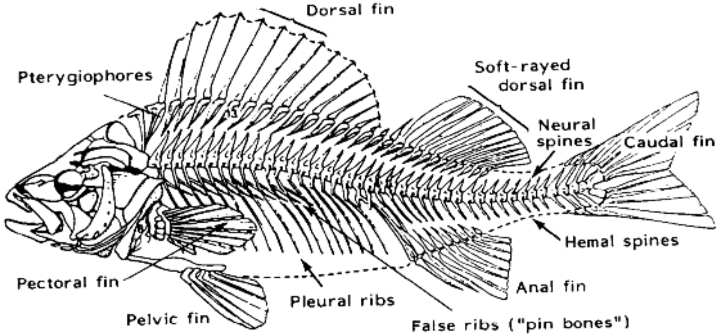

Figure 2.1. Skeleton of bony fish (Eriksson and Johnson, 1979)

Muscle anatomy and function

The anatomy of fish muscle is very simple. Basically, there are two bundles of muscles on each side of the vertebral column and each of these bundles is further separated into an upper mass above the hori-

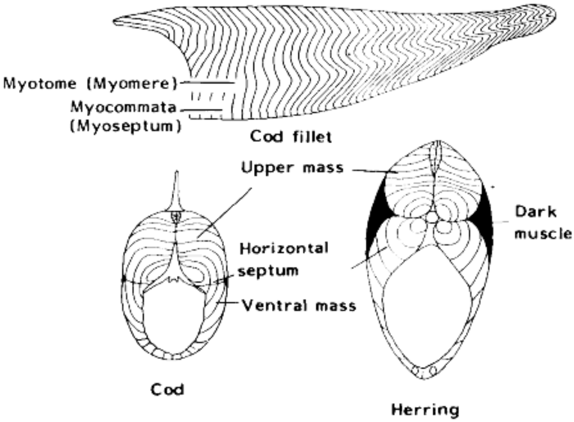

Figure 2.2. Skeletal musculature of fish (Knorr, 1974)

zontal axial septum and a ventral mass below this septum. The muscle cells run in a longitudinal direction separated perpendicularly by sheets of connective tissue (myocommata). The muscle segments lying in between the sheets of connective tissue are called myotomes. The longest muscle cells are found in the twelfth myotome counting from the head (Fig. 2.2) and the average length of these is around 10 mm in a cod that is 60 cm long (Love, 1970). The length of the cells, as well as the thickness of the myocommata, will increase with age.

With this anatomy the fish muscle tissue contains comparatively far less connective tissue than mammalian muscle (Chapter 3).

As in mammals, the muscle tissue of fish is composed of striated muscle. The functional unit, i.e. the muscle cell, consists of sarcoplasma containing nuclei, glycogen grains, mitochondria, etc. and a number (up to 1 000) of myofibrils. The cell is surrounded by a sheath of connective tissue called the sarcolemma. The myofibrils contain the contractile proteins, actin and myosin. These proteins or filaments are arranged in a characteristic alternating way making the muscle look striated upon microscopic examination (Fig. 2.3).

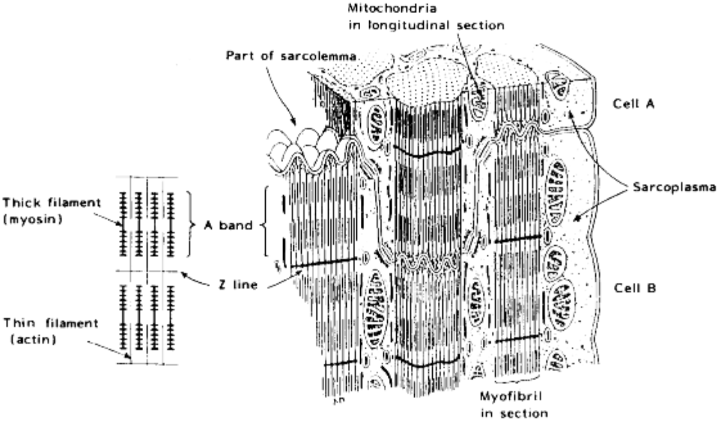

Figure 2.3. Section of a cell showing various structures including the myofibrils (Bell *et al.*, 1976)

Most fish muscle tissue is white but, depending on the species, many fish will have a certain amount of dark tissue of a brown or reddish colour. The dark muscle is located just under the skin along the side of the body and, in the case of certain active species, also in a band near the spine.

The proportion of dark to light muscle varies with the activity of the fish. In pelagic fish, i.e. species such as herring and mackerel which swim more or less continuously, up to 48 percent of the body weight may consist of dark muscle (Love, 1970). In demersal fish, i.e. species which feed on the bottom and only move periodically, the amount of dark muscle is very small.

There are many differences in the chemical composition of the two muscle types, some of the more noteworthy being higher levels of lipids, haemoglobin, glycogen and most vitamins in the dark muscle. From a technological point of view, the high lipid content of dark muscle is important because of problems with rancidity.

The reddish meat colour found in salmon and sea trout does not originate from myoglobin but is due to the red carotinoid, astaxanthin. The function of this pigment has not been clearly established and the fish cannot synthesize astaxanthin to any significant degree. Thus, the meat colour of these species depends on the intake of astaxanthin or closely related pigments in the diet.

The two muscle types have different functions. It is believed that the dark muscle primarily functions as a cruising muscle, i.e. for slow continuous movement, while the light muscle is sprinting muscle used for sudden, quick movements needed for escaping from a predator or for catching prey.

Muscle contraction starts when a nervous impulse sets off a release of Ca^{++} from the sarcoplasmic reticulum to the myofibrils. When the Ca^{++} concentration increases at the active enzyme site on the myosin filament, the enzyme ATP-ase is activated. This ATP-ase splits the ATP found between the actin and myosin filaments, causing a release of energy. Most of this energy is used as contractile energy making the actin filaments slide in between the myosin filaments in a telescopic fashion, thereby contracting the muscle fibre. When the reaction is reversed (i.e. when the Ca^{++} is pumped back, the contractile ATP-ase activity stops and the filaments are allowed to slip passively past each other), the muscle is relaxed. Several substances are involved in the process; ATP is one of the most important, functioning both as a fuel for contraction and as a plasticizer (in the presence of Mg^{++}) when the muscle is in a relaxed state. When myofibrillar ATP is absent, the actin and myosin filaments stay interlocked (actomyosin). This type of rigid muscle is found post-mortem during rigor mortis (see Chapter 4).

The cardiovascular system

The cardiovascular system is of considerable interest to the fish technologist since it is important in some species to bleed the fish (i.e. remove most of the blood) after capture.

The fish heart is constructed for single circulation (Fig. 2.4). In bony fish, it consists of two consecutive chambers pumping venous blood toward the gills via the ventral aorta. After being aerated in the gills, the arterial blood is collected in the dorsal aorta running just beneath the vertebral column and from here it is dispersed into the different tissues via the capillaries. The venous blood returns to the heart, flowing in veins of increasingly larger size (the biggest is the dorsal vein, which is also located beneath the vertebral column). The veins are all gathered into one blood vessel before entering the heart.

During blood circulation, the blood pressure drops from around