HARVESTING THE OCEAN

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Summary

The human species descended most probably from an early primate that lived and collected its food in shallow marine waters some 7 to 9 million years ago. The evolution of our brain and species has always been closely related to the resources of the ocean. Methods for catching fish have been known since the earliest days of mankind, involving spearing, harpooning, trapping, catching with hooks, and use of nets. Seagoing craft were developed 5000 years ago. The Industrial Revolution had its impact on fisheries, and the Second World War led to rapid development of technologies. Another important issue was the development of synthetic materials for boats and nets. This enabled the industry to develop highly efficient mid-water trawls and power systems to handle these. The first generation mariculture farms were established towards the end of the twentieth century.

The harvesting potential of the ocean is 100 million tonnes/yr. FAO statistics show that harvesting is primarily undertaken in the coastal ocean. The total marine harvest is in the range of 105 to 110 million tonnes/yr, but only mariculture has increased since 1990. Harvesting is most likely beyond the level of exploitation that secures an optimal multi-species yield of marine resources. We exemplify the importance of variability in time and space and trophic position. Studies have concluded that improved technology

and increased demands for seafood rather than over-exploitation of higher trophic levels is the mechanism that control development and composition of catches.

Humans feed two trophic levels higher in the marine food web than in the agricultural one, and 99% of the marine primary production is lost. The potential to enhance marine harvesting is to catch and culture more organisms at lower trophic levels. We present three scenarios predicting future fisheries and mariculture activities. These scenarios assume different availability of marine resources for mariculture feed.

1. Introduction

A current belief among many evolutionary biologists is that the human species descend from an early primate that lived and collected its food in shallow marine waters some 7 to 9 million years ago. This theory is in opposition to the traditional belief that our species developed on the savannah after leaving the trees. Many morphological and behavioural characteristics support the idea of an early marine or coastal phase, for example our hairless skin and our new-born children's ability control breathing during swimming. There are many other characteristics that points to our marine origin as well, but our large and well developed brain that is a prerequisite for our superior mental capacity compared to other animals is suggested to be the strongest indication. It seems well documented that the brain size of terrestrial animals has not kept pace with the general increase in body weight of the animal during the course of evolution. This is particularly apparent for herbivorous animals feeding on plants, and extremely low brain to body ratios characterised the large plant eating dinosaurs. Michael Crawford has been a pioneer in developing these theories on human evolution, claiming that only animals feeding on marine food were able to maintain a high brain to body ratio as body size increased during evolution. The theory implies that the quality of the diet may constrain specific evolutionary developments, and the specific example of seafood and brain is quite easy to understand. Our brain and nervous system is built up of long chain omega 3 (ω3) fatty acids that are found in high amounts only in marine and freshwater organisms. The most important fatty acid is docosahexaenoic acid (22:6ω3, DHA), which is crucial for both vision and mental processes. Humans and other animals are only able to a limited extent to synthesise DHA, which therefore must be supplied in the diet. Michael Crawford and colleagues has postulated that a high intake of DHA in the food was crucial for developing the brain capacity of our species in the course of evolution.

With this evolutionary perspective in mind, we may conclude that the modern human species in many ways originates from the ocean. Contrary to other marine mammals, we never left the shore, but remained partly in the terrestrial hemisphere with its characteristic challenges as driving forces for further evolutionary developments. Crawford and colleagues have recently provided support for the idea that the modern human species, *Homo sapiens sapiens*, developed in southern Africa some 100 000 years ago and that food items with high ω3 fatty acid content was indeed an important components of their diet.

Seafood thus contributed to make humans mentally superior to other animals, and it made us in turn able to develop tools and technologies to make life easier. We have

continued to harvest food and material from the ocean, and these tools and technologies include those needed to harvest food more efficiently from the sea. These tools in turn made us able to exploit all the major fish stocks of the global oceans. A couple of generations ago, no one would believe that this could be possible. However, there is currently ample evidence that we today over-exploit the marine biological resources of the world's oceans. Many policy makers as well as scientists now call for improved management regimes.

When the steady increase in harvesting of marine natural resources levelled off in the early 1990s, a major new event was already discernible. The developments of mariculture was in rapid progress, involving cultivation methods that with varying extents of intervention with nature make it possible to enhance and control production. Most likely this development will continue, starting some 9000 years after the first efforts to culture plants and to domesticate animals on land. This represents a shift in paradigm, we are making predictions for the future but are, of course, unable to see how things will actually develop. In any event, the fatty acids found in seafood will still be important for human's mental capacity and ability to solve future problems and challenges, including our future exploitation of marine biological resources.

2. History of human harvesting technology

Methods for catching fish have been known since the earliest days of humankind. The design, manufacture and use of fishing gear is one of our oldest technologies. Improvement of existing techniques and the development of new ones have continued right up to the present. Remains of pre-hominids have been excavated in northern Tanzania together with bones of fish and pebbles that may have been shaped by those creatures as tools for killing fish. Such pebbles may have been the fishing gears of creatures before the advent of *Homo sapiens*. In those days, and some times even today, fishing might be considered to be nothing more than gathering, the simplest form of economy known to man. In their natural state, the world's oceans provide a rich variety of suitable materials of vegetable or animal origin. Fishes may belong to the most important group, but it is improbable that humans in prehistoric times would have been able to catch the fast-moving animals on a regular basis. It is more likely that the catches would consist of plants and slow-moving animals like molluscs, worms and crustaceans. Today fish provide a significant percentage of the foodstuff consumed by humanity. However, great volumes of algae and water plants are also harvested. They are used for human food and animal feed as well as for fertiliser, and for the extraction of chemicals, pharmaceuticals and cosmetic products.

A global review of fishing methods may easily lead to the conclusion that there are innumerable ways of catching fish. However, in his classic book, "Fish Catching Methods of the World", the German scientist Andres von Brandt concluded that there are only a dozen or so different basic principles for fish catching. The origins of the various methods of fishing are rather obscure. Ethnologists have found striking similarities in the fishing methods in primitive fisheries in different parts of the world. Most likely, fishing has represented similar challenges and opportunities all over the world, leading to the development of more or less identical solutions in different parts

of the world. However, there are instances from the last couples of millennia, where methods for fishing have migrated over very large distances.

Fishing and hunting may be traced to the same origins, and between them there has always been an interchange of techniques, such as spearing, harpooning, trapping, catching with hooks, and the use of nets. It is interesting to note that modern fishing with all its sophisticated equipment still contains strong elements of hunting, and in fact is considered a form of hunting by the industry itself.

Early man was only interested in catching enough for the daily needs of his family. As time passed, coastal people became aware of the seasonal variations in the abundance of the fish species they caught, and started to use storage ponds to ensure a sustained food supply. There is evidence of such activities from ancient Greece. With the advent of methods for preserving fish, such as smoking, drying, salting and fermentation, it became possible to catch greater quantities of fish for storage and future consumption. Preservation also led to barter and trade with fish. Dried cod became Norway's first export commodity more than 1000 years ago, and is still exported to the same markets as in the olden days. The first inhabitants along the coast of Norway, the way to the North, arrived as the last Ice Age came to an end. The main attraction was the abundant fish stocks in the ocean. They settled along the barren coast to exploit the riches of the sea. Some 8000 year old fields of pictographs (rock carvings) found in Norway depict boats and scenes from fishing activities. Interpretations of these pictographs suggest that the boat played a central role in the religious system of the time, and that it was an artefact of great importance to the people.

As the Norseman developed his seafaring skills, the basis for the development of ocean-going craft was probably the technologies used for constructing fishing vessels. Archaeological findings support such a notion. Most likely the people of the North developed their Viking longships from smaller vessels used in fishing activities. Vessels of this type were used for crossing the Atlantic and settling on the shores of Newfoundland 500 years ahead of Columbus. Norsemen were probably the first explorers to discover the prolific cod stocks inhabiting the cold Atlantic waters of North America. Their technology was, however, not able to support the logistics necessary for the long term development of these settlements. Some archaeologists have claimed that there are reasons to speculate on possible transfer of fishing technology across the Atlantic in both directions. However, seagoing craft were developed independently in many parts of the world. In Europe, the people of the Mediterranean established ocean-going trade more than 5000 years ago. Archaeological evidence indicates that this had its origin in fishing activities as well. One of the oldest surviving vessels is an Egyptian ship, built 3000 years BC.

The early Pacific islanders added outriggers and sails to their near-shore canoes, and were able to fish offshore for migratory fish such as tuna. This was probably the basis for the colonisation of the pacific islands 4000 years ago. Their vessels were extremely fast and seaworthy, enabling the islanders to travel vast distances. Magellan observed these vessels in the Pacific on his circumnavigation of the globe. He actually tried to measure the speed of these craft by using his European tools for measuring ship´s speed. He failed to do so because the maximum speed that his log could register was 12 knots.

His estimate of their speed was twice that, 24 knots. He reported that they were by far the fastest vessels known to man.

In the Age of the great explorations, abundant fish resources were discovered, such as the Newfoundland cod. Following the great explorer John Cabot, the Basque, the French, the British and the Portuguese established a migratory fishery in the early 1500s. Two types of fishing were carried out, the wet fishery, and the dry fishery. The wet fishery was carried out offshore, on the banks. The fish was simply gutted, split and salted on board, and taken back to Europe. The dry fishery produced *bacalao* for the southern European market. Hundreds of vessels crewed by 20 to 40 men, left the shores of Europe in early summer to fish for the cod. The fish were caught from small boats in near-shore waters. There were usually three men in each boat using baited hooks on hand-lines. A shore crew gutted, split and salted the fish, later to be dried in the sun and wind on the beach. In the mid-1800s, dory-fishing schooners from New England and the Canadian East Coast dominated the cod fisheries on the banks off Nova Scotia and Newfoundland.

Europe saw development of fisheries for pelagic species like sardine and herring. Fishermen from southern Sweden started catching North Sea herring spawning on their coast in the eleventh century. As the migration pattern of the herring stocks changed over the centuries, fishing vessels from most of the nations around the North Sea participated in the herring fisheries, using drift-nets and preserving the fish in barrels with salt. In the 1600s, sardines were caught with fine mesh nets in France, off the Breton coast. The catch was sold fresh or salted, but later on technology was developed for producing sardine oil, which became a popular commodity all over Europe. An important offshore fishery for tuna developed in the Bay of Biscay, the fish being caught by trolling lines. By the mid 1800s, canneries were in operation in many parts of Europe. Sardines and tuna were popular for canning. These events could be considered the start of industrialisation in the fishing industry.

The Industrial Revolution rapidly had its impact on fisheries in Europe and North America. British fishermen had introduced beam trawling with sailing vessels in the North Sea in the early 1800s. With the advent of the steam engine, and its subsequent introduction into ships, mechanical propulsion for the first time became available in fisheries. Paddle steamers were used for bottom trawling in the North Sea in 1860, and in the 1880s steam trawlers began replacing sailing vessels. The beams used for spreading the nets were difficult to handle, and limited the size of the fishing gear. For better utilisation of steam power, the otter trawl was developed. These nets were more suitable for fishing on rough sea bottoms. The first otter trawl was constructed in 1892 in Scotland. This fishing gear consisted of a conical net with the mouth extended into wings. These were attached to and spread by otter boards or trawl doors, as they were called in the colloquial. These doors were large door-like wooden rectangles heavily weighted with iron shoes, towed from the trawler by steel ropes. Water pressure against the boards kept the net open.

At the turn of the nineteenth century, the first steam trawlers appeared in North America. The success of these ventures was moderate at first. This was, however, the starting gun for a large trawl fishery on Georges Bank and Grand Banks. This activity

was later to be joined by most major fishing nations, an intensive activity that might be a primary cause of the collapse of the Newfoundland cod stocks.

In Scandinavia the mechanisation of fishing took a different course. From about 1900 simple small oil engines were constructed in blacksmith shops along the coast. Tens of thousands of these engines were installed in the fishing fleet before World War 1. Efforts by merchants to gain control over the fishing fleet by the introduction of capital intensive vessels were unsuccessful, and the ownership of the fishing fleet remained to a large extent with the fishermen.

Steam winches had been introduced into the trawler fleet to handle the steel warps used for towing and to ease the toil of the fishermen when handling the nets and the catch. The lack of steam power suitable for smaller vessels led to a quest for finding other power sources for mechanising fishing operations and gear handling on fishing vessels. This led to the use of internal combustion engines. In the 1920s the first engine-powered mechanical hauling devices were constructed. The invention of the low-pressure hydraulic system was an important breakthrough in fishery technology that followed ten years later. This became a boon for fishermen in many parts of the world, being a very robust system that gave fingertip control of fishing and gear-handling operations.

In the 1820s, ice was introduced as a means to prolong freshness, but it would take another 100 years before the American Clarence Birdseye introduced the freezing of fish into fisheries. He had made experiments with freezing of food for years and he later founded the company Birdseye General Seafood.

World War II led to a rapid development of a variety of technologies, some of which later proved to be of great importance for the fisheries of the world. The development of acoustic equipment for detection of submarines spurred the construction of very efficient devices for fish finding and surveillance of fish-stocks. Modern fishing would hardly be conceivable without echo sounder and sonar. Of similar importance was the development of radio navigation systems such as Decca, Loran and the more recent satellite navigation systems. Radar, developed for detecting enemy ships and aircraft, has greatly improved safety for the fisherman, and his ability to fish under severe weather conditions. The combination of position-finding devices and radar has made retrieval of stationary nets and long-lines infinitely easier.

Another vastly important change was the rapid development of new synthetic materials for boat building and net-making. This enabled the industry to develop impressive fishing gear like enormous mid-water trawls and vast purse seines with enormous catching power. The handling of large size nets has been facilitated by inventions such as the hydraulic power block, invented on the US West Coast in the 1950s—another milestone in the history of fisheries.

This long row of innovations made possible the development of the factory ship. These are large diesel-powered vessels combining the use of high-tech fish finding and navigation equipment with the use of huge nets made from synthetic fibres, filleting machinery, and rapid freezing technology. Large armadas of such ships have been

roaming the oceans for several decades, exploiting and over-exploiting fish stocks in international waters.

The development of mariculture is in its beginning. The developments have gone from production of zoobenthivores and large algae in open or closed coastal locations or ponds to land based farms, for example producing shrimps, and sea cages used for fish. Cages have been shown to be very efficient and cost effective for fish production. An efficient generation of land based and cage based mariculture farms was established at the end of the twentieth century, but developments in mariculture are most likely still in a very early phase. Coastal waters are normally exposed to strong winds and currents, at least occasionally. Sea cage systems developed for exposed or partly exposed regions will become a technological challenge of great importance because this technology will increase the area available for mariculture and reduce possible negative interaction with society.

3. Harvesting marine biological resources

Humans have harvested marine biological resources for a long time, but mariculture has gradually become increasingly important during the latter part of the twentieth century. These recent developments are in many ways comparable to those of agriculture that took part some 8000 to 9000 years ago. Mariculture has a long tradition, but it has been developed more rapidly since marine harvesting levelled off in the early 1990s (see below). The triggering mechanism for starting cultivation is therefore most likely the need to produce more food, comparable to what initiated agriculture when harvesting nature became insufficient for feeding the growing human populations. The early developments of mariculture have of course taken advantage of a far longer tradition of culturing freshwater fish. There has also been some cultivation in coastal waters in earlier times, in particular in well-developed cultures and densely populated areas of the world. Other important factors that have made developments possible are increased knowledge on the marine ecosystem, technological development, and more knowledge and experience in managing marine biological resources. The current cultivation efforts of the sea involve a wide range of methods. These includes moderate intervention with nature during sea ranching, which normally involve release of juveniles and sometimes also improvements of their habitat, and the far stronger intervention that is associated with intensive cultivation. Intensive mariculture represents cultivation with efficiencies far higher than the carrying capacity of nature and can in many ways be compared with modern agriculture. Extensive mariculture, like for example sea ranching, is more comparable with cultivation methods used in forestry.

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Biographical Sketches

Yngvar Olsen was born in Sandnes, Norway, in November 1953. He is a biologist with master thesis from the University of Bergen and doctoral thesis from the Norwegian University of Science and Technology (NTNU), Trondheim. He currently works as a professor at NTNU in Trondheim and as a scientific adviser in SINTEF Fisheries and Aquaculture. In his university, he is involved in research and teaching in plankton ecology and marine aquaculture, and he was the Program Manager of MARICULT Research Programme (1996-2000,) with the ultimate aim of identifying possibilities and constraints of harvesting more resources from the ocean. Beside this, he has chaired a number of large national and international research projects in the field of mariculture and coastal sciences, and has published a number of papers in international journals and taken part in the organization of many international conferences.

Anders Endal was born in Trondheim, Norway, in December 1961. He is a Naval Architect from the Norwegian University of Science and Technology, (NTNU) Trondheim. Professionally, his life was at the outset dedicated to the industrial design of fishing vessels and fishery technology and later on to research, development and education in the field of fisheries and aqua-culture. He has an extensive design and

engineering background at home and abroad, as well as managerial experience from shipbuilding, consulting, marketing and research. He was a member of the UN Expert Committee on the Future of Fisheries in 1994. In 1978 he became adjunct professor at the College of Fisheries, Tromsoe, Norway, and since 1988 professor at NTNU, where he was Dean of the Faculty of Marine Technology (1992-1998). He has been manager and participant in national and international research programs.