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Fishery and commercial exploitation of *Calanus finmarchicus* in Norway

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In Norwegian coastal waters the copepod *Calanus finmarchicus* ("red feed") is abundant during summer with local concentrations of 3–25 g/m³, in swarms 6–15 kg/m³. A fishery for *Calanus* started about 1960 and is still on an experimental stage with annual catches of 20–50 tons. The fishery is carried out from April to July with fine-meshed nets either anchored or towed. The *Calanus* is stored deep-frozen and used as supplementary food in culture of salmonids and as pet fish food. Experiments are going on with products for human consumption. The potential of the fishery is thought to be large, and the yield may be increased according to demand.

Introduction

During the later years there has been a growing interest in pelagic crustaceans as commercial sources of protein, with the main emphasis on krill or euphausiids. The large populations of krill in the Antarctic ocean have been especially in focus. Other organisms of interest are Mysids, Galatheids and Copepods. According to Parsons (1972) catches of more than 100 kg of the copepod *Calanus plumchrus* have been taken off the west coast of Canada and used as fish food in aquaria and hatcheries. In Norway, both krill and copepods have been fished commercially on a small scale for nearly 15 years (Wiborg, 1966; Wiborg & Bjørke, 1968, 1969; Wiborg & Hansen, 1974).

The fishery for copepods, mainly *Calanus finmarchicus*, started in some fjords in western Norway about 1960. During spring and early summer, some people towed plankton nets from small boats. Catches up to 100 kg or more of *Calanus* were taken per boat per night. The *Calanus* was either deep-frozen and later used as food in the culture of salmon and trout, or canned for pet fish food. In 1962 about seven metric tons were caught. In 1967 larger nets were tried in fjords south of Bergen, and catches up to 40 kg/h were taken. The nets were also anchored in sounds and between skerries. Investigations and experimental fishery started in 1967 (Wiborg & Bjørke, 1968, 1969).

At present, the annual catch is about 20–50 tons. The *Calanus* is used for feeding of salmonids in aquaculture, or as pet fish food. Experiments are also running with various products for human consumption. Even if this fishery is still at an experimental stage, the prospects seem promising, and it may be worth while to describe the present state of development.

Biology

The biology of *Calanus finmarchicus* in Norwegian waters has been described (Wiborg, 1954). In coastal and bank waters of western Norway, the wintering *Calanus* migrates towards the surface in late February, the generation originating from the first spawning in March reaching copepodite stage V in late April or early May. At this time there may be a maximum in the biomass of plankton, mainly consisting of *Calanus*. The next generation of *Calanus* produces another maximum in July–August, but at this time there may be a considerable admixture to the plankton of medusae, cladocerans and other neritic organisms, especially in the fjords and near the coast. Along northern Norway the spring maximum in plankton biomass may occur later in May or at the beginning of June.

Quantitative distribution

The patchy occurrence of zooplankton in the sea is generally recognized. In an area the maximum density may be far above the average figure, but swarms of plankton are often of a very restricted size and difficult to locate, or the plankton may be concentrated in a narrow layer at a certain depth. However, such concentrations are very important for e.g. fishes and marine mammals feeding on zooplankton (Parsons, 1972). *Calanus finmarchicus* is also known to occur in patches, and the surface of the sea is sometimes reported to be coloured red by this copepod. In the

Barents Sea, concentrations up to 9 g of wet zooplankton per m^3 have been reported (Manteifel, 1941). Off western Norway near-surface concentrations of 16 ml and 24 ml of drained zooplankton, mainly *Calanus*, per m^3 have been observed (Wiborg & Bjørke, 1969; Wiborg, unpublished). In fjords and bays, small patches of densely concentrated plankton have been observed during early summer. These may be recognized as red clouds, 1–3 m long and ½–1 m in diameter, either at the very surface or immediately below. Sea gulls, auks and fulmars are often crowding at such patches, and below, shoals of saithe are feeding voraciously. A bucket with 8 l of water taken at the surface contained 50 ml of *Calanus*, corresponding to about 6 kg/m^3 (Wiborg & Bjørke, 1968). Concentrations up to 15 ml/l or about 15 kg per m^3 have been measured (Wiborg & Hansen, 1974). Such concentrations are most often observed during the afternoon and evening, when the *Calanus* migrate towards the surface and are carried into fjords and bays by tidal currents.

Fishing gear

The gear used in fishery for *Calanus* is still under development. Various models have been tried, from ordinary plankton nets of various sizes, to trawls held open by small otter boards, beam trawls, and nets using the parachute principle.

At present the beam trawl is mostly used (Fig. 1). In the net, a gauze with meshes of one mm was first tried, but was found to catch very little of *Calanus*. (During spring and early summer, the adults and stage V copepodites measure about 3–4 mm, with a diameter of one mm or less, and are apparently squeezed through the meshes). For economic reasons, ordinary plankton gauze had to be left out of question, but a fabric produced commercially for making curtains was found to fit the purpose. It is of nylon, with meshes of 0·5 × 0·8 mm (Fig. 2) and a porosity of about 0·5. The price is about N. kr. 3–4 per m^2, and the gauze is of sufficient strength to be used in stationary nets.

The opening of the net is rectangular, 4 m wide and 3 m high. The upper and lower edges of the net are attached with plastic rings to steel or galvanised iron poles (Fig. 3). In order to prevent larger organisms, especially medusae, from entering the net, the mouth is covered by a coarse net with meshes of about 30 mm, either straight across the opening, or wedge-shaped, fastened in a forward position by a rope (Fig. 4, 1). The fishing net may either taper towards the codend, or may have one cylindrical and one conical part, as recommended by Tranter & Smith (1968). The first nets made were approximately 10 m in length, and for stationary nets this seems to be sufficient. For towing, however, the importance of having a large filtering area is recognized, and

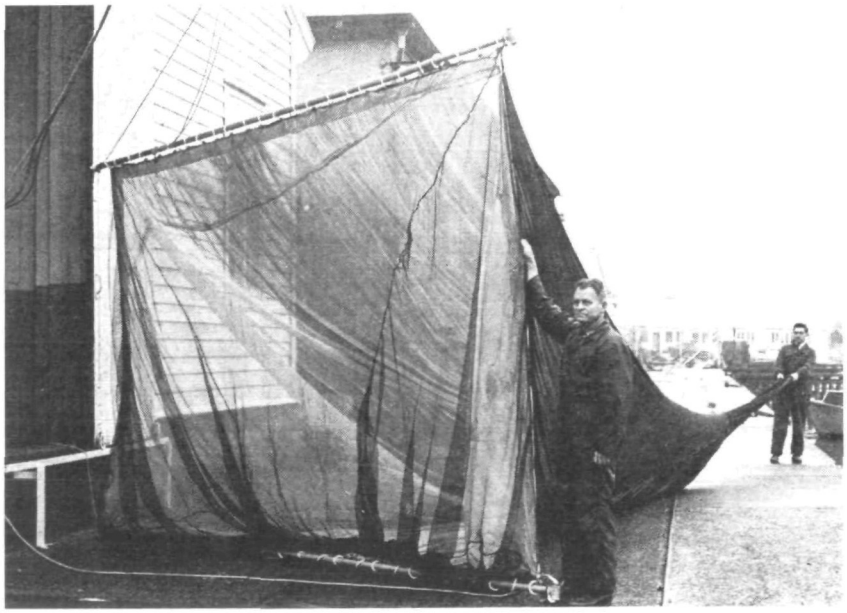

Figure 1. Beam trawl for zooplankton (*Calanus finmarchicus*), opening 4 × 3 m, with protecting net.

such nets are usually made longer. Following Tranter & Smith (1968) it has been suggested to have a cylindrical part of 7 m and a conical codend 10 m long. In 1975 larger nets will be built with an opening of 5 × 4 m and a filtering area of 550 m^2. In stationary nets, the codend is reinforced with a lining of cloth with a heaving-line attached to easy the hauling of the net (Fig. 4, 2).

Fishing procedure

Anchored gear

This net is usually placed in a sound or between skerries where tidal currents are of moderate strength. It is moored to a single anchored buoy by means of a bridle, and kept afloat by two other buoys. A third small buoy is tied to the heaving-line (Figs 4 & 5). The net is allowed to turn freely in the current. Usually it is set at, or close to the surface. The fishery is carried out from vessels 7·6–10·7 m long, with 1–2 men on board, often in combination with a fishery for salmon with gape nets. One man may take care of as many as 10–15 anchored plankton nets.

During the fishing season, the nets are emptied in the morning, sometimes also in the evening. In periods with small catches, the nets are left open. For emptying, the codend is hauled in by the heaving-line, and lifted into the boat by hand. For large catches, a lift-net of coarser meshes may be pulled over the codend, and a small winch used if necessary (Fig. 6). The catch is emptied into a box lined with fine-meshed cloth (Fig. 7) and allowed to drain. Afterwards it is filled into plastic bags and brought to the freezing plant. The catches vary considerably, a few days with good catches alternating with long periods without any catch. Catches of up to 400 kg per net per night have been reported.

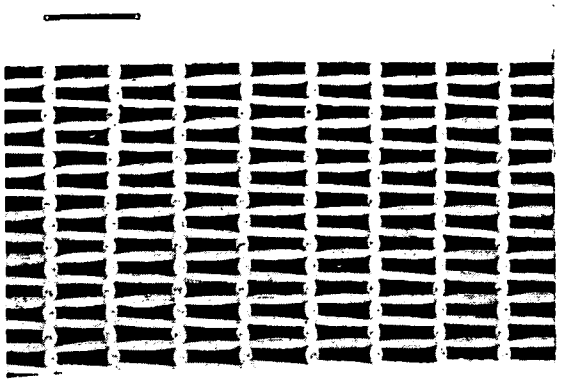

Figure 2. Nylon gauze used in nets for fishing *Calanus*' enlarged 10×.

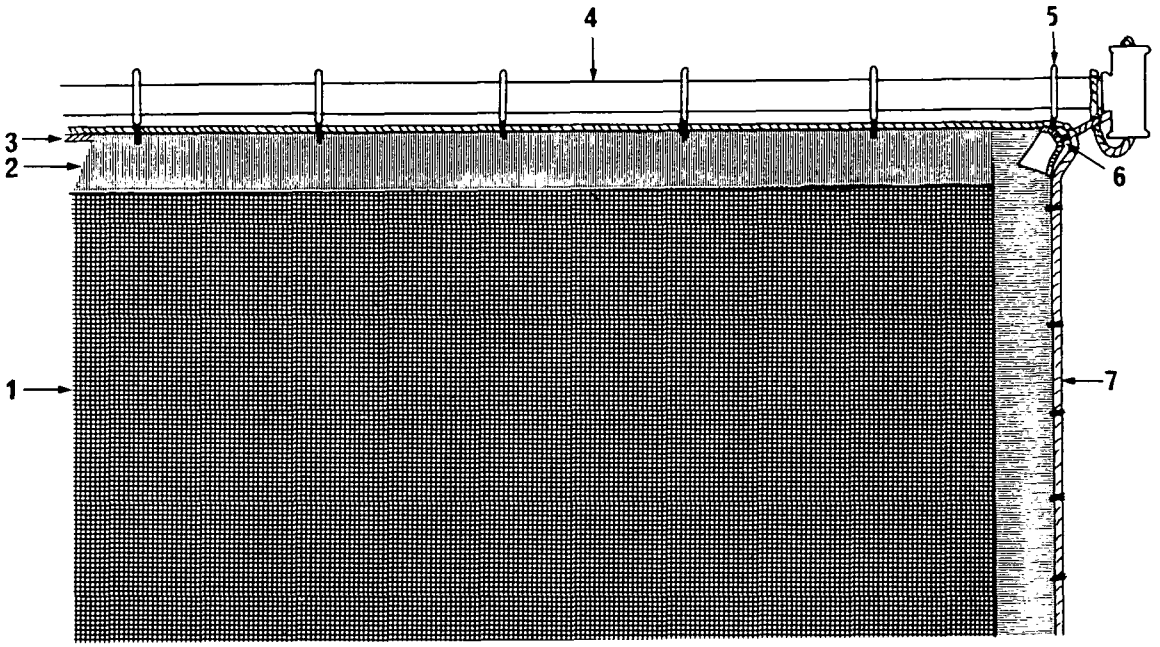

Figure 3. Detail of construction of *Calanus* trawl. 1. Nylon gauze. 2. Reinforcement of nylon cloth. 3. Nylon rope, 2·5 cm. 4. Steel tube, 4·4 cm. 5. Plastic ring, 6·4 cm. 6. Attachment of net to steel pole.

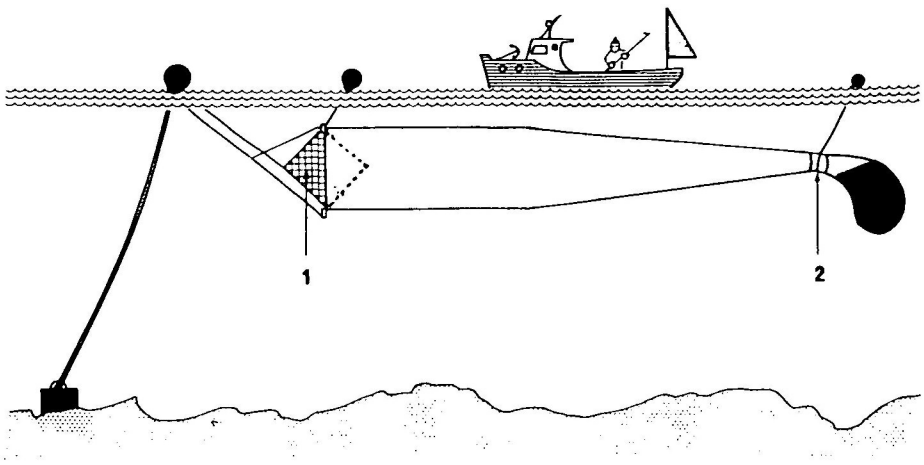

Figure 4. *Calanus* trawl used as trap. 1. Medusae net in forward position. 2. Heaving-line.

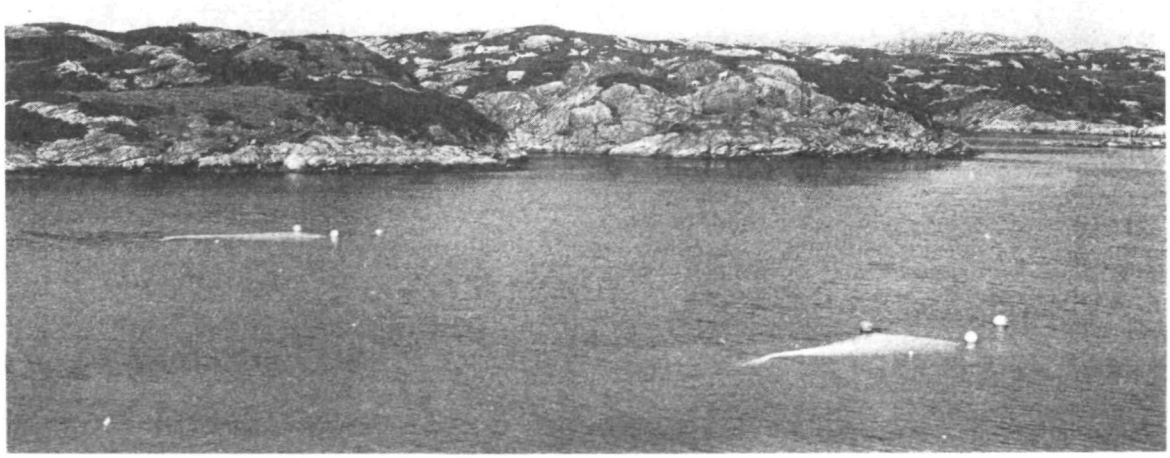

Figure 5. *Calanus* trawls anchored in a sound in western Norway.

Towed gear

The net used for stationary fishery is also used for towing, but with a coarse net outside for protection. The lower tube is filled with lead, and further weights added if necessary. The trawl is towed from a single rope, 120–150 m in length, fastened to the bridle. The depth of trawling may be changed by varying the lengths of rope on the buoys. At a speed of 0·5 m s^{-1}, the upper edge of the mouth will usually be at a depth corresponding to half the length of the buoy ropes. The depth may be checked either with an echo sounder from another boat, or by a simple arrangement of marked lines with one end attached to the beams, the others to small buoys, which are picked up from a skiff following during trawling (Fig. 8). By hauling the lines tight, the depth of the beams may be found from the markings on the lines. During the day the nets are usually fished at depths from 5 m to 25 m, during evening and night between 10 m and the surface. Minor changes in depth may be accomplished by changing the speed of trawling. The time of towing may sometimes extend to 6–10 h, the reason being that the *Calanus* will stay alive and keep better than if stored onboard the vessel. During such long hauls there will always be a risk of clogging of

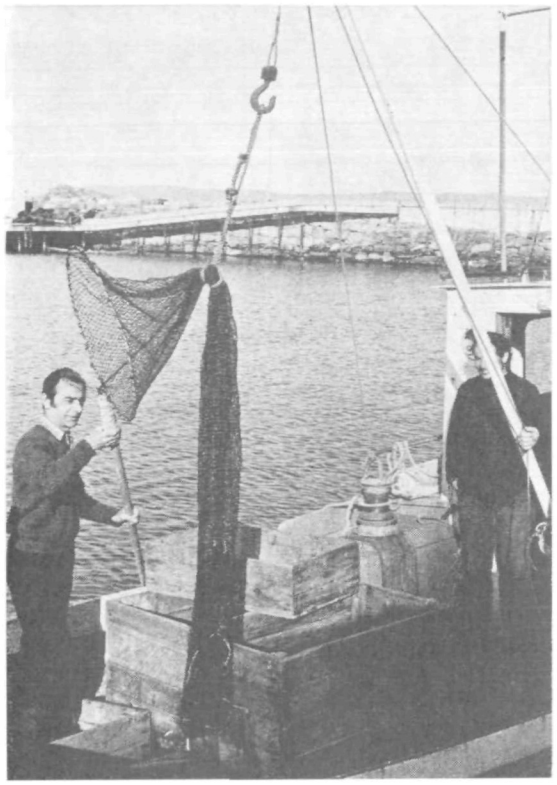

Figure 6. Lift net to heave the cod end of *Calanus* traps in case of large catches.

Figure 7. Box for draining of *Calanus*, inside covered with gauze.

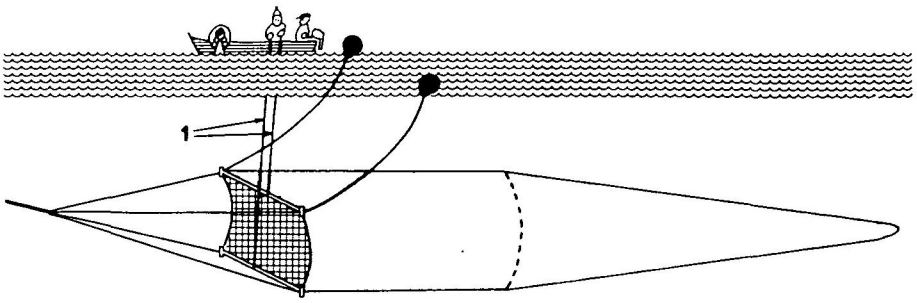

Figure 8. Simple method for measuring trawl depth. 1. Measuring lines (further explication in text).

the net, and various procedures have been proposed to clean the net during the fishing.

In order to have good catches, the concentrations of plankton have to be located. Surface swarms may be seen directly, or from aggregations of birds, whales or basking sharks. Subsurface concentrations are sometimes recorded on the echo sounder, and with experience may be distinguished from traces caused by other organisms, but most often sampling is needed. At regular intervals a plankton net is hauled either horizontally or vertically, and the plankton sampled measured in a plexiglass cylinder with fine-meshed netting at one end (Fig. 9). Concentrations of 1–3 ml/m^3 or more are needed to give reasonable catches.

With two trawls, each with an opening of 20 m^2, a catch of 1600 kg of *Calanus* has been obtained in a haul of 8 h at a speed of about 0·5 m s^{-1}. Assuming a minimum of clogging, this would correspond to an average concentration of plankton of about 3 g/m^3.

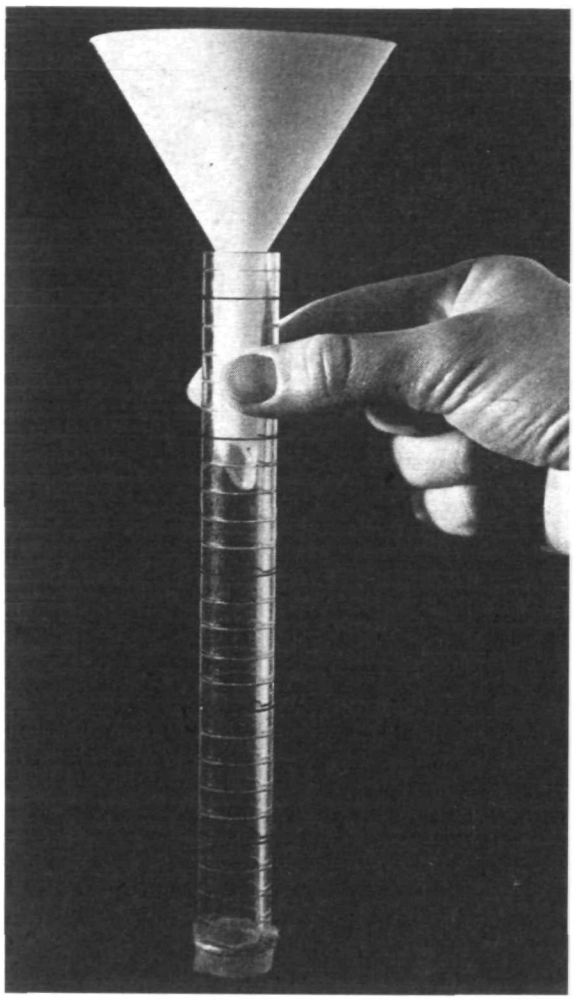

Figure 9. Plexiglass cylinder with bottom sieve for measuring the volume of plankton samples.

The catch is treated in the same way as for stationary nets. The bags with plankton are sometimes stored with ice in the hold of the vessel.

Preservation and storing

It is important to have the catch preserved as soon as possible. Freshly caught *Calanus* is usually of a violet-red colour, but very soon it changes to bright red, and after some time, a fishy smell is developed. Catches from stationary nets have sometimes been kept at temperatures of 6–8°C for 8–12 h and afterwards deep-frozen without any appreciable decrease in quality. After freezing, the *Calanus* is stored at −35°C for a maximum of one year.

Preservation with 2% of concentrated acetic acid has been tried for plankton used in fish farming. The *Calanus* proved still to be fit for use after two months of storage at room temperature. The experiments will be continued. The *Calanus* may also be boiled for a short time in order to inactivate the enzymes, and stored up to one week in a refrigerator, or deep-frozen.

Localities and time for fishing of *Calanus*

The fishery for *Calanus* has hitherto mainly taken place at and off the coast from Bergen to Trondheim (60–64°N); but successful experiments have also been made in the Lofoten area in northern Norway. The fishery usually starts at the end of April, and may last till the end of June. Northerly winds are unfavourable, causing the plankton either to be carried away from the coast, or to stay too deep to be caught. In May-June, cladocerans and bottom invertebrate larvae may sometimes decrease the quality of the plankton in the fjords and skerries.

Medusae, especially ctenophores, such as *Bolinopsis infundibulum*, which are occasionally very numerous and may clog the nets during towing, are less of a problem to the stationary nets. A few kilometres off the coast, just outside the fjord water but still in the coastal current, conditions may be quite different, with a plankton consisting entirely of *Calanus finmarchicus*.

Catches are usually best during late evening and night, when the plankton rises to the surface. Off the coast, euphausiids are sometimes caught together with the *Calanus*, especially when fishing close to the surface.

During recent years, the annual catch of *Calanus* is about 50 metric tons, most of it taken in stationary nets. A fishing experiment is planned for 1975, with the aim of catching about 80 metric tons of *Calanus* with towed nets. Rough calculations indicate that the production of zooplankton along the Norwegian coast is of an order of size of 10–100 million tons a year and it is supposed that the output of the fishery might be increased considerably, but a detailed study of the occurrence of patches and other concentrations of plankton is necessary. At present, the fishery with stationary nets seems to be most economical.

Present and future utilization of *Calanus finmarchicus*

In Norway, the *Calanus* has hitherto mainly been used as a source of astaxanthin in salmonid culture,

for giving the fish the desired red colour. Raw *Calanus* may contain up to 85 mg of astaxanthin per kg (Utne, 1974), the oil as much as 918 mg/kg (Fisher, Kon & Thompson, 1952). In an experiment to determine the effect of various sources of astaxanthin for colour and taste of the flesh of rainbow trout, Ugletveit (1974) found *Calanus* to range highest for both. For colour, shells and offal from deepsea prawns ranged second; for taste, krill.

At present, *Calanus* is too expensive (about N. kr. 2–3 per kg) to be used as a major food item in fish culture, but some fish farmers catch *Calanus* themselves and store it for later use. Some of the marine farms have also a favourable location, the fish obtaining a certain amount of *Calanus* from the water passing the farm. On some occasions the fish have been seen to feed on *Calanus* very voraciously, and the amount of food given may be appreciably reduced.

The use of *Calanus* (and other copepods) for human consumption is still on an experimental stage. Many of the problems are similar to those met with in the utilization of the krill. The chemical composition is very similar, the dry weight content 15–35% (mostly 20%). Dry *Calanus* contains 10–40% protein, 12–47% fat, 3% chitin and 3·6% ash (Marshall & Orr, 1955). The fat contains about 80% of unsaturated fatty acids (Lowern, 1935; in Marshall & Orr, 1955). The protein is of similar quality to casein, containing about 20 of the most important amino acids (Cowey & Corner, 1963). The amino acid profile is shown in Table 1.

Table 1. Content of amino acids in raw *Calanus finmarchicus* taken off Bergen, western Norway, in May 1973 (Wiborg & Hansen, 1974).

	g amino acid per 100 g protein		g amino acid per 100 g protein
Taurine	1·65	Methionine	2·28
Aspartic acid	7·37	Isoleucine	3·72
Threonine	3·25	Leucine	5·92
Serine	3·11	Tyrosine	3·70
Glutamic acid	10·20	Phenylalanine	2·88
Proline	2·94	Lysine	6·67
Glycine	6·89	Histidine	1·92
Alanine	5·85	Arginine	7·11
Valine	6·17	Arnithine	0·62
½ Cystine	0·71	Tryptophan	1·01

More than 70 years ago zoologists and others discussed the possible use of copepods as food for ship-wrecked sailors. Herdman (1891), during a research cruise off northern Norway, caught a lot of *Calanus*, boiled it in butter with salt and pepper and found it to taste excellent, with a flavour like that of lobster. Later Hardy (1956, p. 164), made similar experiences. The present author has also used boiled *Calanus* as snacks with success. Freeze-dried *Calanus* is being tried as an addition to soups, and cheaper methods for drying are under development. Experiments with production of a paste, similar to that produced from krill, will also be carried out.

At present, it is too early to give any forecasts as to the future prospects of the exploitation of *Calanus finmarchicus* and similar copepod species. But the quantities which might be taken if desired, are possibly of the same order of size as those expected from krill, if not even larger. Because of the pattern of distribution and the relatively short fishing season, no overfishing of the copepod plankton is immediately foreseen.

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