ISSN: 0001-5113 AADRAY	ACTA ADRIAT., 49(3): 201 - 232, 2008	UDC: 597(091)

Evolutionary steps in ichthyology and new challenges*

Walter NELLEN [1*] and Jakov DULČIĆ [2]

[1] ***Institut for Hydrobiology and Fisheries, University of Hamburg, Olbersweg 24, 22767 Hamburg, Germany***

[2] ***Institute of Oceanography and Fisheries, P.O. Box 500, 21 000 Split, Croatia***

**** Corresponding author, e-mail: wnellen@uni-hamburg.de***

One may postulate that man's interest in fish emerged as soon as he was able to express his thoughts and notions as fish, among other animals, were subject of early communications. These were transmitted first by drawings, later by inscriptions and in writings. It was but much later that fishes began to occupy man's interest as objects of science. Aristotle's treatises on "History of Animals" is the first known document dealing with fish as a zoological object. No earlier than in the 16th century fish regained the interest of learned men, among these Olaus Magnus (1490 –1557), Gregor Mangolt (1498–1576), Guillaume Rondelet (1507–1557), Pierre Belon (1512–1564), Hippolyto (Ippolito) Salviani (1513–1572) and, above all, Conrad Gesner (1516–1565). The 17th and more so the 18th century is known as the period of Enlightenment. Respect must be paid to three pioneers in this field, i.e. Francis Willughby (1635–1672), Peter Artedi (1705–1735), and Marc Elieser Bloch (1723–1799) who became clearly aware that the class of fish consists of species which may be classified and typically described as such. After the species concept had been embodied in the scientific way of thinking by Linné, a tremendous expansion of activities emerged in the field of ichthyology. Many different regions and aquatic localities were researched and described by their fish fauna. In the 19th century until the beginning of the 20th century ichthyology was dominated by disciplines such as taxonomy, descriptive biology and classification. This was followed by more advanced physiological, ecological and ethological research on fishes, yielding quite new insights in modern ichthyology. Nowadays research is largely orientated towards aspects of applied ichthyology, i.e. fishery biology and aquaculture. Fish and ichthyological records, respectively, proceeded discontinuously and recurred periodically. Many scientific questions on fish still remain unsolved, allowing ichthyologists of today to continue working on this highly diverse and species-rich group of vertebrates. In the future new challenges in ichthyology will be emerging in the fields of a) taxonomy, b) evolution and systematics, c) population biology, d) ecology, e) studying unknown regions for their fish fauna, f) expanding and improving an international global catalogue of fishes, g) exploring and analysing not yet recognized literature.

Key words: ichthyology, history, evolutionary steps, new challenges

* Presented at ECI XII European Congress of Ichthyology, Cavtat (Dubrovnik), Croatia, 9-13 September 2007

INTRODUCTION

Much of what will be said in this paper is certainly not new. Nevertheless it may be worthwhile to repeat some of the issues which others have said in extent much earlier - especially ARTEDI (1788), CUVIER (1828) and GÜNTHER (1880). This is certainly justified as most of their original ideas are today not very present any more but may be seen in a new perspective today. Further, new knowledge, ideas, and methods in ichthyological science disciplines have developed as time went by and these justifies to revisit the perception on the evolution, advances, and new challenges in this subject area of human interests.

By preparing this manuscript the authors realized many facts which were new to themselves and on which we should have known more before, even as fishery biologists. Certainly, the past is the key to the present. Often young students of applied ichthyology are not too much concerned to consult publications which have been written more than one or two decades ago and they are not necessarily much interested in the origin, development and growth of their science discipline. However, for a deeper understanding of the development of fish and fisheries biology a serious consideration of the history of the discipline is certainly of great importance to fully understand the ecological and economic importance of the most species-rich group of vertebrates and how our understandings of this diverse animals developed and progressed. Many times new ideas grow on the basis of old findings. Without a basic knowledge on the species of interest for either basic or applied science any approach to a sustainable use or most economic exploitation as resource must fail.

How did man's understanding on fishes progressed with time and which were the main motivating powers of the scientific process? Though ichthyology did not develop in a straight line, however, its evolution is nevertheless clear and holds on to this day.

Mankind was early concemed with fishes probably since man exists. People showed always great interest in fishes because the exploitation of fish stocks are at increasing demand many of these wild living resources are still considered the last ones existing shortly before over-exploitation. For many early human communities it was most likely mainly fish which provided people with nutritionally high quality protein. To wait patiently for capturing a large salmon or spearing a pike on the edge of a lake or on the banks of a river is certainly much easier than to hunt a bird or a mammal in a dense wood. The importance of fish as human food has frequently been documented by the rich findings of fish bones in the litter of ancient settlements the prime locations of which had often been alongside waters (TSEPKIN, 1980; HEINRICH, 1987). But the attention of man was also attracted by the beauty and curiosity of many fish species and their way of life, providing good reasons why fishes became an early subject of art. From the Crete culture colourful wall paintings are still available which are three and a half to four thousand years old, showing fine pictures of species that can easily be identified (Fig. 1). Further

Fig. 1. Wall painting from Thera (San Turin) about 3500 years old

fish and fishing stimulated poets, and fish were also subject of religious worship. Finally fishes have been and still are objects of science and they were so almost right from the start of scientific thinking, though it can't be said when scientific ichthyology actually began, as we don't have any documentation whether men engaged themselves with fish in a manner that comprise the application of systematic and methodical rules. Such were agreed upon late and gradually. Therefore we may speak about ichthyology whenever and wherever solid information on this group of vertebrate animals is found.

ARCHAEOLOGICAL DOCUMENTS

As soon as man was able to express his thoughts and notions by lasting notes his messages also concerned fish. The earliest information goes back to some 20 000 years ago (Fig. 2; Fig. 3). We do not know for which reason the Cromagnon people painted flat fish, salmons and other fish species on the stony walls of their caves, whether it was to announce fish to make a good eating or to obtain rich catches by invocation or to worship fish as a religious symbol like Christianity does up to now. Whatsoever the reason, written information is lacking.

The oldest inscriptions on fish are lists of fish names from Schuruppak at the River

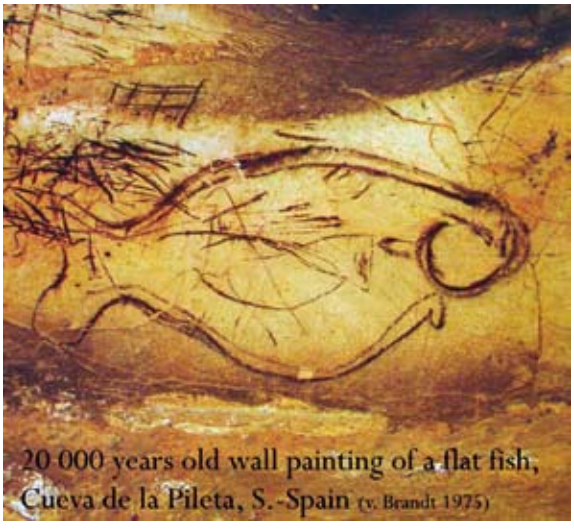


Fig. 2. 20.000 years old wall painting of a flatfish Cueva de la Pileta, S.-Spain (from v. BRANDT, 1975)

Fig. 3. Trout scrached in a clay floor, Cave Niaux S. France, 16 000 years old (from SAHRHAGE, 2007)

Euphrates, Mesopotamia, written in cuneiform about 2600 B.C. (SAHRHAGE, 1999). Many fishes and fishing techniques were also depicted as relief's testifying their high importance in these early civilizations. A religious poem of that time mentions 17 fish species. Not surprisingly fishes or at least one species of fish (*Barbus esocinus*) obviously had a powerful religious status in that priests used to dress in its skin (Fig. 4).

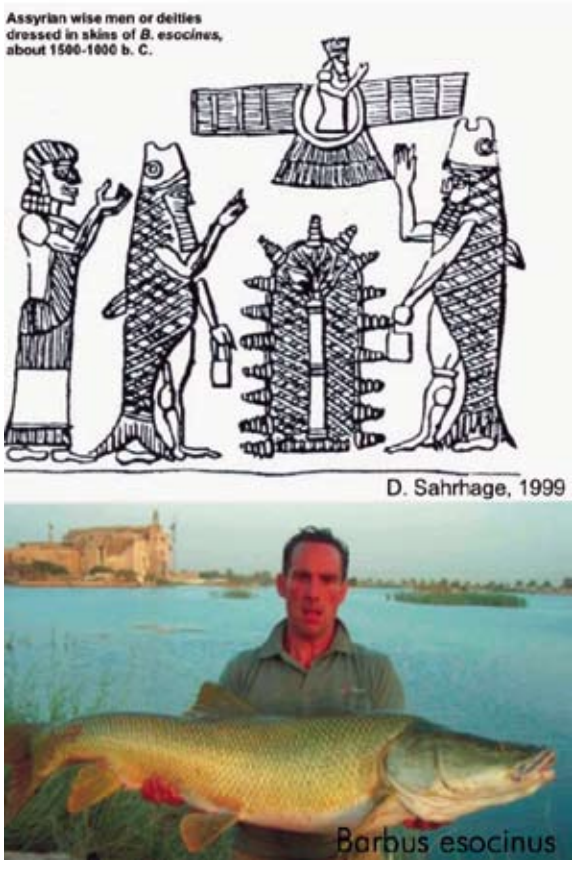


Fig. 4. Barbus esocinus (copied from "Fish Base") and Assyrian wise men dressed in a skin of Barbus esocinus 1500-1000 b. C. (from SAHRHAGE, 1999)

In the centuries thereafter fish were extraordinarily important to the empire of the ancient Egyptians. Like the people of Mesopotamia they depended very much on a big river, the Nil. It is almost natural that their knowledge on fishing was early developed. More than 2000 years B.C. almost all fishing techniques still used to this day were known in Egypt: spears, rod and hooks, fish baskets, seines, and probably even trawls (SAHRHAGE, 1998). Because of the high ability of the Egyptians to express their way of life by writing, inscribing, and engraving we are informed how much knowledge they had not just on fishing but on fish itself too. The existence of an anatomical vocabulary, descriptions of many different species, and knowledge about specific patterns of fish behaviour as well as habits may let us argue that fishes were treated already in a kind of scientific way. Fishes were looked at most thoroughly and species were catalogued as paintings and engravings on the walls of many private Egyptian tombs. Out of the 65 Nil fish species known today about 30 can be identified from ancient figures (SAHRHAGE, 1998). Of certain fish species mummies and tombs were found. One may assume that these had a mythological meaning, but it seems more likely that as a whole the people of the Nil valley had mainly a pragmatic view on fish. This suggests the meticulous representation of fishing scenes which may be interpreted as instructions how to handle different gears (Fig. 5). Not before four thousand years later a comparable visualization on fish catching methods was given by DU MONCEAU (1772).

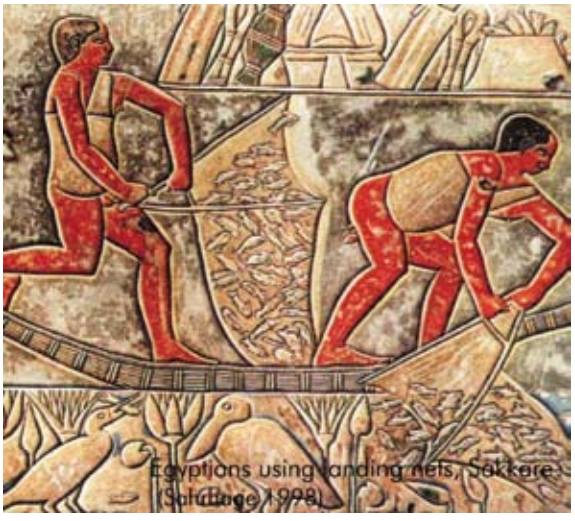


Fig. 5. Egyptian fishermen handling landing nets, Sakkara (from SAHRHAGE, 1998)

CLASSICAL ANTIQUITY

The ancient Greek naturalists were highly knowledgeable about many aspects of fish biology. According to MAIR (1963a) the earliest classification of animals in any detail occurred in a collection of writings which pass under the name Hippocrates in the 5th century B.C. This classification is particularly based on animals used for human consumption and they are grouped according to similarity in quality of flesh, but a sub-grouping considers the habit or habitat of animals as well: Fishes are specified as rock-haunting, wandering, as living in muddy places, in rivers, and in lakes.

Generally ARISTOTLE (384–322 B.C.) is considered as the real founder of scientific zoology though not necessarily of ichthyology in the sense of today as he never wrote a kind of monograph on fishes. But the advances he made both in practical observations of fishes as in theoretical considerations about their nature are just overwhelming. Many examples illustrate the original reflections of Aristotle resulting in new ideas and knowledge as for instance why bony fishes are so prolific or how the *Chondrichthyes* and *Osteichthyes* differ in their reproductive biology. Aristotle's zoological definition of fish was the first clear and correct one so far: the tribe of fishes is a unified group, distinct from other water-animals, and includes many sorts of various appearance, …they have two peculiarities, gills and fins …Aristotle: Historia Animalium (translated by PECK, 1970).

One may wonder why his classification did not follow his deep understanding of zoological facts. But in this regard he had probably followed rather ecological than anatomical and physiological rules and by doing so all animals of the hydrosphere should be grouped as "fishes". Aristotle's writings typically show how the author is firmly convinced that there is absolutely no doubt about the correctness of his innu-

merable results. But several were gained just by his philosophical considerations on fishes, their manifold characteristics and nature and without proof he uses frequently terms like "the cause of this", "that the reason why" or "the reason for this is". An example of this style is given when he argues why (bony) fishes are so very prolific and why the larvae necessarily have to grow as fast as yeast grows. (De Generatione Animalium III, translated by PECK (1963). In a preface Peck refers to previous scientific workers quoted by Aristotle "in order to disagree with them". All this may have contributed to the fact that people were so much convinced about and satisfied with Aristotle's scientific statements that his work stayed unquestioned for almost eighteen hundred years although it contains many contradictions and curiousness as well.

The Romans appreciated fishes first of all as food and as decorative elements in mosaic work, wall paintings and even on coins. Many of them show relatively precise the external characteristics of the species (Fig. 6). SAHRHAGE (2002) gives a list of 125 different fishes known to the Romans. This is slightly more than Aristotle mentions, who recorded about 115 species. But here as there we often lack the means of recognizing the named species when it was not depicted. Common names were used popularly and greatly differed regionally as it is the case to this day.

In Roman times applied ichthyology was of main interest. There are records on instructions how to prepare good fish meals or how to catch, to keep and to culture fish. Two fine literary records of this period are left, Halieutica or Fishing by OPPIAN, 2nd century and The Mosella by AUSONIUS, 4th century. The Halieutica is an anecdotal but nevertheless very instructive, competent, and dramatic poem on fish waters, fishing, fishermen and fish behaviour by a well-informed author. Who ever has tried to catch a mullet will be able to understand when reading for instance:

"The Grey Mullet, when caught in the plaited arms of the net, is not ignorant of the encircling snare, but leaps up, eager to reach the surface of the water, hasting with all his might to spring straight up with nimble leap, and fails not of his wise purpose. For often he lightly overleaps in his rush the utmost bounds of the corks and escapes from doom (Halieutica III 99-104)."

While originally written in Greek, the entire text is still much worthwhile to read, because

Fig. 6. European seabass depicted in two Roman fish mosaics and in a modern textbook, pay attention how the second dorsal fin is represented

it is excellently translated by MAIR (1963b). The Mosella is a Latin song of praise. Among other things it tells enthusiastically about sixteen fishes of the River Moselle. The following quotation of Ausonius' words about the eelpout (*Lota lota)* demonstrates this very vividly: "... with what colours has Nature painted thee! Above, dark spots pick out thy back and rings of saffron surround them; azure hue continues the length of thy sleek back; up to the middle of thy length thou art full-fleshed and fat, but from there right on to thy tail's tip, thy skin is rough and dry."

Interesting to read is also what Ausonius says with regard to the superb ecological state of the Moselle River at his time: "... though through thy smooth surface showiest all the treasures of thy crystal depths – a river keeping naught concealed……we behold things whelmed far below, and the recesses of thy secret depth lie open."

A Roman interest in fishes as zoological objects, however, is largely to completely lacking. The best to summarize the antiquity is to quote CUVIER (1828): "From a careful comparison of ancient works it seems to me that the ancients distinguished and named about 150 species of fishes, or nearly all the edible species of the Mediterranean Sea, but they did not precisely establish their characteristics and did not even dream of methodically classifying them, so they themselves were constantly confused in their nomenclature." But it should be added that, apart from this deficit, the great many of ideas which ichthyologists as well as fishery biologists are occupied with to this day had been developed in the classical antiquity.

THE MIDDLE AGES AND THE EARLY MODERN AGE

The Middle Ages should be judged from an ichthyological point of view mainly under ecological aspects. Economy expanded considerably in medieval Europe fraught with severe environmental impact and with complex interactions between human societies and the ecosystems they lived in. The hydrological conditions in many European countries changed drastically and basically. Deforestation, aggregation of people in steadily growing cities, intensification of agriculture, proliferation of water-powered grain and saw mills caused a great change in the hydrographic balance and in the ecological conditions of aquatic habitats (HOFFMANN, 1996; NELLEN, 2005). Floods as well as dewatering of streams, pollution, cutting off migration routes of fish etc. had unpleasant consequences and with these a severe impact on fish stocks resulted. Interesting social response of medieval Europeans to rising pressures against the fish resources of inland waters were privatization, commercialization, public regulation of fish exploitation, and pond culture of fish (HOFFMANN, 1996; NIEDERWOLFSGRUBER, 1965).

Though in the course of the Middle Ages Aristotle became important for his rational and logical approach to knowledge, influencing the scholars at the newly forming universities during the 12th Century Renaissance his natural science gained less interest. Scientific literature about fish does not exist except that clergymen by ignoring (or happily accepting?) the findings of Aristotle found some riverain animals as beaver, otter and some birds being "fishy" enough to make a good eating during fasting days.

The Middle Ages were but also the beginning of the time of exploration and seafaring and with it an interest in foreign geographic areas arose with their populations, animals, plants, and riches.

A respected man having travelled on behalf of the king of Sweden to gather information on the almost unknown region of the Northern Scandinavian peninsula and its bordering seas was OLAUS MAGNUS (1490-1557). He first had been an assistant of a catholic trader of letters of indulgent, later he became last archbishop of Uppsala. His travel report is a mixture of reliable observations and credulity. Among other things he gained knowledge on the tremendous richness of fish thriving in these regions. Though this resource was used by the people living along the shores of the Gulf of Bothnia and the North Sea for some time already the North and the North Sea were still largely unknown to the civilized world. Not surprisingly Olaus'

reports contain many new informations on fish, fishing, fish behaviour, fish trade and mysterious aquatic beasts as well. The famous Carta marina of 1555 by OLAUS MAGNUS as well as his Historia de Gentibus Septentrionalibus (History of the Northern People) tell for instance about river migration and catch of salmon at the Baltic, about fishing with light, about salting of fish or about the rich herring fisheries near Bohuslän Western Sweden and at the coast of Skåne (Schonen) (Fig. 7). Much of this was seen by himself, but strange fishes and sea monsters of the North Sea he just regarded as likewise real by trusting in the reports of others (BALZAMO & KAISER, 2006).

The first book of modern age addressing entirely fishes is by GREGOR MANGOLT (1498–1576). It deals with the fishes of Lake Constance and may be called the first ichthyological book on the whole. It is the first treatise on this subject not written in Latin but rather in a native language. It may be called the first ichthyological book on the whole. Its title reads:

„Fischbuch von der Natur und
Eigenschaft der Vischen, insbesondere
derer so gefangen werden im Bodensee
und gemeinlich auch in anderen Seen
und Wassern, durch den wohlgeleerten
Gregorium Mangolt beschrieben
vormals nie gesähen" (Fig. 8).

It deals with the fishes of Lake Constance "never seen before. His simple and partly quite native descriptions relate to the reproduction and food of fishes, their value as human food and, in detail, to the nature and characteristics of many. The book surely indented to inform local people of "their" fish as well. Mangolt mentions 76 fish-names which were commonly used only by people of Konstanz (RIBI, 1942). This

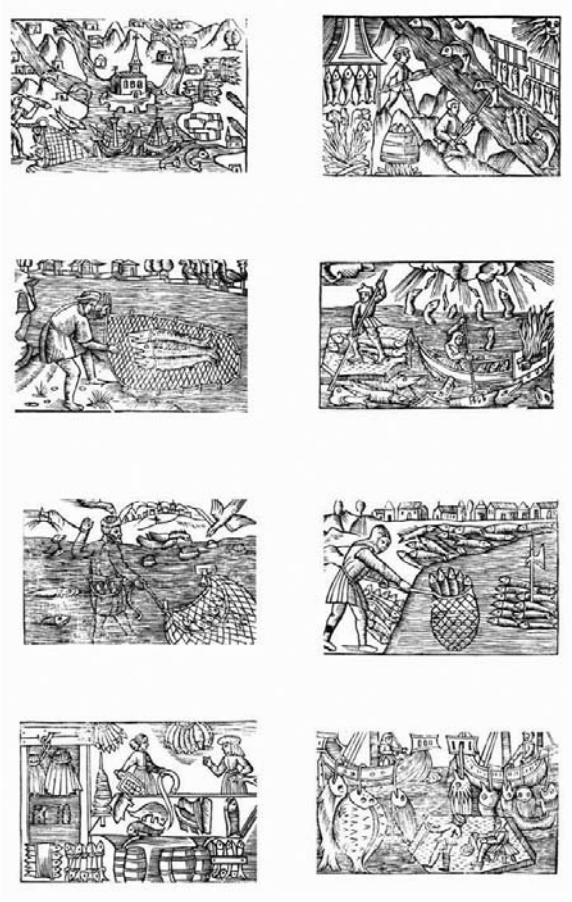


Fig. 7. Olaus Magnus, 1555 - pictures from "History of the Northern people" (from BALZAMO & KAISER, 2006)

Fig. 8. Title page of Gregor Mangolt's „Fish Book", Zürich 1557

high number of common names is partly to be explained by the fact that for some of the fishes more than one name was in use and it can not be decided in each of the case whether some of the species Mangolt mentioned are just duplicates to others.

For nearly 2000 years after Aristotle few original observations about fish were recorded because Aristotle was considered to have completely covered all areas of natural history. In the 16th century, however, a general interest in fishes, not at least marine ones, progressed and fish gained a deeper and new scientific interest again. Aristotle's grip on ichthyology (and science) was finally broken by five natural historians. Within the short period of 15 years these five men were born in the first quarter of the 16th century. All of them were destined to revolutionize the study of natural history in southwestern Europe, and to lay a broad, deep and solid new foundation of ichthyology. These scientists were in order of birth: GUILLAUEM-RONDOLET (French) (1507-1566), HYPPOLYTO SALVIANI (Italian) (1514-1572), CONRAD GESNER (German-Swiss) (1516-1565), PIERRE BELON (French) (1517-1564) and ULYSSIS ALDROVANDI (Italian) (1522-1605 or 07). They can be considered as a product of the Renaissance, the time of intense mental ferment which had its precursor in the „Revival of Learning" due to the resurrection of Greek and Roman art and literature and the development of humanism by Dante, Petrarca, Boccaccio and others who lead the way to overcome the Dark and Middle ages.

Each of the works by Rondelet, Belon and Salviani are complemented by rich illustrations of fishes, those by Rondelet and Belon are quite simple to naive, a few of them are just fantastic. The 99 copperplate engravings Salviani had added to his book "De Historia Aquatilium Animalium", however, are not only very well done but also especially famous because of their accuracy. Salviani had been a private physician of three popes and according to his social status he became acquainted with several well known artists who took care for the performance of the fish pictures of this scientist (Fig. 9). Belon wrote several scientific works of considerable value, particularly the Histoire naturelle des estranges poissons (1551), De aquatilibus (1553), and L'Histoire de la nature des oyseaux (1555), which entitled him to be regarded as one of the first workers in the science of comparative anatomy. He published a natural history of fishes in 1551, in which he classified about 110 species according to anatomical characteristics. Rondelet's work is in advance on Belon's. His descriptions are fuller in detail, with notes on habits and natural history, the woodcut figures were highly prised by Cuvier. The names of fishes are given by Rondelet in various languages, and he made a definite effort to bring together related forms in broad groups. His work undoubtful served as a basis for that of Willoughby and Ray, and later of Artedi and Linnaeus. Later, CUVIER (1828) stated that Rondelet's work was the outstanding one on Mediterranean fishes until that of Risso in 1810 (Ichthyologie de Nice). Essentially, Belon published the first modern systematic treatise on fishes, Salviani created the first regional work on an ichthyofauna and Rondelet wrote the first text on ichthyology.

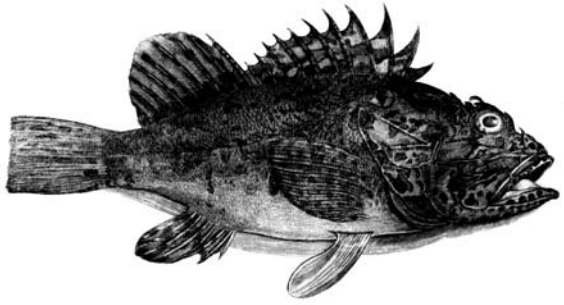


Fig. 9. Hippolyt Salviani, 1558 – Scorpaena

Conrad GESNER (1516–1565) was an encyclopaedist of the early modern age the first one after Aristotle and 1800 years later. One of the six volumes of Gesner's Historia Animalium (printed 1551-1634) is on fishes. In contrast to Aristotle some of his work is ichthyology in the strict sense. This part was translated into German already in 1598. It became most popular wherefore many reprints followed. The author had intended to describe all fishes of the world: those from the Mediterranean, from lakes, rivers, and from waters not only of Europe but

Fig. 10. Title page of the "Fischbuch" by C. GESNER

Fig. 11. C. GESNER, 1598 - "Fischbuch": some illustrations of marine fishes

also of Asia, Africa, America, East and West Indies, as its subtitle says (Fig. 10). Gesner had the fishes arranged according to their outward appearance, so putting a certain (though not very sophisticated) classification in place. He labelled the so far imagined groups with names. Moreover he still regarded water mammals and invertebrates as fish too and, even more uncritical, he included each of the sea monster he ever gained knowledge about into his fish book, many of them copied from Olaus Magnus. It is obvious that many of the fishes in Gesner's book were illustrated just by hearsay or copied from others but not collected and seen alive or as fresh specimens by the author himself. He likely preferred first and formost to illustrate as many kinds of fishes he had heard about as possibly being in existance rather than to depict them as proven species, accurately and down to the last detail. Gesner's work is an omnium-gatherum, but it became a standard work in Europe of the 16th and 17th century. This was probably because of its exiting text and sensational illustrations of strange creatures. People certainly amazed the book's touch of creepy superstition and Christian Mythology. Several of the woodcut figures are quite acceptable and allow a rough identification of a certain species (Fig. 11). Many pictures are poor, however, surprisingly even those showing domestic fresh water fishes. But the figures of monsters, "Wallfischen" (whales, sea monster, and other "sea miracles") are well-done

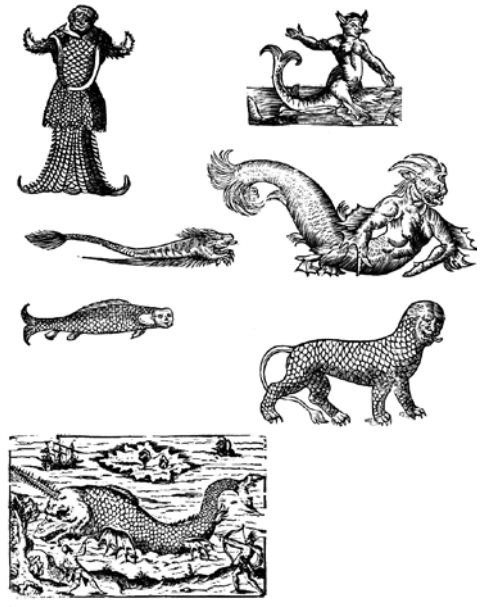


Fig. 12. C. GESNER, 1598 – " Fischbuch": some illustrations of sea monsters

(Fig. 12). Gesner's Historia Animalium is much less sober minded so far the fishes are concerned when compared to Aristotle's Historia. In Greek such implausible beasts like mermaids and other hybrids of man and fish were obviously lacking. But as the Roman Pliny (23-79 a. C.) was convinced in Nereids and Tritons as living beings (KÖNIG, 1979) his tales may have given rise to some stories about aquatic monks and bishops. We would hesitate a bit to state that Gesner had a genius for grafting the new onto the old as BOORSTIN (1986) does.

GRMEK & BALABANIĆ (2000) presented documents that came into being between 1580 and 1584, in the collaboration between Ulisse Aldrovandi and Jakov Sorkočević, gentleman, of Dubrovnik and kept in the Aldrovandi Museum in the University Library in Bologna. Jakov Sorkočević persuaded Aldrovandi that the description in Aristotle and Pliny was no invention, but that they really recorded knowledge they had arrived at by observation. Another very interesting idea of him is that it should be possible, only on the basis of the size and shape of a tooth from an unknown fish, to conclude what shape and size the fish itself was (the later law of correlation). Further, while the learned university professor in Bologna and great natural scientist, in connection with origin of gaovica (one of the genus *Phoxinus* or *Paraphoxinus*, most recently of the genus *Phoxinellus*) in Popovo polje (southern Adriatic) still supported Aristotle's theory of spontaneous generation, Sorkočević, who based his thinking of the opinions of the fishermen, held the fish to be generated via sexual reproduction, and that this could be confirmed by dissection, that is, by finding out how many eggs the female fish had, how much milt was in males. Sorkočević was the first one who describe the behaviour of certain fish (*Thunnus thynnus*) and he simply observed: "All this can be seen by anyone who looks well at these things." It is interesting to see that Sorkočević, an amateur natural historian, had his own experience-based opinion about some very important biological questions (animal physiology, behavioural natural history), as well as the fact that the great Aldrovandi, paying heed to Sorkočević, changed his own thinking, which was based upon later medieval authors (GRMEK & BALABANIĆ, 2000).

THE ENLIGHTENMENT

At the end of the 16th century and especially in the 17th century not only a broad interest in science, but also in nature awoke. Man began to escape his own made mental immaturity as Emanuel Kant said. Curiosity also for the interior of the animal body awoke and anatomical contributions of the enlightenment are remarkable, not least with regard to fish anatomy (CUVIER & VALENCIENNES, 1828). Natural history collections were set up as a modern fashion by wealthy people belonging to the educated classes. Such collections included frequently domestic as well as exotic fishes which were brought to the interest of scientists. Also specific knowledge on the fishes of defined geographic areas or just locations quickly increased in the 17th century. With it ichthyo-geography gradually developed as a scientific field by its own and, most conspicuously, people dealing with fish as an interesting group of animals devoted more accuracy to illustrate the species much more detailed and exactly as before.


ICHTHYOLOGIA
Et
NOMENCLATVRÆ
ANIMALIUM MARINORUM,
FLUVIATILIUM, LACUSTRIUM, QUÆ
IN FLORENTISSIMIS DUCATIBUS SLESVICI ET
Holſatiæ & celeberrimo Emporio Hamburgo
occurrunt triviales.
ac
Plerorumq; hactenus deſideratorum imagines, breves deſcriptiones, & explicationes
Auctore
STEPHANO à SCHONEVELDE Do-
CTORE MEDICO, CIVE HAMBURG:
HAMBURGI
Ex Bibliopolio HERINGIANO.
ANNO CIↃ IↃC XXIV.

Fig. 13. Title page of St. Schonevelde's Ichthyologia, 1624

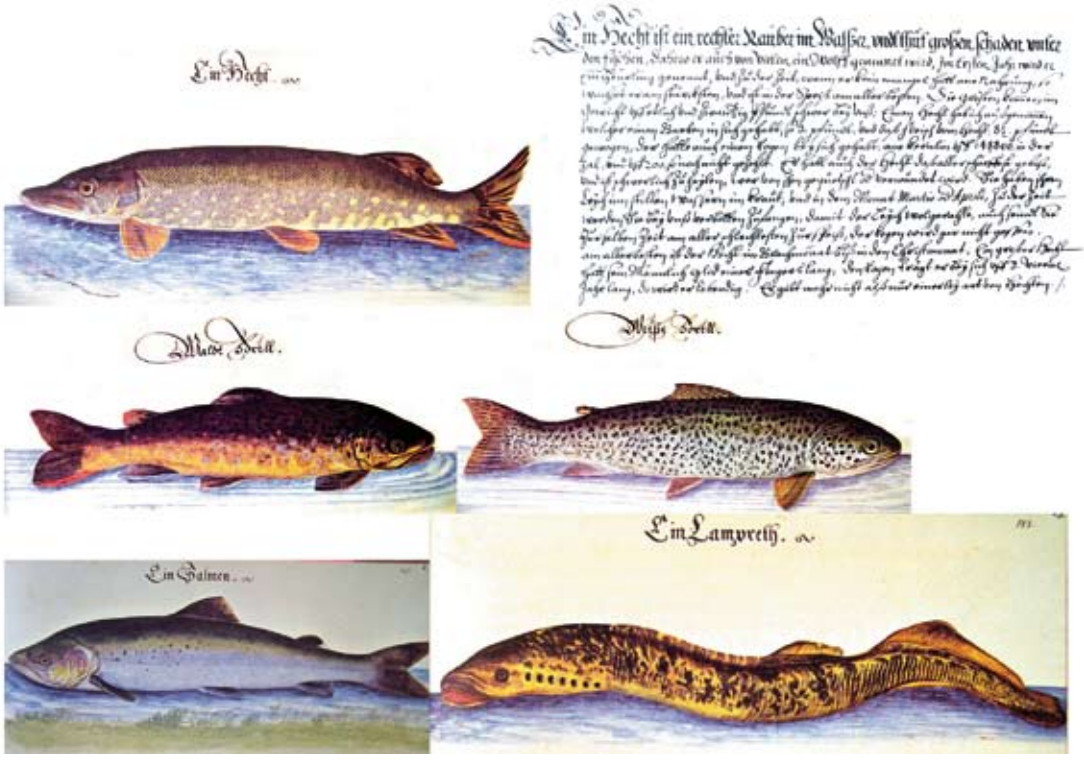


Fig. 14. Some easily to identify fish species of Leonhard Baldner's, Fischbuch, 1666

Stephan von SCHONEVELDE published a book on the fishes of the lower River Elbe and the lakes of Holsatia 1624 (Fig. 13), some were named and illustrated also by PETER HESELIUS in 1675. In 1666, LEONHARD BALDNER depicted 38 fishes and other water life down to midge larvae of the River Rhein. He was a fisherman by himself and obviously a most observant one. So his descriptions are still much acceptable today and were really a kind of innovation at his time. His book is handwritten and very nicely illustrated by watercolours giving a lifelike impression of the fishes. Also the text is artistically done (Fig. 14). Only very few copies of this book existed, and some of them were destroyed during wars (LAUTERBORN, 1903). The very last copy of high quality became fortunately facsimiled in 1974.

Fishes were now collected and described in foreign countries as well. Knowledge of fishes subsequently expanded rapidly, stimulated in good part by discoveries and reports of naturalist explorers. Guilielmus Piso (1611-1678) and George Margrave (Markgraf) (1610-1644) accompanied Prince Moritz of Nassau


GEORGI MARCGRAVI
RERVM NATVRALIVM
HISTORIÆ
LIBER QVARTVS:
Qui agit de Piscibus Brasiliæ.
CAPVT PRIMVM.
Guamajacù apé Species utraque. Guacucujà.

Fig. 15. Title page of Georg Margrav's "Historia naturalis Brasiliae", Leyden 1648

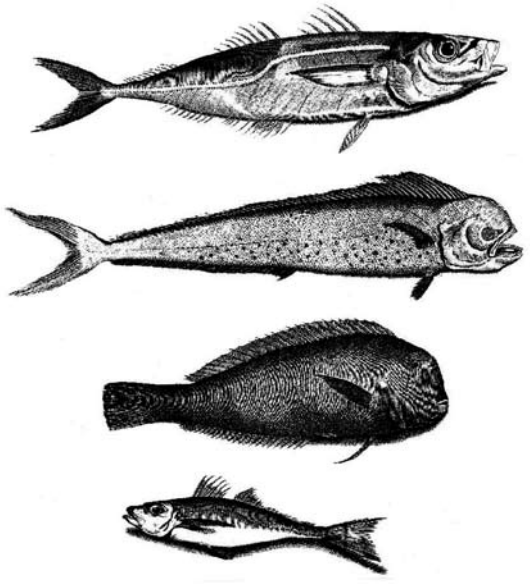


Fig. 16. WILLUGHBY & RAY, 1686, some illustrations of fishes

Fig. 17. Title page of Willughby & Ray's "Historia piscium", 1686

(1604-1679) to Brazil in 1637-1644. MARGRAVE OF SAXONY composed the Naturalis Brasilae including the Natural History of the Fishes of Brazil which was published posthumously by his friend PISO (1648) (Fig. 15). This work describes 100 indigenous fish species of the Brazilian coast. Late in the 17th century the Irish physician Hans Sloane and the French Dominic-Father B. Dutertre collected fishes of the Caribbean, the first on the West Indies the second on the Antilles. These collections were utilized by John Ray from England and a publication belonging to them appeared in 1713 after Ray's death.

Expeditions through the England and to the continent were performed by John Ray (1628–1705) and his younger friend and pupil Franciscus Willughby (1635–1672). Both intended to explore the flora and fauna for the purpose of a deeper insight in the structure of forms and to arrange them accordingly for a better classification and understanding. This was undoubtedly a new basic approach. Willughby and Ray found that only fishes are animals with blood, breathing by gills and provided with a single ventricle of the heart. The fishes were classified and catalogued first according whether they were of cartilaginous or osseous nature, then whether they were long or plane, sharks/rays – flatfish / others. The latter were grouped by paying attention to differences in forms, fins, scaling, and spines. It also were Ray and Willughby who first made concrete the idea of species. In 1686, RAY & WILLUGHBY collaboratively published Historia Piscium, a scientific manuscript containing 420 species of fish, 178 of these newly discovered. The fishes which are described by this informative publication were arranged in a provisional but quite reasonable system of classification. The many pictures of fish species shown by Willughby/Ray are a good help for identification though not necessarily an art work (Fig. 16). Works such as these are perhaps most important because they were a kind of starting point on which Peter Artedi built the classification system of fishes. The Historia piscium libri IV, 1686 (Fig. 17) was published after Willughby's death by his friend Ray. Most surprisingly it included "Cetacei Pisces" as a last group again. GÜNTHER (1880) thinks that Ray had been afraid of such great an innovation as their separation from fish. Was he cautious because of Aristotle or of the church (Gallilei was dead for just for 44 years). It is hardly to believe that Ray still cared

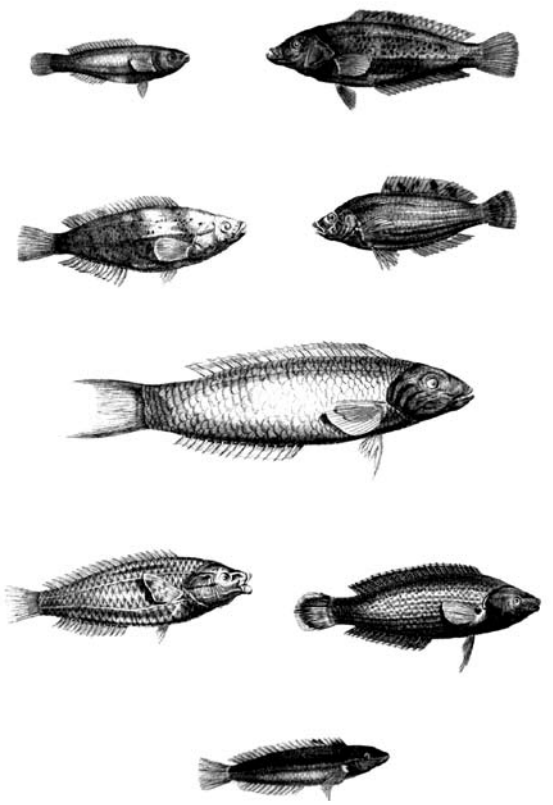


Fig. 18. Labrids from the Thesaurus Tomus III of Albertus SEBA, 1758

about Gesner as he and Willughby abandoned speculation, and adhered to facts only.

Outstanding ichthyologists thereafter were Peter ARTEDI (1705–1735) and Marc Elieser BLOCH (1723–1799). Artedi's most important work Ichthyologia, *Pars* I-V which is accompanied by several illustrations was edited by his friend and fellow in science Carl v. Linné 1738. The physician, naturalist and taxonomist Julius Walbaum from Lübeck did the same fifty years later again (1788-1793). This edition is a revised and enlarged *(emendata et aucta)* one supplemented by notes taken from all subsequent authors. As an example, Pars II contains in addition to Artedi's Systema also those suggested by J. Ray, J.T. Klein, J.C. Schaeffer, C. Linné, & L.T. Grovius (for more see SIMPSON, 1995). Walbaum's edition of Pars I (1788) quotes 645 references, some more than the original copy. Pars III names 242 species and 52 genera. Some drawings by Artedi are attached. The last text Artedi had prepared in 1734/35 was for the Thesaurus, Part III of Albertus Seba, a rich merchant of Amsterdam. This was shortly before Artedi was killed in an accident in this city to where he had gone to work on the fish collection of Seba after an intervention of Linné to have his friend sponsored by Seba. The fish part the famous Thesaurus became but printed only much later in 1758. It is accompanied by drawings of 132 fish species arranged on 34 plates in a systematic order (Fig. 18).

It is no need to say too much about Artedi and his pioneering Ichthyologia because several ichthyologists paid already previously much tribute to him (MERRIMAN, 1938; WHEELER, 1961), but it should be recapitulated that his contribution is the first scientifically valid introduction to a zoological system using the concepts of genera, families, orders and classes based on thorough morphological investigations. Further, Artedi set a positive example in taking most comprehensively the earlier literature into consideration. Artedi's species characterization "are even now models of exactitude and method" as Günther put it in 1880. In the year of Linné's 300 anniversary (2007) it should be recalled that Artedi (if he would have survived for some more years) would likely be named always together with Linné and many fish species might have carried a capital A. instead a L. behind their scientific names. The number of species recognized by Linné and named in his Systema naturae came to some 420 as he took a lot of fish species from many other sources besides Artedi (CUVIER, 1828).

Thereafter, Bloch was the very first scientist who cared about visualising fishes in a scientifically most precise and accurate manner. We would say he may be regarded as the first ichthyologist who had a very clear feeling for 'taxonomical correctness'. A physician by profession, he spend much of his free time studying fishes and finally managed to be supported by many sponsors including King Friedrich II of Prussia (KARRER, 1980). His main work "Oeconomische Naturgeschichte der Fische Deutschlands" (1782-1784) (Fig. 19) and "Naturgeschichte der ausländischen Fische" (1785-1795) were unusually expensive prints. The pictures were drawn and


D. MARCUS ELIESER BLOCH'S.

OECONOMISCHE

NATURGESCHICHTE

DER FISCHE DEUTSCHLANDS.

MIT SIEBEN UND DREISSIG KUPFERTAFFELN NACH ORIGINALEN.

ERSTER THEIL.

BERLIN, 1782.

Auf Kosten des Verfassers und in Commission bei dem Buchhändler Hr. Hesse.

Fig. 19. Title page of M. E. Bloch's Naturgeschichte der Fische Deutschlands, 1782

copperplate engravings were cut according to Bloch's advise by Berlin artists. Being aware that some species are difficult to distinguish he took care having them precisely drawn to their body proportions, fin positions, number of fin rays, scaling, way of the lateral line, and colours (Fig. 20). Bloch appears as the first biologist who treated the colours of fish most rigorously. He had criticised Linné leaving out of account variations of meristic characters and colours which both are important to know for taxonomic reason. The text is most informative, critical, avoiding speculation, and earlier publication are very well reflected. After having for instance discussed in extension and in a most objective scientific manner the phenomenon of eel reproduction he finally confessed frankly that the question must remain still unsolved. But he found out about the two morphs of eel, the one having a pointed the other one a wide head. Other ichthyologists had suggested them as two species.

For today's ichthyologists Bloch's book is still a treasure chest, as for instance as far as the existence of a certain species is concerned, say sturgeon in Germany, its neighbour countries, in the Baltic and in the North Sea in the 18th century. The ichthyological contemplations cover many details of the morphology and anatomy of the species, their occurrence and behaviour, their eggs, reproduction biology, value, taste, fishing techniques, culture, and even how they are prepared best as a meal. Bloch's work covers both, pure and applied ichthyology. It comprises 12 volumes with a total of 2040 pages. The foreign fishes are not always depicted in equal quality compared to the domestic ones. Many of the first originated from collections, and so

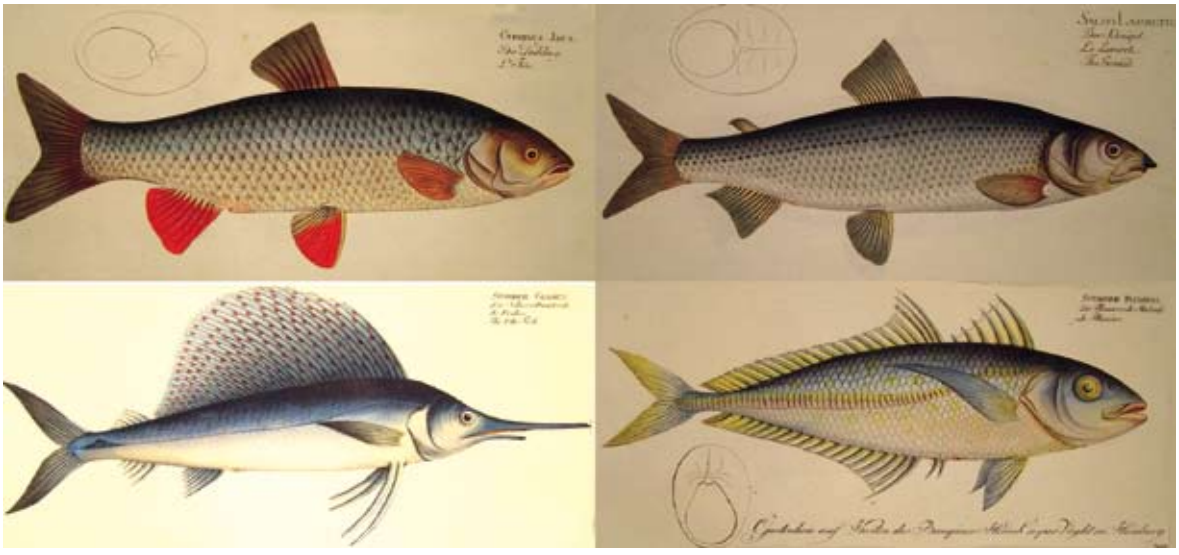


Fig. 20. Four of Bloch's fish illustrations. Some of those were financially sponsored by wealthy people interested in natural science, an example is given by the plate showing the horse mackerel. It was paid by Baron Caspar Voght a merchant from Hamburg

Bloch didn't have an opportunity to see those alive or not even as reasonably prepared specimens. Attachments to his book are registers of scientific fish names and of popular ones from ten European regions.

After having finished his Naturgeschichte Bloch started to work out a systematic of all fishes known so far. It lists 1519 species and was published posthumously by Schneider in 1801, i.e. two years after Bloch's death. Bloch followed in large Linné's Systema naturae which 10th edition of 1758 had stimulated zoologists very much. It irritates, however, that Bloch categorized the Cetacea as fishes again though he was aware of Linné having grouped them correctly as mammals. Was he not aware of Aristotle, Historia Animalium 566b XII 1-15, where it says about the Cetacea:

> "None of these is to be seen carrying eggs……they begin with the actual foetation, which……gives rise to the young animal, exactly as occurs with the human species….All animals which have a blowhole breathe in and out, as they possess lungs……Both dolphin and purpoise have milk and suckle their young…." (translation by PECK, 1970).

Bloch justified himself by arguing that it would be just schicklich, "proper" to leave the whales where the older ichthyologist had put them since they stay in water all their life and move by fins, - by no means a good scientific argument at his time anymore.

Bloch's Naturgeschichte der Fische was much sought after already at his time. It turned out to be a great success. Today it is almost completely unavailable. Sometimes single cut out plates are on the market and may be purchased for a high prise. It is somehow astonishing that no reprints at reasonable costs are available, since the book is still a rich information resource for ichthyologists. Only some of the plates were published as scaled down reprints accompanied by a biography of Bloch (KARRER, 1980).

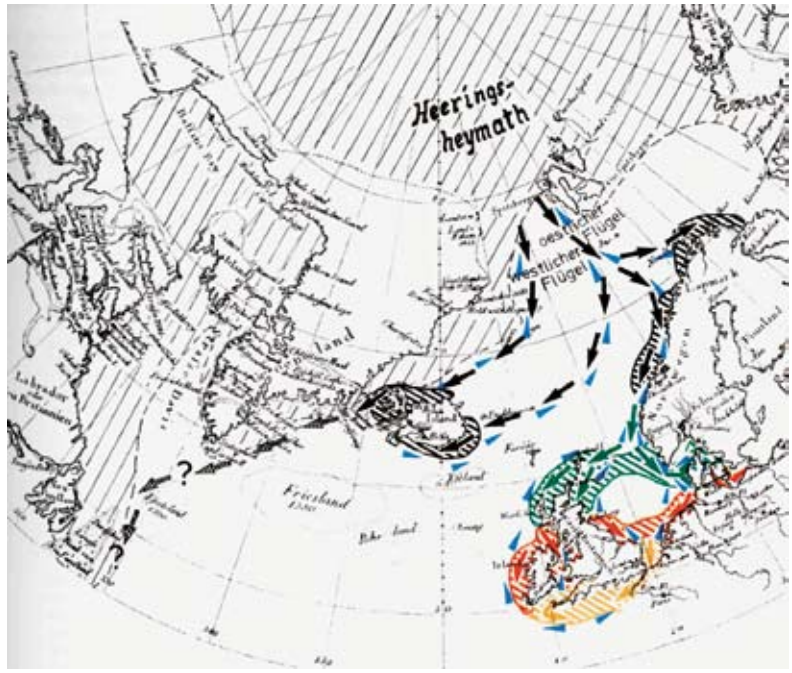


Fig. 21. Migration routes of herring according to the theory of J. ANDERSON, 1746, after WEGNER, 1993. Meaning of arrows: black = Jan. to April, green = April to June, red = July to Sept., yellow = Sept. to. Dec., grey = a likely route of a western branch of the poulation, blue = retreat to the North, hatched = fishing areas

As already indicated by the title of Bloch's book he sees fishes also as an economic resource. Not least because of this fishes became increasingly the focus of public attention in the 18th century. This then resulted in new scientific ideas under applied aspects. Johann Anderson, a major of Hamburg, for instance put forward a "theory" on the migration routes of herring in 1746 (Fig. 21). Herring was of great economic importance for his city at that time. Though his hypothesis turned out to be not correct it was regarded as valid almost throughout the 19th century (WEGNER, 1993). An exceptionally comprehensive handbook on applied as well as pure ichthyology which describes most comprehensively commercially important fish species and

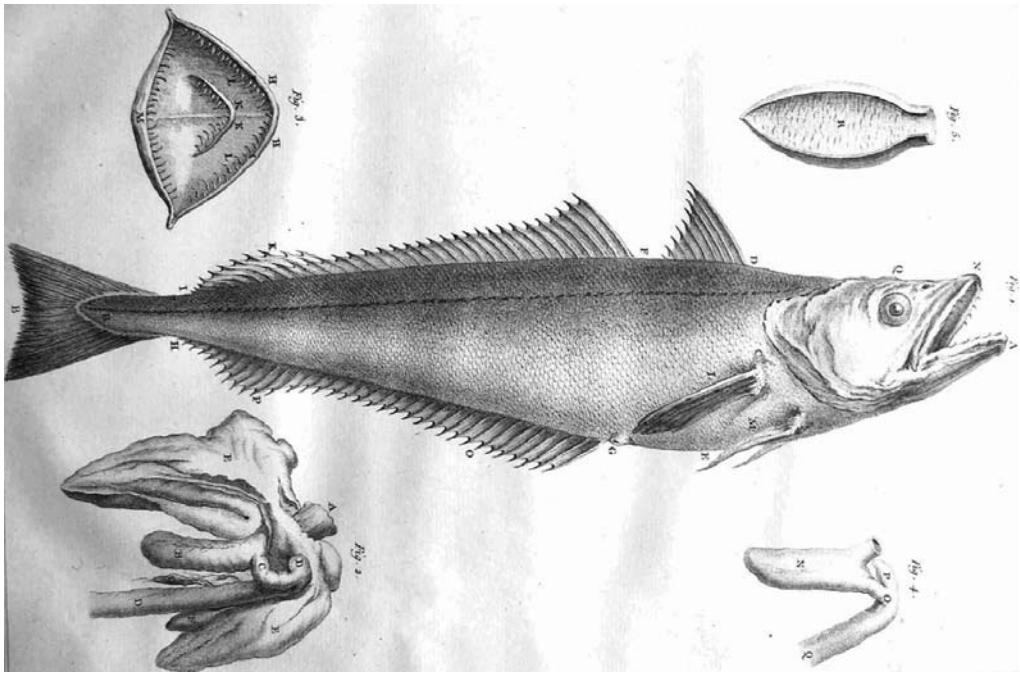


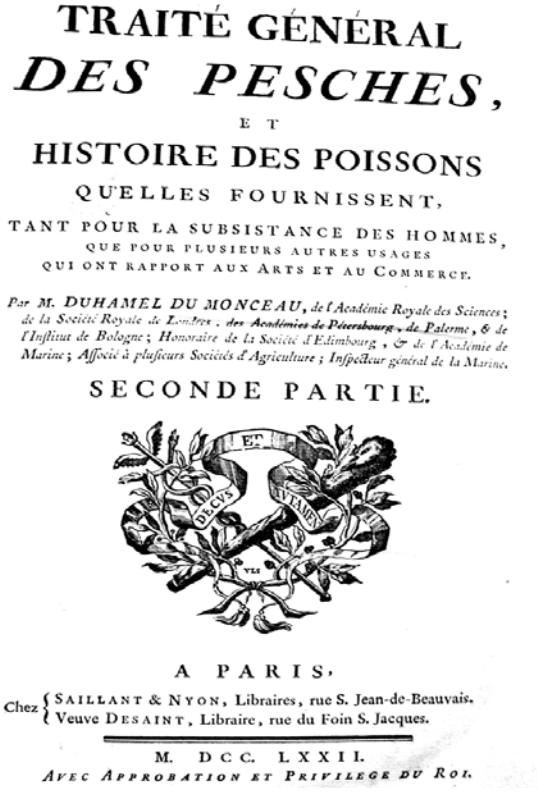
Fig. 22. M. D. du MONCEAU, 1772, plate showing some anatomical details of hake

all different kinds of fishing and fish processing methods was published in 1772 by M. DUHAMEL DU MONCEAU (Fig. 22, Fig. 23, Fig. 24).

Almost simultaneously to Bloch's Naturgeschichte B.C. LACÉPÈDE's five volume "Histoire des Poissons" was published in the years 1798-1803. Having read some chapters of the German translation by Loos (Fig. 25). I would not necessarily agree with GÜNTHER (1880) who says "But as regards originality of thought, Bloch was far surpassed by his contemporary B. G. E. Lacépède's."

Also Cuvier's comments on his compatriot sound a bit more critical. May be Lacépède's wording is more illustrative, concerning his graphs, however, he is far beyond Bloch. Lacépède was likely the first who pointed out explicitly the proportionality of body size and the size of a specific organ of it. So he could assess the length of an extinct huge shark by a fossil teeth of it. This is in the end the base for back calculation of body lengths from annual rings of fish scales.

Further, in the second half of the 18th century a great many of short ichthyological publications treating local situation were produced, about eight



TRAITÉ GÉNÉRAL
DES PESCHES,
ET
HISTOIRE DES POISSONS
QUELLES FOURNISSENT,
TANT POUR LA SUBSISTANCE DES HOMMES,
QUE POUR PLUSIEURS AUTRES USAGES
QUI ONT RAPPORT AUX ARTS ET AU COMMERCE.

Par M. DUHAMEL DU MONCEAU, de l'Académie Royale des Sciences; de la Société Royale de Londres; des Académies de Pétersbourg, de Palerme, & de l'Institut de Bologne; Honoraire de la Société d'Edimbourg, & de l'Académie de Marine; Associé à plusieurs Sociétés d'Agriculture; Inspecteur général de la Marine.

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AVEC APPROBATION ET PRIVILEGE DU ROI.

Fig. 23. M.D. du MONCEAU, 1772, title page of handbook "Traité Général des Pesches et Histoire des Poissons"

Fig. 24. M.D. du MONCEAU, 1772, process of cod salting and shipping

Fig. 25. B. C. LACÉPÈDE, "Histoire des Poissons", 1798-1803, title page of the German translation by Ph. Loos

just from German waters (for more see CUVIER & VALENCIENNES, 1828). But reports on the results gained at large expeditions date from this time too. The one originating from G.W. Steller is particularly worth mentioning in particular. During the great expedition to the North sent out by Peter the Great from Russia in the years 1740 to 1744 Steller was the leading zoologist who then detected and described the famous sea cow which was named after him and which had been wiped out thereafter in 1768. Steller was occupied also with ichthyology by following his own interests. But as fish was of economic interest to the Russian crown he had to pay attention to instructions he had received as well. Steller's handwritten most accurate notes are full of new findings. Only in Kamchatka he detected and collected more than 30 new fish species and nearly half of the number known today of this peninsula and its coastal waters came under his notice. His merits didn't but restrict to collecting. He was first to observe the specific feature of the migration routes and spawning behaviour of Pacific salmon (*Oncorhynchus*) species and he described the different morphs of charr (*Salvelinus alpinus*). Steller died untimely in 1746 at an age of 27 when suffering severe ingratitude. He therefore never came to publishing his "Ichthyology of Siberia" he had composed. Steller's scripts are left with the Academy of Science St. Petersburg. His Observationes generales universam historiam piscium came to notice in Novi. Comment. Acad. Sci. Impér. Petro. in 1753 (HINTZSCHE & NICKOL, 1996).

THE 19TH CENTURY AND THE PERIOD FOLLOWING

A tremendous expansion in the scientific way of thinking emerged after the species concept had been embodied. Ichthyology experienced a burst

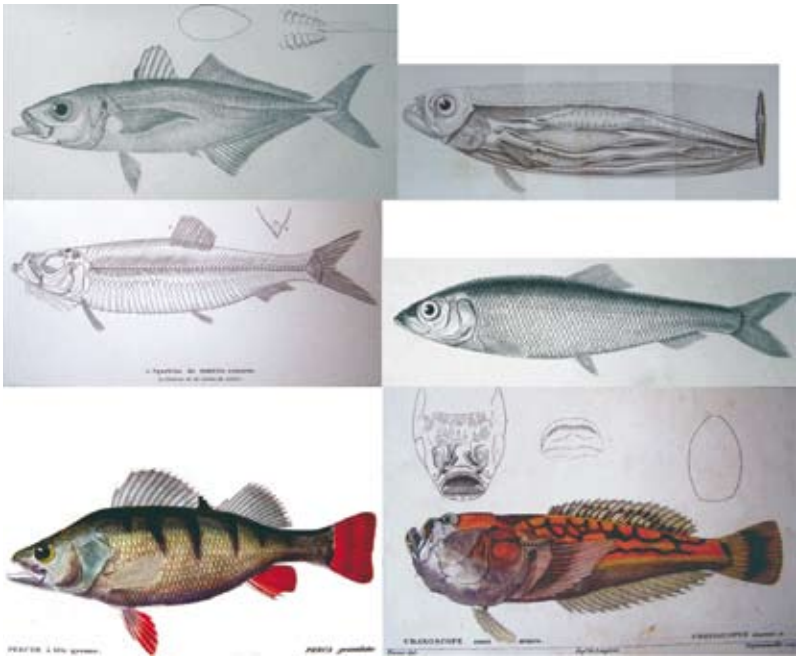

Fig. 26. Some fish illustrations of Histoire naturelle des poissons by CUVIER & VALENCIENNES, 1828-1849

in its evolution. Following PAULY (2004) the 19th century may be called the "Golden Age of ichthyology" More different regions and localities around the world were researched and described by their fish fauna in the 19th century and modern languages were used now instead of Latin.

Georges CUVIER (1769–1832) and Achille VALENCIENNES (1794–1864) tried to describe all fish species known so far by their 22 volume work "Histoire naturelle des poissons" (1828-1849) which was left unfinished but nevertheless became a stupendous feat with each species illustrated on a separate sheet quite often complemented by anatomical details (Fig. 26). The Histoire naturelle contains descriptions of 4055 nominal species, of which 2311 were new to science. This piece of literature still remained one of the most ambitious treatises of the modern world.

Peter BLEEKER (1819-1878) published 500 separate contributions, chiefly on the fishes of the tropical Indo-Pacific. His book which was not only fully illustrated was one of the best 9 volumes from previous works of other authors. Its title is "Atlas Ichthyologique des Indes Orientales Néerlandaises" (1862-1877). The literature from that work is the most accurate and comparable to many literature found today. Bleeker was employed as a medical officer in the Dutch East Indian Army from 1842 to 1860, stationed in Indonesia. During that time, he did most of his ichthyology work, besides his duties in the army. Many of his specimen he got from local fishermen, but he also built up an extended network of contacts who would send him specimens from various government outposts throughout the islands. During his time in Indonesia, he collected well over 12000 specimens, many of which are today at the Natural History Museum in Leiden. Subsequent to his return to the Netherlands in 1860, he started publishing his Altlas Ichthyologique, a comprehensive account of his studies done in Indonesia with over 1500 illustrations. It was published in 36 volumes between 1862 and Bleeker's death in 1878, and has been republished by the Smithsonian in 10 volumes between 1977 and 1983 (BLEEKER, 1862-1878). Bleeker published more than 500 papers on ichthyology, describing 511 new genera and 1925 new species.

The scientific exploration of the Americas progressed our knowledge of the remarkable diversity of fish. Charles Alexandre LESUEUR, a student of CUVIER, made a cabinet of fish dwelling within the Great Lakes and Saint Lawrence River regions. Adventurous individuals such as John James AUDUBON and Constantine Samuel RAFINESQUE figure in the faunal documentation of North America. These persons often travelled with one another and composed Ichthyologia Ohiensis in 1820 (MYERS, 1964).

Since then results of far reaching new expeditions increased the number of known species continuously and local studies added to our knowledge on the fish fauna of specific regions and water bodies which continues to this day.

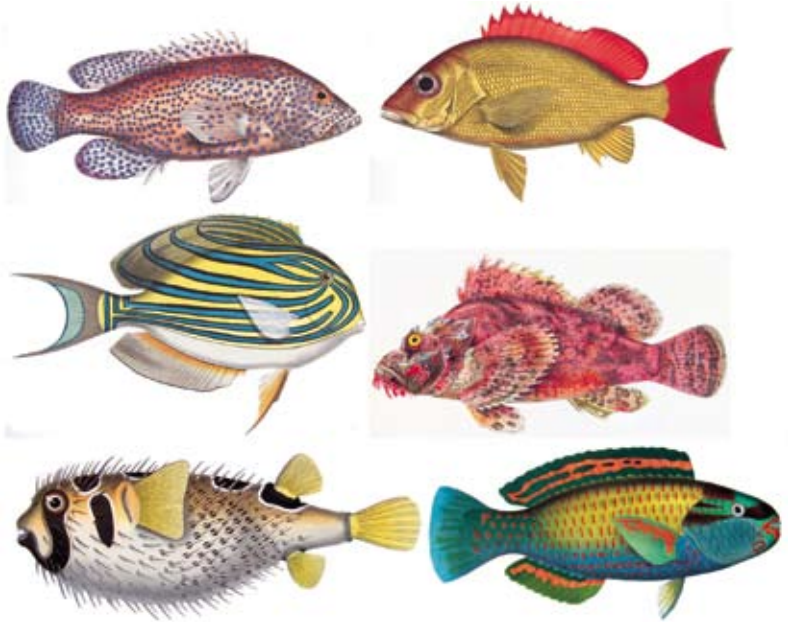

Fig. 27. Some of A. Günther's fish illustrations in the Journal des Museums Godroffoy, Hamburg 1873/75

Some of the respective scientists may be recalled: v. BAER (1851, 1858) on fishes of Lake Peipus and some fish species in Russia and on fishing strategies; AGASSIZ (1829) on species of America and on fossil fish; KRÖYER (1838-1853) on Denmark fishes; v. SIEBOLD (1863) on the fresh water fishes of Middle Europe; GÜNTHER (1873/75) on fishes from the Southern Sea collected by the British Museum and by J.C. Godeffroy a ship owner and overseas merchant from Hamburg comparable to Seba (see above). The Godeffroy family foundation allowed a most spectacular illustration of Günther's work (Fig. 27); in 1880-1895 he published further on the fishes which had been collected by H.M.S. Challenger in 1873 to 1876. JORDAN & EVERMANN (1896-1900) described the fishes of North, Middle and South America and RICHARD (in the 1890ies) the fishes of the Mediterranean (Fig. 28). VOGT & HOFER's "Fresh water fishes of Middle Europe", part II, (1908) became famous for the most reliable fish lithographs ever published. BRAUER (1906) worked the deep sea fishes colleted by RV "Valdivia" in the Indian Ocean 1898/99 and increased the species number of bathypelagic fishes by 54 new ones and 14 new genera. The total number of known fish species from depths of >400m was then about 1000. Brauer's specimens were immediately inspected and noticed by the zoologist and artist Fritz Winter, thus he was able to draw them in the most excellent way. EIGENMANN (1909, 1912, 1922) investigated cave fishes and fishes throughout South America. EHRENBAUM'S book on the 'Sea fishes of Northern Europe' (1936) became a standard work in Germany and so did DUNCKER's 'Fresh water fishes of Northern Germany (1945). Krefft, Post, Stehmann and others worked on the mesopelagic fish fauna of the Atlantic Ocean collected in the years 1966-1986 (s. POST, 1987). EVERSON (1984) and KOCK (1992) both took care on the fishes of the Antarctic Sea. Meanwhile progress in photography and print techniques enable an extremely rapid publication of fish atlases, identification and nature guides**,** see for instance PAULIN & ROBERTS (1992), GLOERFELTTARP & KAILOLA (1984), MUUS & NIELSEN (1998), or UIBLEIN *et al*. (1999). FROESE & PAULY (2000) opened a worldwide field to a large information to ichthyologists who are much interested in creating 'www.fishbase.org'. When Günther published a "Catalogue of the Fishes of the British Museum" in the years 1859-1870 he described some 6800 valid species and some 1680 doubtful ones. Today the number of existing fish species is estimated by ESCHMEYER (1998) to come to >30 000. Taxonomy expanded also with regard to fish larvae especially by EHRENBAUM (1904-1909), RUSSEL (1976), MOSER (1996), PINDER (2001) and RICHARDS (2006).

Modern fish classification and systematics on the base of orders and families began early in the 20th century and the work on it still holds on (REGAN, 1909, 1929; BERG, 1958; GREENWOOD *et al*., 1966; LINDBERG, 1974; MOSER, 1983; NELSON, 2006). In this connection, it is of some interest to

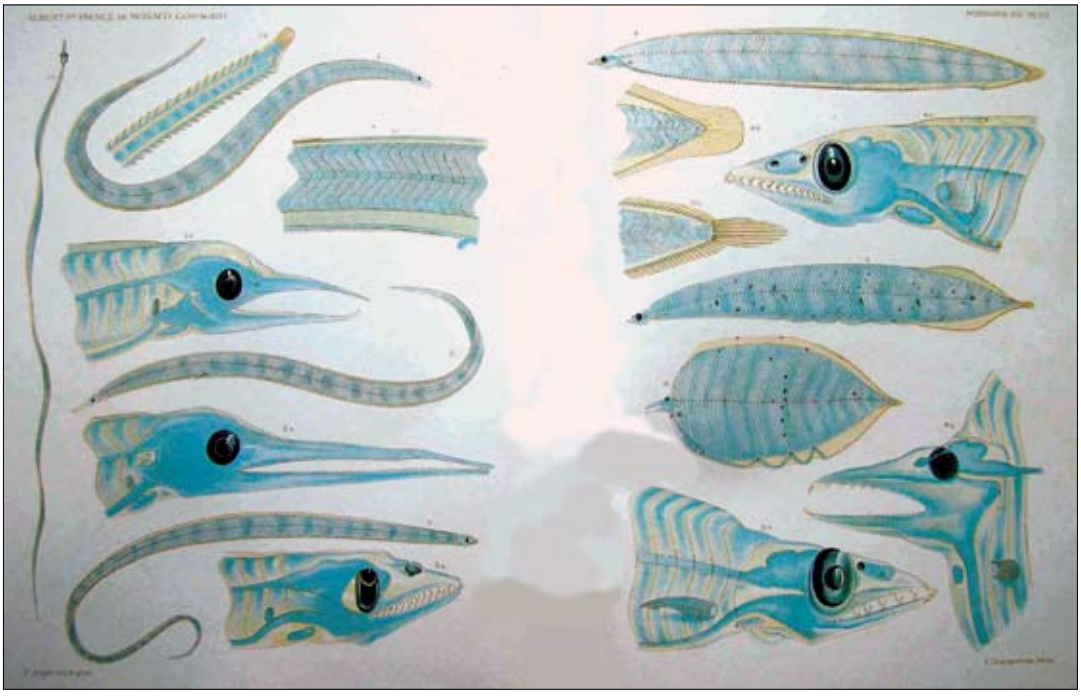

Fig. 28. Leptocephali from M. J. RICHARD (in the 1890's), results of the scientific expedition carried out with a research vessel of the Albert Ier Prince Souverain de Monaco

note the identity of titles of Lindberg's and Nelson's books. They differ in that Lindberg gives much more detailed illustrations and quotes three times as many references (some 3960) compared to Nelson (Fig. 29). Lindberg named 62 orders and 495 families, Nelson's respective numbers are 60 and 515. Ichthyologists do not agree yet much in fish classification. Surprisingly, there exists only one edition of Lindberg's "Fishes of the World", whereas the fourth edition of Nelson's book became published meanwhile.

In the late 19th century, textbooks on pure and applied ichthyology appeared and became popular (GÜNTHER, 1880; VON DEM BORNE, 1886); nowadays fish are increasingly studied by ichthyologists for their anatomy, morphology, histology, physiology, ecology, growth performance, production, ethology, pathology, and genetics. Almost no field of natural science is left out by the scientists who study fish. (v. FRISCH & DIJKGRAAF, 1935; LAGLER *et al*., 1977; MALZAHN *et al*., 2003). Fish were discovered to be able to build populations and "races" (HEINCKE, 1878) some of them being able to adapt to extreme conditions, for instance the brackish water environment of the Baltic Sea (STROTHMANN, 1906, 1915; NELLEN, 1993). After the depletion of fish stocks became more and more obvious, applied ichthyologists were not primarily concerned any longer with fish catching methods, search for more exploitable stocks, fish marketing and processing methods, but developed theories on population dynamics (BEVERTON & HOLT, 1957; PAULY, 1984, 2006; TEMMING *et al*., 2007) and concepts on sustainability of yields, a subject that gained high priority. A fishery biologist who was early concerned about coastal marine fish habitat deterioration by pollution was KÄNDLER (1953, 1963) in Germany.

Because of the increasing interest in fish stock management and harvesting and the worries which followed about fish stock degradation caused by overfishing and in addition by pollution, global warming and other habitat threats respective textbooks came out (BÜCKMANN, 1929; PITCHER & HART, 1999; POTTER, 2007). Large national and international scientific programmes were implemented (GLOBEC since about 1995) and scientifically well founded warning reports on the situation were published (ICES, 2003; GIWA,

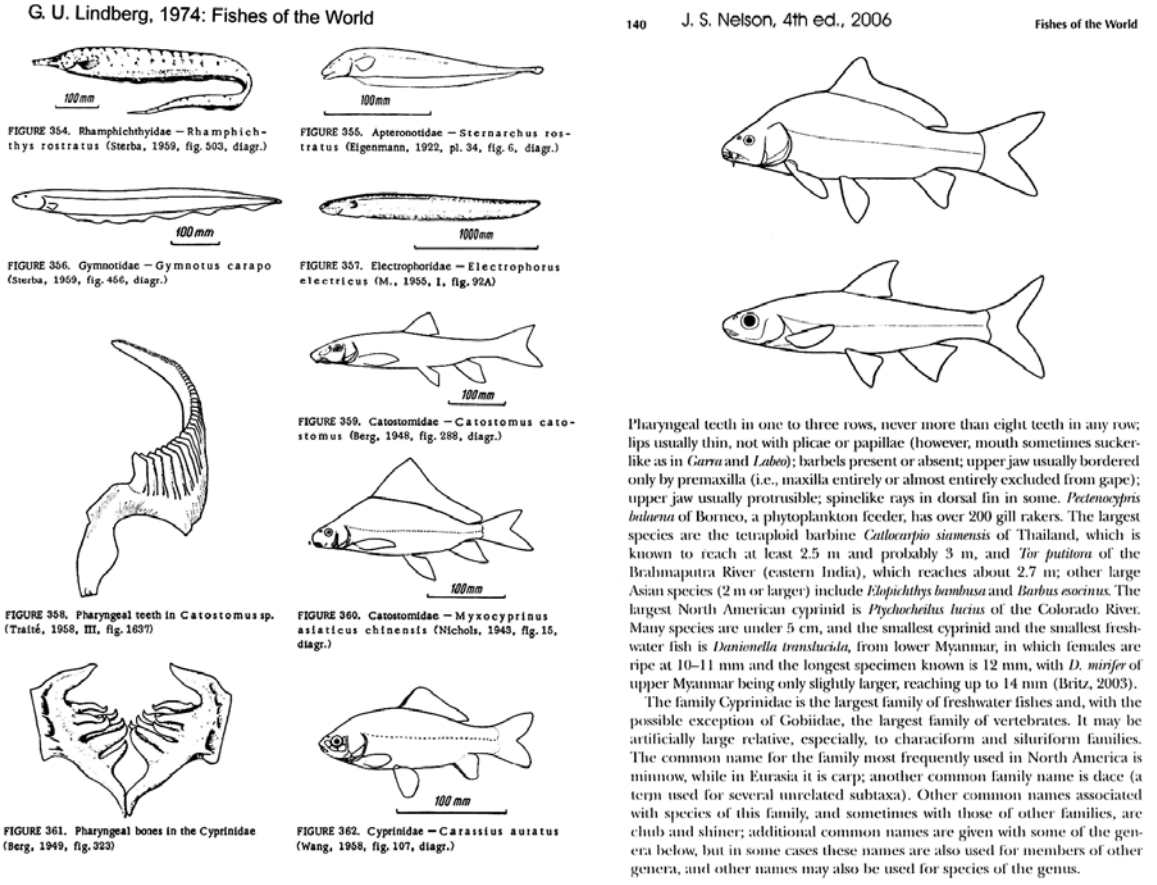

Fig. 29. Interesting to compare: two pages from Lindberg's and Nelson's book „Fishes of the World", respectively, referring to cyprinids

2006). Fish species and their stocks or populations are looked at no more mainly separately but as integrated parts of ecosystems which lead to the concept of large marine ecosystems (LONGHURST, 1998; HEMPEL & SHERMAN, 2003).

Publications on specific themes as well as modern textbooks and monographs are meanwhile enumerable, several of them are multi volume works as for instance BÖHLKE (1952-1989), HOAR *et al*. (1969-1992), or WHITEHEAD *et al.* (1984-86). Finally one should be aware of the many regional and international journals on fish and fisheries. All these publications include quite an expanded and new understanding in ichthyology which presently and even more in future will be of tremendous importance with regard to both: basic ichthyology as well as to the two branches of applied ichthyology and exploitation of wild living stocks and fish aquaculture. Obviously the latter had learned much more from new scientific results to establish a controlled fish production than the fish managers did for the sustainability of sea harvesting.

It should be mentioned as well that once awhile publications appear which speculative and cursory approach, respectively, and which are annoying and in no way helpful (WORM *et al*., 2006) especially when getting published in prestigious journals and which invite much criticism (HILBORN, 2006, 2007; HÖLKER *et al*., 2007).

New challenges

In the future a new or better to say progressing challenges in ichthyology may be seen mainly in the fields pointed out below and on which some catchwords and recommendations for further reading will be given in the following section.

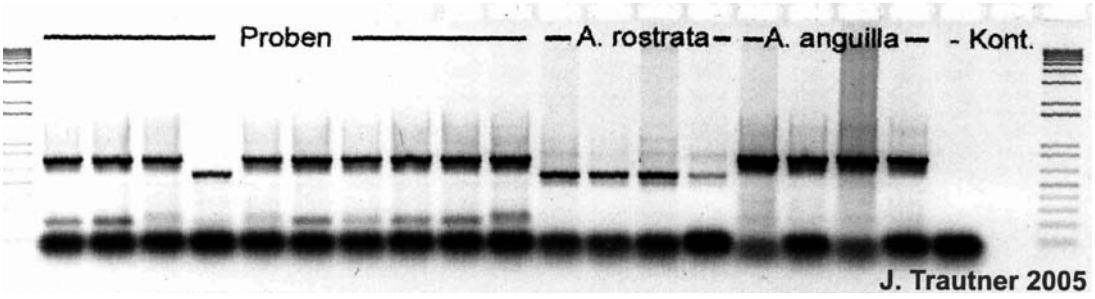

Fig. 30. Results of a DNA-analysis for identification of European and American eels, TRAUTNER et al. 2005

Evolution, classification, systematics, and taxonomy

According to NELSON (2006) there is no generally accepted classification in ichthyology (s. above), still much effort seems to be necessary to further clear up relationship between fish groups. By comparative anatomy much had been cleared up, but results which emerge from methods of molecular biology and genetics (Fig. 30) will contribute to further understanding, besides morphology and palaeontology (GODFRAY, 2007; JOYCE *et al*., 2005; KOCHER & STEPIEN, 1997; STIASSNY *et al.,* 1998; SMITH & WHEELER, 2004; THACKER, 2004). How indisputable results from these new methods will finally clarify the situation has still to be seen.

A new insight into fish evolution and speciation, respectively, is given by recent research on haplochromine cichlid fish. It was shown that new species do not mainly evolve within allopatric populations but may do so in sympatric ones too. The latter occurs when mating flocks separate due to specific attraction, like colour patterns or other morphological features, between the sexes and specimens. This kind of behaviour results, at length, in the building of new species. (DIECKMANN & DOEBELI, 1999; BARLUENGA *et al*., 2006; MEYER, 2007). Such processes were also observed in large lakes of east and south Africa, as in small crater lakes of Nicaragua. Mostly natural selection of the fittest (linked to resource competition) and geographical isolation are assumed as the driving force of speciation. But already C. DARWIN had noticed that the differences between sexes in many species could be important in mate choice. It may be assumed that not only morphological features but also behaviour patterns can cause such a sexual selection and group separation. Then making use of distinct feeding niches by parts of a population would result in sympatric speciation too. This is probably the case in some coregonid and char populations (NELLEN, 1979; SANDLUND *et al*., 1992) which are characterized by subpopulations sticking to different food resources. In case this causes an assortative mating one can expect a corresponding process of speciation. When, in case of Lake Constance, the ecological situation for the coregonids changes such a process may well be reversed (SVÄRDSON, 1975). Corresponding results of speciation and hybridisation in connection with habitat changes are discussed by GALIS & METZ (1998) for the situation of cichlid species of Lake Victoria.

Fish taxonomy is very much disputed still, probably more than is the case with other vertebrates. This is because in many groups of teleostian fish, like herrings, salmons, cyprinids or cichlids, a rapid speciation by adaptive radiation and/or geographic isolation takes place. That's why ichthyologists like KOTTELAT & FREYHOF find it easy to 'create' new species and to raise the number for European fresh water fish from 170 in the early 1990 to 358 for the same area in 1997 or for the fish fauna of Laos from 216 to some 370 (KOTTELAT, 1998). In their recent book KOTTELAT & FREYHOF (2007) stated that:

> "...the number of species we recognized increased steadily during our work … at least 47 species new to science were discovered……we (now) recognize here 546 native ….. species in European freshwaters (page x)."

One should be sceptical about such information which is in many points unconvincing. A species is a variable unit by nature. When using the phylogenetic instead of the older and more practical biological species concept (MAYR, 2000) each subspecies becomes a species which results in a kind of taxonomic inflation. This may have unpleasant consequences as is commented in an interesting paper by MARRIS (2007):

> "The implication….for conservation are wide-ranging, from increasing the number of endemic species in well studied areas and heating up 'hot spot' to making it almost impossible to figure out whether rates of extinction are slowing down or speeding up. Severe inflation can also, as in economics, lead to devaluation: if the smallest distinctions are raised up to the level that defines a species, the idea of a species loses some of its power (page 251)."
>
> "Why should there, for instance, be several "valid species" of *Coregonus* distinguished by slight differences in their morphology but only one valid species of *Anguilla* in a lake, though for both genera quite polymorph phenotypes occur in one and the same habitat? In both cases this is likely to be caused by different feeding habits. How much more may we assume geographical polymorphism of a species."

As "... the taxonomic status of several populations (of European freshwater fish) is not clear…." (KOTTELAT, 1998) and as long as no more knowledge exists about processes of speciation in time and space it is certainly better to be cautious and to accept the existence of polytypic species and to use terms like 'subspecies' 'local type', 'variation' or 'race', as done for instance by the EUROP. COMM. CONS. NATURE (1986-2004) and authors of other fish books. By describing species nobody (except maybe the author) will easily recognize them again, causing nothing but confusion. KOTTELAT's statement:

> "…it is better to overestimate biodiversity than to underestimate it" and to serve a "precautionary approach (KOTTELAT, 1998; page 68) which may be retorted that it needs no additional, namely 'political' concept of taxonomy."

Concerning the worries of conservationists it is suggested that the answer to all these problems is to ditch the taxonomic approach and shift to a totally different model of conservation law, such as ecosystem based conservation (MARRIS, 2007; page 253).

It would be most helpful to have one international global catalogue and encyclopaedia of fish species. Existing catalogues should be revised and preferably be amalgamated into one world wide web catalogue in which any new, peer reviewed (BORREL 2007) finding on a fish species will be added under defined categories and in conformity with useful norms (IBARRA & STEWART, 1987; KNAPP *et al.,* 2007). A comment by GODFRAY (2007) on such an idea is:

> "I think that a move to a universally accessible, web-only taxonomy is essential for the future health of the subject (page 260)."

KNAPP *et al*. (2007) are of the opinion that:

> "... the products of taxonomy are too useful to be relegated to a handful of obscure journals (page 261)."

The facility "www.fishbase" is very helpful already, but in its given concept hardly matches the ICZN rules for describing and publishing new taxa. Further, it seems comparatively understaffed today (see SKELTON, 1997). Because, aside plants and other animals, also fish are objects of genetic engineering it is necessary to keep an eye on trans-genetic fish which may become a threat to wild living fish populations and aquatic ecosystems as well.

Ecology

The effects of climate changes and fishing on aquatic environments with regard to fish species distribution, faunal composition, speciation, population dynamics, and fisheries must be investigated with high priority to understand and to predict, as far as possible, the consequences of these very severe global human impacts on

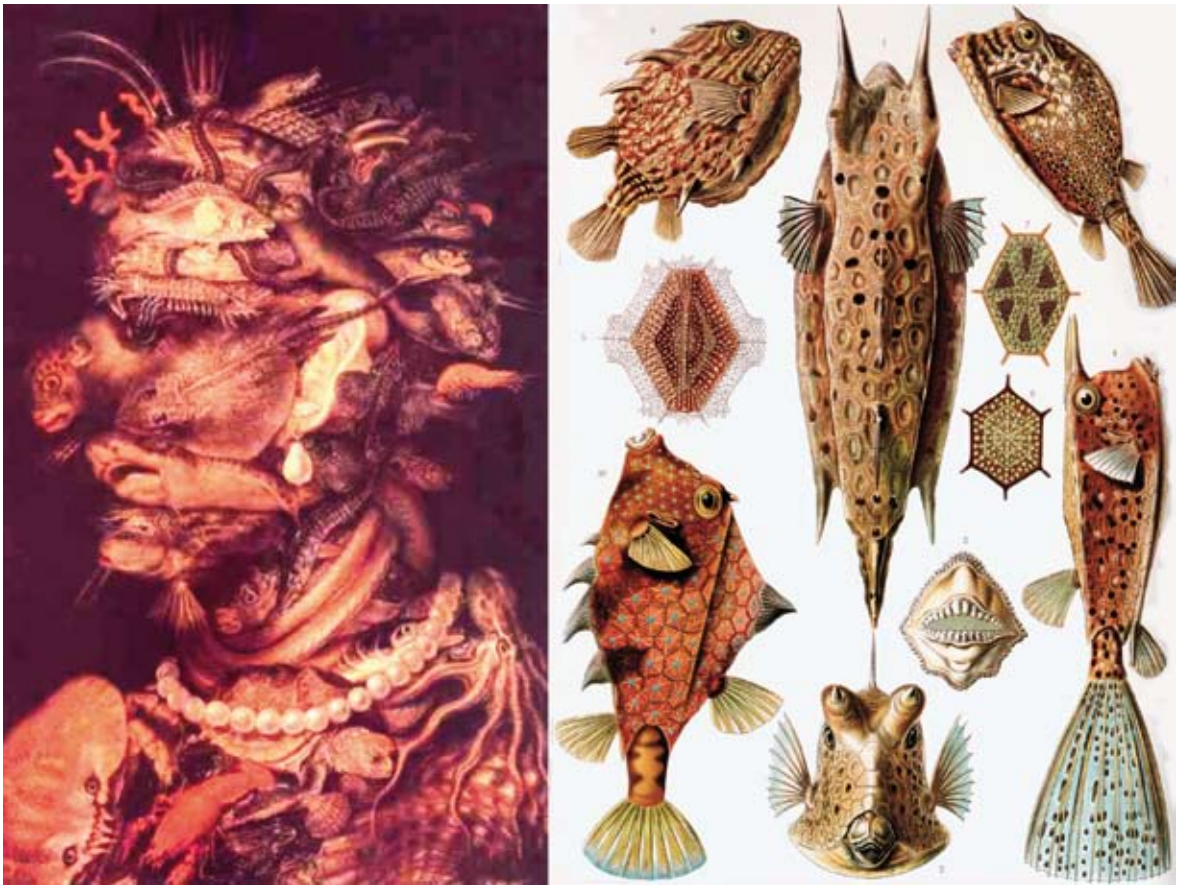

Fig. 31. Artists or ichthyologists, or vice versa? Guiseppe Acriboldo, 1566 (left) and Ernst Haeckel, 1904 (right)

the biosphere (CUSHING, 1982; JENNINGS & KAISER, 1997). Defined areas and habitats should be monitored for their fish fauna and old and new data should be compared for an ecological evaluation and changes of ecological states (HARDMANN *et al*., 2002; VORONINA, 1997; TSEPKIN, 1980; HEINRICH, 1987; MURIN, 1977; KOCHER, 2005). So-called regime shifts and their character and lasting effects have to be evaluated critically (DEYOUNG *et al.,* 2004; TEMMING, 2007; ALHEIT *et al.,* 2005). Regions and areas still unknown for their fish fauna have to be identified and investigated (CARPENTER & PAXTON, 1999). To do so concepts how best to expand the knowledge on fish populations in such areas have to be developed and applied. Ways have to be found how to protect fish species and fish populations best from becoming wiped out. The same is true for a protection of fish habitats against persistent perishing (STIASSNY, 2002).

Population dynamics

The formation, differentiation, and interaction of fish and, perhaps, squid populations as the other important nektonic group in the ocean (SAUER *et al.,* 2002; TEMMING *et al.,* 2007) is not yet well understood. Therefore it is necessary to increase our knowledge on wide ranging as well as on local migrations of fishes by tagging and tracking specimens with electronic devices. This will also help to better understand the extant and importance of genetic exchange between populations (CARVALHO & HAUSER, 1998). The reproduction strategy of most teleostean fishes is still somewhat mysterious. When asking why most bony fish species are so extremely prolific and often produce several thousands of tiny early life stages instead of some few but robust offspring as is the case in elasmobranches, the answer is not easy (ARISTOTLE, DE GENERA-

TIONE ANIMALIUM I-III; NELLEN, 1986; FREEMAN & NOAKES, 2002).

Hidden knowledge

Exploring and analysing not yet recognized and forgotten literature may result in new information from a quite different point of view as we are used to. One may assume that, apart from the early European and American works on ichthyology, early literature originated from other regions in the world as well, first of all China and Japan. To explore it adequate translation of the relevant literature into western languages and its analysis is certainly worthwhile not just for historical reasons.

However, there is no doubt that man and fish will remain connected as they always have been, as documented by the two last pictures (Fig. 31), the one painted by an artist, the other one by a scientist at interval of 450 years.

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büchlein wie man visch und vögel fangen sölle mit dreyssig neueren und bewärten Recepten. Auch zu was zeyten im gantzen jar ein yeder visch am besten sye (Fish book on the nature and properties of fish, especially those caught in Lake Constance and commonly in other lakes and water bodies, as described fort he first time by the highly respected Gregorium Mangolt Neudruck durch J. Meyer i. d. „Thurgauischen Beiträgen zur vaterländischen Geschichte", XLV, p. 119-185, Frauenfeld 1905.

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Received: 15 March 2008

Accepted: 2 December 2008

Razvoj ihtiologije kroz povijest i novi izazovi*

Walter NELLEN [1*] i Jakov DULČIĆ [2]

[1] *Institut za hidrobiologiju i ribarstvo Sveučilišta u Hamburgu, Olbersweg 24 , 22767 Hamburg, Njemačka*

**Kontakt adresa, e-mail: wnellen@uni-hambuerg.de*

[2] *Institut za oceanografiju i ribarstvo, P.P. 500, 21 000 Split, Hrvatska*

SAŽETAK

Moglo bi se zaključiti da je čovjekovo zanimanje za ribe iskrsnulo čim je čovjek postao sposoban za izražavanje pojmova i misli, jer riba je, zajedno sa ostalim životinjama, bila tema rane ljudske komunikacije. Prvo su ove misli bile izražene kroz crteže, a kasnije kroz simbole i pisani tekst. Ribe su postale predmetom znanstvenog istraživanja znatno kasnije. Aristotelovo djelo "Povijest životinja" je prvi poznati zapis koji se bavi ribama kao objektom znanosti o životinjama. Tek u 16. stoljeću pitanje riba je ponovo zaokupilo zanimanje prosvijećenog čovjeka, izmedju ostalih Olaus Magnusa (1490-1557), Gregora Mangolta (1498–1576), Guillaume Rondeleta (1507–1557), Pierre Belona (1512–1564), Hippolyto (Ippolito) Salviania (1513–1572), a povrh svega Conrad Gesnera (1516-1565). Sedamnaesto, a posebno osamnaesto stoljeće, poznata su kao razdoblja prosvjetljenja. Posebna zasluga se u tom vremenu mora odati trojici začetnika ihtiologije, Francis Willughbyu (1635–1672), Peter Artediju (1705–1735), te Marc Elieser Blochu (1723–1799), koji su već tada bili svjesni da se unutar klase riba mogu jasno i precizno određivati i opisivati vrste u svom punom smislu. Nakon što je Carl von Linné znanstveno opisao koncept vrste, obimna istraživanja su započela unutar ihtiologije te ujedno i doprinjela utemeljenju ihtiologije kao posebne znanosti. Brojni predjeli te brojne vodene površine su tada istražene s gledišta sastava njihove ihtiofaune. Tijekom 19. stoljeća, pa sve do početka 20. stoljeća, unutar ihtiologije posebna se pozornost posvetila taksonomiji, opisnoj biologiji te klasifikaciji. Kasnije je slijedilo razdoblje značajnog istraživanja riba sa gledišta fiziologije, ekologije i etologije, što je stvorilo sasvim nove poglede i vidike prema modernoj ihtiologiji. Danas su istraživanja uglavnom usmjerena prema primjenjenoj ihtiologiji, odnosno takozvanoj ribarstvenoj biologiji i akvakulturi. Sakupljanje ihtioloških podataka se nastavlja bez prekida, a određena neriješena pitanja se vraćaju s vremena na vrijeme. Mnoge znanstvene nedoumice vezane uz ribe još uvijek ostaju, u nekim segmentima, neodgovorene, uslijed čega današnji ihtiolozi i dalje nastavljaju istraživati ovu izuzetno raznoliku grupu kralješnjaka. Budući izazovi u ihtiologiji su svakako područja: a) taksonomije, b) evolucije i sistematike, c) populacijske biologije, d) ekologije, e) istraživanja raznih lokaliteta neistraženih po pitanju faune riba, f) rada na proširenju i usavršavanju međunarodnih kataloga riba, i g) istraživanja i analiziranja još uvijek neprepoznate znanstvene literature.

Ključne riječi: ihtiologija, povijest, novi izazovi

* Prezentirano na 12.-om Europskom ihtiološkom kongresu (ECI XII), Cavtat (Dubrovnik), Hrvatska, 9-13. rujna 2007.