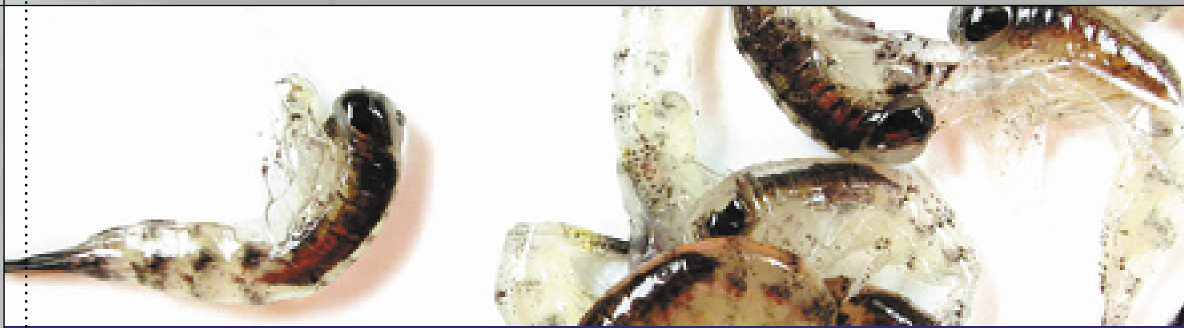
FOCUS ON MARINE RESEARCH

3-2005



NEW RAW MATERIALS FOR FISH FEEDS

krill and other types of plankton

INSTITUTE OF MARINE RESEARCH
HAVFORSKINGSINSTITUTTET

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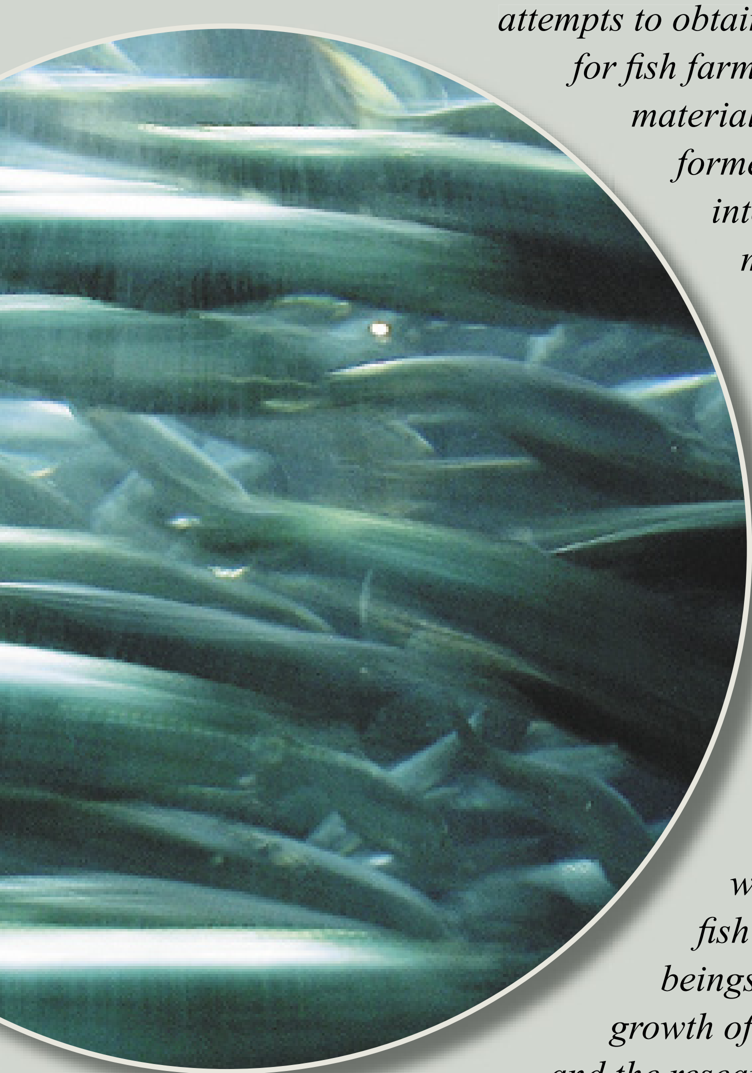


Photo: Hans Stockhausen

The fish-feed industry is facing a major challenge as it attempts to obtain sufficient high-quality raw materials for fish farming. Traditionally, marine raw materials such as fish meal and fish oil have formed the backbone of the Norwegian and international feed industry. These raw materials have usually been of high quality and have ensured that farmed fish have had a healthy nutritional profile. A large proportion of these raw materials come from the huge stocks of anchovetas off the coasts of Peru and Chile, but a number of other pelagic stocks are also used to produce fish oil and fish meal. Several of these stocks are now under severe pressure and some of them are being overfished. The question has also been raised as to whether it is ethically responsible to use fish as feed instead of as food for human beings. Whatever the case may be, the rapid growth of fish farming has led the feed industry and the research sector to try to identify alternative raw materials for feed. Marine fats have been the most important bottleneck, but marine sources of protein (fish meal) will also be scarce in the future.

IS VEGETABLE MATTER THE SOLUTION?

Even today, other raw materials than fish meal and oil are being used as sources of protein and fat in fish feeds. As much as 50 % of the oil and 25 % of the protein content of a typical salmon feed may come from other sources. The proportions will vary according to the availability and price of the individual raw materials on the world market. It is first and foremost soya that is used by the feed industry. Soya is available in virtually unlimited quantities thanks to intensive agriculture. Fish such as salmon have not evolved to eat soya or other vegetable sources of feedstuffs. Fatty fish like salmon are regarded virtually as health foods because of their healthy fatty acid profile, their high content of DHA and EPA, which come from marine feeds. However, vegetable oils do not contain these fatty acids, which means that some of the healthy effects of fatty fish are lost if the fish have been fed a high proportion of vegetable oils. Moreover, fish are not genetically adapted to fats of this type, which means that they may suffer gastrointestinal damage. So it is not completely unproblematical to base the future growth of the aquaculture industry only on raw materials from the soil.

Genetic modification of the fish or of the feed would largely enable us to adapt the fish to the feed, or vice versa. However, since genetic modification is regarded as undesirable in itself, this is not a possibility at present. Bacteria and algae can also be used in feed production, although production costs would probably be high.

KRILL A POTENTIAL ALTERNATIVE

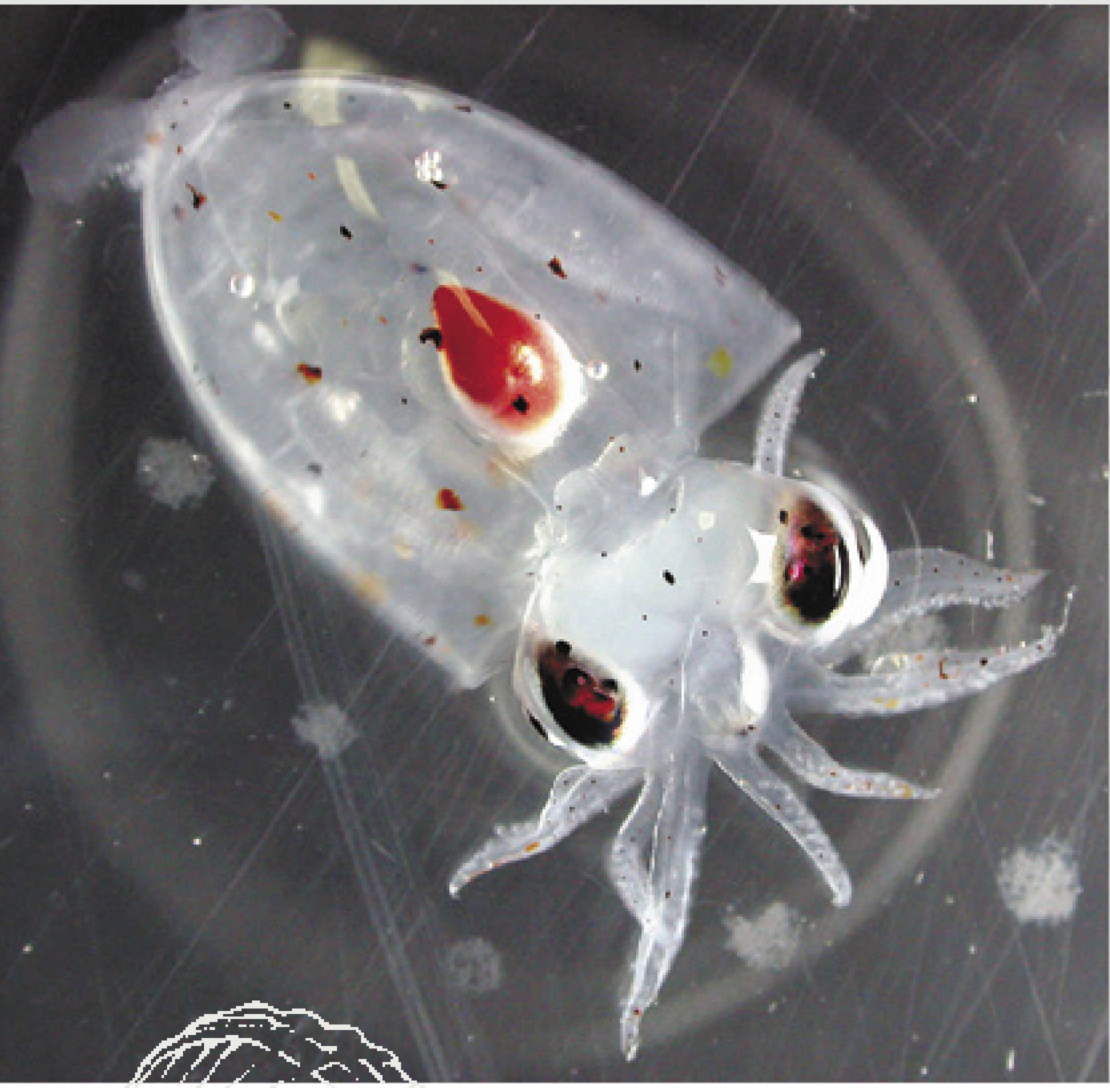
At the Institute of Marine Research, we have been studying for several years the possibility of using organisms lower down the food chain as raw materials in fish feed. There has long been a commercial interest in harvesting the huge stocks of krill in the Antarctic, first and foremost *Euphausia superba.* In the North Atlantic, there are large quantities of krill and other types of plankton that could also be used as sources of both fat and protein. Previous trials have shown that krill can be suitable as a feed. However, most of these studies were carried out in the late 70s and early 80s, when both feed technology and requirements regarding growth and profitability were different from what they are today. Furthermore, many species of krill and plankton contain certain problematic substances which will need to be studied in more detail before they can be used in fish feeds. For example, the fat in certain species of plankton is rich in wax instead of ordinary fat. Large amounts of wax tend to be injurious to animals and may thus also lead to problems in fish. Most species of krill and plankton also contain greater or smaller

Krill, amphipods and copepods are available in ample amounts, but the effects an outtake of such species would have on the ecosystem are still unknown.

quantities of chitin, which can cause diarrhoea in fish if it is present in large amounts, but which in small proportions is capable of stimulating the immune defence system. The content of fluorine and certain heavy metals could also be a barrier to further use if these remain in the fish. Environmental toxins such as PCBs, dioxins and brominated flame retardants are concentrated upwards in the food chain, and could be a problem. However, precisely since such environmental toxins are concentrated as they rise through the food chain, their content in krill will be relatively low. In fact, it is possible that feeding fish a diet of krill or plankton would result in a distinct reduction of such substances in fish in comparison with the present situation.

There are currently a number of uncertainties regarding the catching of organisms low in the food chain. There are wide divergences in estimates of quantities and production rates of krill and plankton, and it is not known what effects an outtake of such species would have on the ecosystem as a whole. We also lack good methods of stock analysis and of measuring these stocks.

The content of fat and protein in krill and plankton species varies widely. There will also be both geographical and seasonal variations. Calanus finmarchicus, a copepod, and Thysanoessa inermis, a small species of krill, are both found in our local waters, and are among the species with the highest fat content; as much as 70 % of their dry weight. The fat, however, is deposited as wax, a form that fish find difficult to digest. This is a problem that we are studying in a new project financed by the Research Council of Norway. Generally speaking, we can say that krill tend to be a good source of protein, with a dry matter content of about 60 %, while their fat content tends to be moderate to low.



EXPERIMENTS ON FISH

COPEPOD OIL FOR SALMON

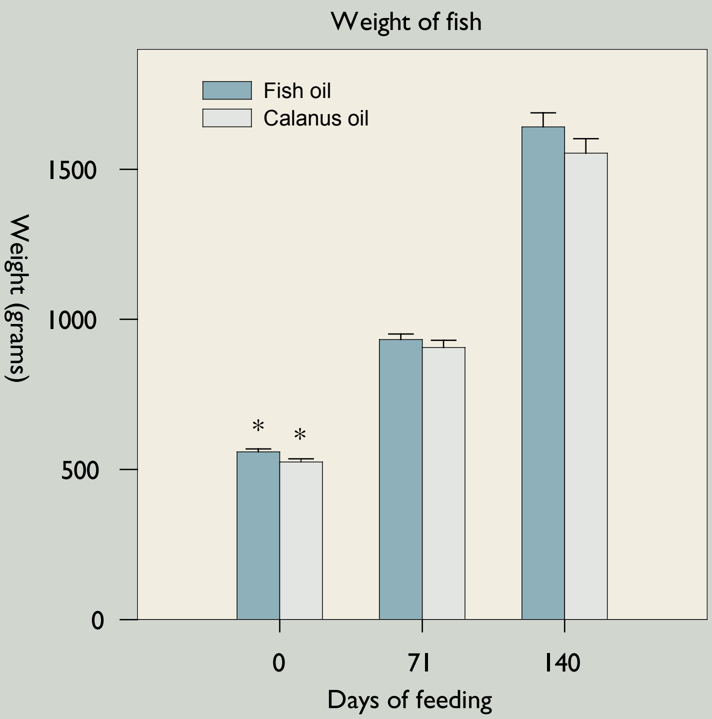
In feeding experiments on salmon, copepod oil has turned out to produce growth rates and food utilisation factors similar to those obtained with fish oil. The fatty acid profile (EPA and DHA) in the fish was also similar in the group given copepod oil. In this experiment the fat content was 25 %.

On the basis of these experiments we can conclude that copepod oil could be a good substitute for fish oil in the salmon diet. However, more studies of growth, feed utilisation and fish size are needed. It would also be interesting to try out diets with extremely high proportions of oil, perhaps as much as 40 %, which is normal in commercial growth diets for large fish.

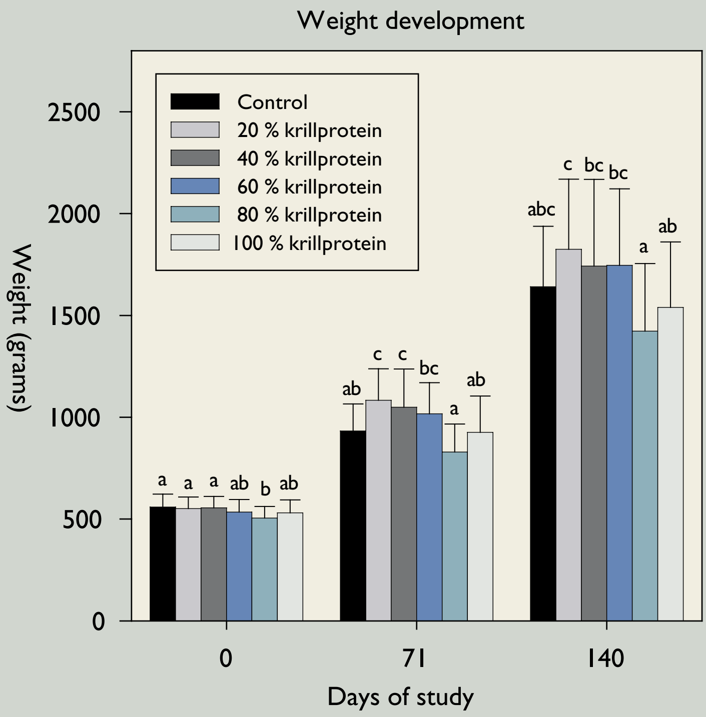
KRILL AND AMPHIPODS FOR SALMON

In another experiment, the proportion of protein derived from krill was varied in six diets from 0 to 100 % (i.e. 0–68 % dry matter). Apart from the two groups with the highest proportions of krill meal, (80 and 100 %), all the feeds produced fairly similar rates of growth and feed utilisation. This means that it would be quite possible to add a significant proportion of krill meal to fish feed without the prospect of negative effects on growth or other indicators.

Other experiments suggest that salmon can also tolerate, and grow well with, a large proportion of Norwegian Sea krill or amphipods in their feed.



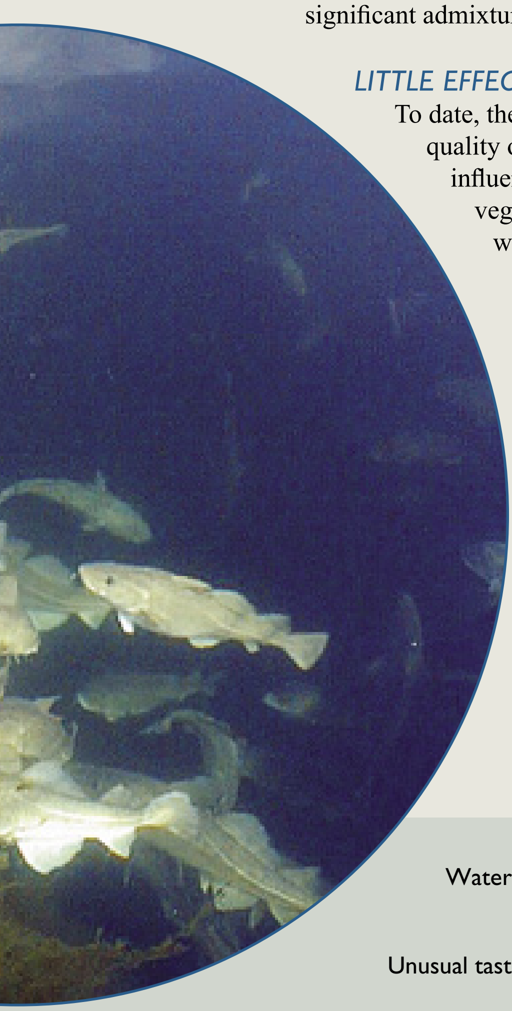
Weight of salmon fed on diets containing fish oil or wax ester oil for 140 days. * indicates significant differences between fish fed the different diets.



Weights of Atlantic salmon fed diets in which 1–100 % of the fish meal protein was replaced with protein from Antarctic krill.

COD AND HALIBUT

A number of experiments have been carried out on cod and halibut fed various admixtures of krill and amphipods. Cod do not appear to have any problems in utilising large proportions of krill in their feed, nor do they seem to have diarrhoea problems suffered by salmon when they are given large amounts of krill. So far, the data also suggest that halibut can also tolerate significant admixtures of Norwegian Sea krill, amphipods and Antarctic krill.

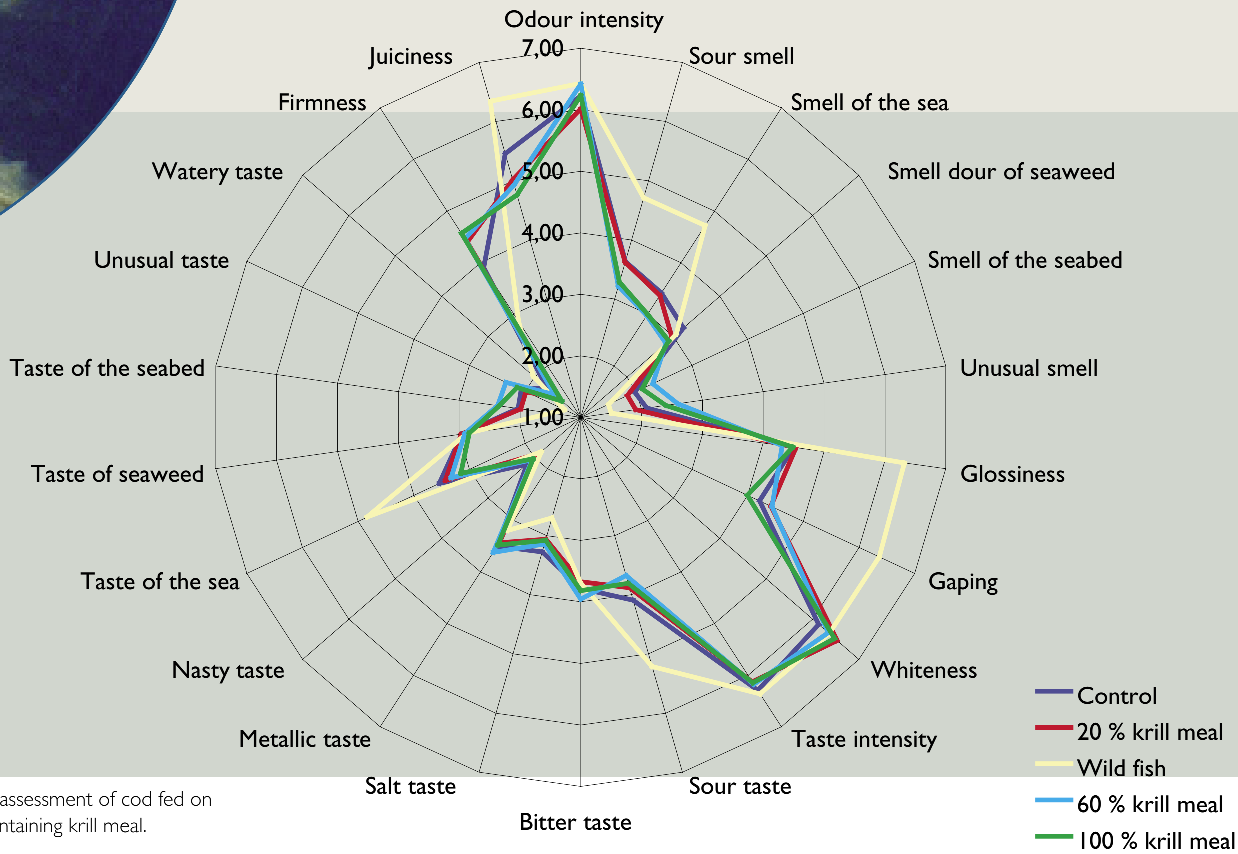


LITTLE EFFECT ON QUALITY

To date, the results indicate that Antarctic krill have limited effects on the product quality of cod and salmon. The fact that the content of the feed has relatively little influence on product quality is also in agreement with results obtained using vegetable protein, for example. The greatest differences are found between wild and farmed fish. This also agrees well with earlier results.

IMPROVES APPETITE

The fact that shrimps, for example, can be used as taste enhancers in fish diets has been known for a long time. Studies at the Institute of Marine Research suggest that krill can also act in the same way. In several cases, we have observed that the appetite of the fish improves, at least for a while, when krill are added to the feed. The mechanism underlying this, and its practical consequences, are currently being studied in more detail.



Quality assessment of cod fed on diets containing krill meal.

CHALLENGES

Even though these introductory experiments demonstrate that there is a great potential for the use of krill and plankton resources in fish feed, we will still need to deal with a number of challenges before these resources can be exploited on a large scale. We can roughly divide these challenges into three categories:

1. Ecological consequences of harvesting
2. Process technological and economic factors in harvesting and production
3. Problem substances.

Even though it is obvious that resources that are low in the food chain, such as krill and plankton, are available in enormous quantities in comparison with fish, there are still major gaps in our understanding of how much of these resources we ought to be able to harvest. Little experience of stock estimation exists, and there is little international experience of managing plankton resources.

Plankton and krill will have to compete with other raw materials as potential raw materials for the feed industry. Major challenges still have to be faced in fishing technology, storage and processing in ways that will ensure that quality is good and that the industry is profitable.

Last but not least, several of the relevant species contain problematic substances of natural or man-made origin. The high fluorine content of krill, for example, may injurious to fish, and the high chitin content of plankton may cause problems in some cases. Unfortunately, it is a fact that much of the pollution that we create on dry land ends up in the sea. Even though the level of environmental toxins tends to be lower the further down we go in the food chain, it may still be necessary to remove such toxins from krill and other species of plankton before they can be used in fish feeds.

CLOSE COOPERATION

The task of evaluating the suitability of krill and plankton in general as a feed resource has been carried out in close collaboration with other research institutions, notably the National Institute for Nutrition and Seafood Research (NIFES) and the Norwegian Institute of Fisheries and Aquaculture Research (Fiskeriforskning). Fiskeriforskning has primarily worked on process technology aspects of the study, i.e. producing feed from the raw materials. NIFES has focused on problem substances such as fluorine, arsenic and cadmium in feeds, and IMR has performed feeding trials in addition to studies of resources. Our research has been financed by the Ministry of Fisheries and Coasts and the Research Council of Norway.

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