Fishing in the past: biodiversity, art history, and citizen science - preliminary results

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CHAPTER 9

Fishing in the Past: Biodiversity, Art History, and Citizen Science – Preliminary Results

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1 Introduction

Fish are important; on the one hand, they are for human society a low-calorie, high-protein food source that also has medicinal value, and also are a source of income and employment, and on the other hand they are a key element for aquatic ecosystems. The importance of fish for human culture is reflected in art and literature. In the early modern period a considerable number of illustrated ichthyological books were published. They often comprised elaborate descriptions and illustrations of fish and other *aquatilia*. These were published not only in Latin but also in the vernacular (Italian, French, English, and German), stressing the importance of these books to a broad readership. Also, artists had access to this information and used these books as a source of information and inspiration for their works. Right after the first ichthyological books appeared, artists, mainly from Italy and the Southern Netherlands, gave a prominent role to fish in their drawings and etchings, often collected and issued in albums devoted entirely to fish (e.g. Giorgio Liberale, Adriaen Collaert, Nicolaes de Bruyn, and Joris and Jacob Hoefnagel).[1] In the early 17th century, detailed realistic oil paintings emerged in Antwerp by artists such as Frans Snyders and Alexander Adriaenssen and were further developed in the Northern Netherlands, for example by Abraham van Beyeren and Jacob Gillig. These oil paintings concerned representations of various topics, such as the element water, kitchen still lives, and market scenes, which became very popular.[2]

1 Rikken M., "Abraham Ortelius as Intermediary for the Antwerp Animal Trailblazers", *Jahrbuch für Europäische Wissenschaftskultur* 6 (2011) 95–128.

2 See Helmus L.M. (ed.), *Vis: Stillevens van Hollandse en Vlaamse meesters 1550–1700* (Utrecht: 2004); English translation: *Fish: Still Lifes by Dutch and Flemish Masters 1550–1700* (Utrecht: 2004). See also the article of Marlise Rijks in the present volume.

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Early modern artists inspired each other and copied certain motifs or scenes from each other. They also based their work on the descriptions or illustrations from the ichthyological books. Thus, Joris Hoefnagel was inspired by both the texts and illustrations of Guillaume Rondelet and Conrad Gessner,[3] whereas Jan Brueghel the Elder had Rondelet's work before him.[4] Apart from drawing inspiration from text and illustration, artists used their daily life experience as an inspiration source. Some painters may have had access to a real specimen, whether from a market, a collection, or a local fisherman.

If we want to know more about the practice of these painters and where they got their inspiration from, it is important that the species in the paintings be identified. When a large body of artwork with labelled species is studied in detail, it is possible to look at several depictions of the same species in books and artwork in order to investigate which works are inspired by second-hand information, who inspired whom and which artworks are based on real specimens. Moreover, it will give insight into the practice of these early modern artists like whether they prefer common species, rare or foreign species, freshwater or marine or combinations of both.

Although the setting of a painting is no guarantee that the depicted objects give a realistic view of the situation, they can provide some information. Thus, fish placed next to kitchenware, such as knives, plates, and bowls, implies consumption.[5] Therefore, paintings including these objects suggest the artist was using fish species meant for consumption as a source for his artwork.

That fish consumption was an important source of inspiration for the painters is confirmed by the exhibition *Vis* (Fish) that was held in 2004 in the Central Museum of Utrecht. This exhibition showed the paintings with fish images by Northern Netherlandish and Southern Netherlandish artists from 1550 to 1700.[6] For the selection of 63 paintings within this exhibition the pictured fish species were identified by Lex Raat.[7] From the 50 species that were represented in these paintings, fish species that were easy to catch with the equipment of that time were pictured most often and rare species did not occur in the paintings. Therefore, the authors of the exhibition catalogue

3 See Hendrikx S. – Smith P.J., "Connaissances ichtyologiques au format emblématique: le cas du *sargus*", *RursuSpicae. Transmission, réception et réécriture des textes, de l'Antiquité au Moyen Âge* (2022). http://journals.openedition.org/rursuspicae/2258 ; DOI: https://doi.org/10.4000/rursuspicae.2258.

4 See the Introduction of the present volume.

5 Stupples P., *Art and Food* (Cambridge: 2014).

6 Helmus, *Vis*.

7 Raat L., "Determinatie van de vissen op schilderijen", in Helmus, *Vis* 375–391.

conclude that the Dutch artists usually depicted fish that were available in the Dutch markets of that time.

This availability of fish fluctuates over time and may be noticeable in art when looking at trends of depicting certain fish species. Recent studies have concluded that fluctuations in marine ecosystems are due to overfishing, pollution, filling of estuaries and other shoreline modifications, the introduction of invasive species, global warming, ocean acidification, and other ecological impacts.[8] Therefore, before discussing the occurrence of fish in the visual arts, it is useful to briefly discuss the most important factors that have influenced the availability of fish, namely climate, human fish consumption, and human alterations of the landscape.

2 The Influence of Climate on Fish Biodiversity

Within the last millennium, two cooler periods occurred in the aquatic environment. The first occurred ca. 1400 AD and the second, more drastic one occurred around 1700 AD.[9] Climatic events not only change the water temperature, they also cause severe changes in ocean circulation and currents.[10] Although most adult fish can resist these changes, young individuals are more affected because their survival depends on the timing of algae blooms and zooplankton availability.[11] Indeed, genetic analysis of remains of the Icelandic cod population revealed that the population declined due to the change in climate around 1400.[12] Around 1700 the diversity of aquatic *invertebrae* and the amount of organic matter in the oceans were at minimal levels.[13] The drop in

8 Southward A.J. – Langmead O. – Hardman-Mountford N.J. – Aiken J. a.o., "Long-Term Oceanographic and Ecological Research in the Western English Channel", in Southward A.J. – Tyler P.A. – Young C.M. – Fuiman L.A. (eds.), *Advances in Marine Biology* 47 (2005) 1–105.

9 Luoto T.P. – Nevalainen L. – Sarmaja-Korjonen K., "Multiproxy Evidence for the 'Little Ice Age' from Lake Hamptrask, Southern Finland", *Journal of Paleolimnology* 40 (2008) 1097–1113.

10 Bianchi G.G. – McCave I.N., "Holocene Periodicity in North Atlantic Climate and Deep-Ocean Flow South of Iceland", *Nature* 397 (1999) 515–517.

11 Pepin P., "Effect of Temperature and Size on Development, Mortality, and Survival Rates of the Pelagic Early-Life Stages of Marine Fish", *Canadian Journal of Fisheries and Aquatic Sciences* 48 (1991) 503–518.

12 Olafsdottir G.A. – Westfall K.M. – Edvardsson R. – Palsson S., "Historical DNA Reveals the Demographic History of Atlantic Cod (*Gadus morhua*) in Medieval and Early Modern Iceland", *Proceedings of the Royal Society B-Biological Sciences* (2014) 281.

13 Luoto a.o., "Multiproxy Evidence for the 'Little Ice Age'".

sea temperature had a negative impact on the Atlantic cod population in the 16th century.[14] Another example of the effect of climate change on the extinction of a fish species comes from the greater weever (*Trachinus draco*), which was abundant in the southern North Sea at the end of the 19th and beginning of the 20th century, but has disappeared almost completely[15] since the strong winter of 1963.[16] A difference in effect of climate change is expected between fish with different reproductive tactics, *i.e.* fish that lay many small eggs or fish that lay fewer large eggs. In theory, fish that spawn larger numbers of eggs (mostly pelagic spawners) are better capable of dealing with environmental change than species with low numbers of eggs (demersal spawners).[17] Therefore, it is expected that after 1400 and after 1700 there was a drop of demersal spawning species. It would be interesting to see if this drop and the drop of cod and greater weever are also visible in the occurrence of these species in paintings.

3 Fisheries, Fish Trade, and Consumption through Human History

Fishing is an ancient activity in human culture that already started from 300,000 BC, after which its intensity increased until 5700 BC, when humans started to have an impact on marine ecosystems.[18] The relative importance of marine and freshwater fish has fluctuated during human history. This predicts changes in human pressures that are different for both ecosystems.

The importance of fish in the human diet fluctuates over time, as does the relative importance of different species. In early medieval Europe (5th–9th centuries AD) mostly freshwater fish were consumed, but there was a rise in marine

14 Geffen A.J. – Hoie H. – Folkvord A. a.o., "High-Latitude Climate Variability and Its Effect on Fisheries Resources as Revealed by Fossil Cod Otoliths", ICES *Journal of Marine Science* 68 (2011) 1081–1089.

15 Daan N. – Bromley P.J. – Hislop J.R.G. – Nielsen N.A., "Ecology of North-Sea Fish", *Journal of Sea Research* 26 (1990) 343–386.

16 Bennema F.P. – Rijnsdorp A.D., "Fish Abundance, Fisheries, Fish Trade and Consumption in Sixteenth-Century Netherlands as Described by Adriaen Coenen", *Fisheries Research* 161 (2015) 384–399.

17 Duarte C.M. – Alcaraz M., "To Produce Many Small or Few Large Eggs – A Size-Independent Reproductive Tactis of Fish", *Oecologia* 80 (1989) 401–404.

18 Erlandson J.M. – Rick T.C., "Archaeology Meets Marine Ecology: The Antiquity of Maritime Cultures and Human Impacts on Marine Fisheries and Ecosystems", *Annual Review of Marine Science* 2 (2010) 231–251.

fish consumption from the 10th century.[19] In the early modern (from 1500) period, the importance of fish in human diets increased due to the Christian calendar which prohibited eating meat during the fasting period of 40 days and weekly on Fridays, but fish consumption was allowed. Mainly dried fish was consumed and freshwater fish. In this period also ponds with fresh water fish appeared mostly attached to monasteries. Only rich people could afford marine fish.[20] Freshwater species: perch (*Perca fluviatilis*), carp (*Cyprinus carpio*), bream (*Abramis brama*), and pike (*Esox lucius*) were most popular. Marine and diadromous species: sole (*Solea solea*), flounder (*Platichthys flesus*), turbot (*Scophthalmus maximus*), halibut (*Hippoglossus hippoglossus*), tench (*Tinca tinca*), bleak (*Alburnus alburnus*), eel (*Anguilla anguilla*), sea lamprey (*Petromyzon marinus*), salmon (*Salmo salar*), trout (*Salmo trutta*), tuna spp., mackerel (*Scomber scombrus*), sturgeon (*Acipenser sturio*) (eggs), cod (*Gadus morhua*), herring (*Clupea harengus*), sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*), shark spp., and ray spp. were consumed in smaller amounts.[21]

Around 1500 a major change in fisheries occurred. From 1300 to 1500 cod was mainly consumed fresh from the sea locally on the coast. After John Cabot discovered the immense cod stock at Newfoundland around 1500, fisheries from Norway, Iceland, Spain, Portugal and France crossed the Atlantic Ocean, which probably led to a 15-fold catch volume of cod.[22] Although the Low Countries took part in the trade of Newfoundland fish,[23] it is unknown how much they contributed to the Newfoundland fisheries. At the same time, the cod population in Iceland declined due to the change in climate during the Little Ice Age.[24] In 1991 the cod stock at Newfoundland collapsed and it is unknown how much both anthropogenic harvesting and climate change contributed to this collapse. In fact, this accounts for most of the changes in the abundance of fish species. Quantitative records of European fisheries before 1750 are few.[25]

19 Ervynck A. – Boudin M. – van den Brande T. – Van Strydonck M., "Dating Human Remains from the Historical Period in Belgium: Diet Changes and the Impact of Marine of Marine and Freshwater Reservoir Effects", *Radiocarbon* 56 (2014) 779–788.

20 Ibidem.

21 Albala K. – Allen R.W., *Food in Early Modern Europe* (Westport, Connecticut – London: 2003).

22 Holm P. – Ludlow F. – Scherer C. – Travis C. et al., "The North Atlantic Fish Revolution (ca. AD 1500)", *Quaternary Research* (2019) 1–15.

23 Glerum-Laurentius D., *A History of Dutch Activity in the Newfoundland Fish Trade from about 1590 till about 1680* (Master's thesis, Memorial University of Newfoundland: 1960).

24 Olafsdottir a.o., "Historical DNA".

25 Michell A.R., "The European Fisheries in Early Modern History", in C.H. Wilson C.H – Rich E.E. (eds.), *The Economic Organization of Early Modern Europe*. [*The Cambridge Economic History of Europe: Volume 5*] (Cambridge: 1977) 133–184.

Most fisheries data are country based and it is difficult to calculate total output rates of certain fishing grounds.[26] Therefore, it is important that there be more data available from this time period about the occurrence of other species and fluctuations in the consumption of fish species, including cod, across countries.

Nowadays, marine fish consumption has surpassed freshwater fish consumption. The European marine fish consumption in 2013 was 1.8 million tonnes, approximately seven times higher than the 0.25 million tonnes of freshwater fish consumption.[27]

Typically human fisheries first target relatively large and long-lived carnivores (whales, cod, tuna, etc.). These large-sized species are characterized by late maturation and slow growth rates that make them particularly sensitive to human impact.[28] After these fisheries lead to large species decline or collapse, they switch to smaller species (herring, lobster, shrimp, etc.). This change represents a switch from higher trophic level species to the species at lower levels.[29] It is obvious that the human impact on commercial species is considerable, but there are also side effects, since predators at high trophic levels have a disproportionate influence on the occurrence of organisms at lower trophic levels.[30] Moreover, non-commercial species are affected too when taken incidentally as by-catches, by poaching or ghost fishing by lost or abandoned gear.[31] In the Gulf of Maine repetitive shifts in targeted species eventually have led to a trophic dysfunctional ecosystem and an accelerated decline in average trophic level[32] known as the trophic cascade.[33] There is debate on

26 Holm a.o., "The North Atlantic Fish Revolution (ca. AD 1500)".

27 Food and Agriculture Organization of the United Nations (FAO) FOA statistics. Accessed January 2021 from https://www.fao.org/faostat/en/#data/FBS.

28 Brander K., "Disappearance of Common Skate Raia-Batis from Irish Sea", *Nature* 290 (1981) 48–49; Jennings S. – Reynolds J.D. – Mills S.C., "Life History Correlates of Responses to Fisheries Exploitation", *Proceedings of the Royal Society B-Biological Sciences* 265 (1998) 333–339.

29 Pauly D. – Trites A.W. – Capuli E. – Christensen V., "Diet Composition and Trophic Levels of Marine Mammals", *ICES Journal of Marine Science* 55 (1998) 467–481.

30 Worm B. – Barbier E.B. – Beaumont N. – Duffy J.E. a.o., "Impacts of Biodiversity Loss on Ocean Ecosystem Services", *Science* 314 (2006) 787–790; Hairston N.G. – Smith F.E. – Slobodkin L.B., "Community Structure, Population Control, and Competition", *American Naturalist* 94 (1960) 421–425; Paine R.T., "Food Web Complexity and Species Diversity", *American Naturalist* 100 (1966) 65–75; idem, "Food Webs – Linkage, Interaction Strength and Community Infrastructure – the 3rd Tansley Lecture", *Journal of Animal Ecology* 49 (1980) 667–685.

31 Dayton P.K., "Ecology – Reversal of the Burden of Proof in Fisheries Management", *Science* 279 (1998) 821–822.

32 Steneck R.S. – Vavrinec J. – Leland A.V., "Accelerating Trophic-Level Dysfunction in Kelp Forest Ecosystems of the Western North Atlantic", *Ecosystem* 7 (2004) 323–332.

33 Jensen O.P. – Branch T.A. – Hilborn R., "Marine Fisheries as Ecological Experiments", *Theoretical Ecology* 5 (2012) 3–22.

whether fishing down the trophic level is a global phenomenon or whether it is restricted to certain geographical regions or periods in time.[34] It would be interesting to see if these effects are seen in other regions and with other species, but since ecosystems are often more complex than that of the Gulf of Maine, more longitudinal studies are necessary to confirm this. On a global scale, there is a drop in the average trophic level of fisheries catch visible from 1950 until 2000, especially in the North Atlantic Ocean (Millennium Ecosystem Assessment 2005).[35] Some indication of a decline of high trophic species comes from a comparison of data from the Dutch fisheries in the 16th and 19th centuries.[36] This study concluded that mainly large species (common smooth hound (*Mustelus mustelus*), common skate (*Dipturus batis*), common stingray (*Dasyatis pastinaca*), blonde ray (*Raja bracyura*), sturgeon (*Acipenser sturio*), pollack (*Pollachius pollachius*), saithe (*Pollachius virens*), and ling (*Molva molva*)) started to disappear in the 19th century. Although the trophic levels of these species are rather high and they are all piscivorous, the trophic level varies between the species (TL on a 1–5 range: starry smooth hound, 3.6 ± 0.3; common smooth hound, 3.8 ± 0.3; skate, 3.5 ± 0.6; common stingray, 4.1 ± 0.63; blonde ray, 3.8 ± 0.61; sturgeon, 3.5 ± 0.51; pollack, 4.3 ± 0.3; saithe, 4.3 ± 0.4; ling, 4.4 ± 0.2).[37] If the artists from the Low Countries were using the fish that were available at the markets it is expected that the mean trophic level of fish species would depict decreases over time.

Which fish species were caught, traded, and consumed in Holland in the early modern period (starting from 1500) is nicely described by Coenen.[38] Characterizing the importance of the herring and plaice trade for Holland is Coenen's description of it: 'the golden mountain of Holland'. Dutch fisheries were active along the Dutch coast and stretched far beyond the Shetland Isles, while in the south, along the French coast, mackerel was targeted. Fresh fish was sold in all Dutch cities and Antwerp, Brussels, Leuven, and Mechelen. Dried fish was exported to Germany. Species which were often consumed in the early modern period were herring, sole, flounder, and cod. Cod was caught in large volumes. To a lesser extent, sturgeon, lesser-weever (*Echiichthys vipera*), and small ray species were consumed by certain parts of the population, although ray was

34 Branch T.A. – Watson R. – Fulton E.A. a.o., "The Trophic Fingerprint of Marine Fisheries", *Nature* 468 (2010) 431–435.

35 Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

36 Bennema – Rijnsdorp, "Fish Abundance".

37 Froese R. – Pauly D. (eds.), FishBase. World Wide Web electronic publication. 2022. www.fishbase.org.

38 Egmond F., *Het Visboek: de wereld volgens Adriaen Coenen (1514–1587)* (Zutphen: 2005).

more often exported to Germany. Herring and European plaice (*Pleuronectes platessa*) were also exported in large quantities. In contrast with the substantial consumption of freshwater fish and the exclusivity of marine fish in early modern Europe,[39] in Holland (and Flanders) the consumption of freshwater fish seems to have been relatively inferior to that of marine fish if one relies on Coenen. He does mention that freshwater fishery was a valuable source of employment,[40] but few species are mentioned as consumed species. Bream is mentioned as food for the common people, the rich, and the wealthy; eel was consumed by everyone; and the anadromous viviparous eelpout (*Zoarces viviparus*) was consumed by the poor and common people. Other freshwater or anadromous fish were exclusively consumed by the rich and the wealthy (salmon, sturgeon, catfish (*Silurus glanis*), and lampern), or by the poor (smelt (*Osmerus eperlanus*) and ruffe (*Gymnocephalus cernua*)). Although perch, carp, bream, and pike were consumed at high rates in early modern Europe,[41] these species are not mentioned as consumed species in Coenen's fish book.[42] This difference may just be a bias caused by Coenen's interest in spectacular marine species, or it may reflect a real difference in fish consumption between the Low Countries and the rest of Europe. Possibly, Dutch fisheries facilitated access to fresh marine fish for the common people, creating a difference between Dutch fish consumption and that of the rest of Europe. However, other sources indicate that until the late 16th century the Dutch consumption of freshwater fish was more important than that of herring and other marine fish.[43] Clearly there was a shift in popularity towards less freshwater and more marine fish consumption at some point after 1500, but more research is needed to confirm the details about the timing of this shift, differences between the Low Countries and the rest of Europe, and whether in the Low Countries there were different freshwater species consumed than in the rest of Europe. Labelling fish species in early modern paintings may help in studying these trends in fish consumption. It is expected that at some point after 1500 the relative proportion of artwork with freshwater fish in a food context would drop compared with that of marine fish.

39 Ervynck a.o., "Dating Human Remains".
40 Bennema – Rijnsdorp, "Fish Abundance".
41 Ervynck a.o., "Dating Human Remains".
42 Bennema – Rijnsdorp, "Fish Abundance".
43 van der Woude A.M. – de Vries J., *Nederland 1500–1815. De eerste ronde van moderne economische groei* (Amsterdam: 1995).

4 How Crowdsourcing Can Be Used to Label Artwork

Paintings with fish are quite numerous. If one only considers Dutch and Flemish artists, there are already more than 2200 pieces of art involving fish from the collection of the Rijksmuseum, Amsterdam, and the online image database of the RKD (Rijksbureau voor Kunsthistorische Documentatie), The Hague. Several of these works include multiple species. It would take too much time for a single scientist to identify all the species on all these pieces of art. Moreover, identifying species from pictures of varying quality is trivial even for specialists and scientists, who do not always agree on the identification of a pictured fish.[44] Therefore, citizen science is a helpful tool, not only to speed up the process of labelling species but also to improve the accuracy. Citizen science is a proven effective instrument in studies investigating the species composition of wildlife, by labelling species from camera traps.[45] Although the answer from a single untrained, non-expert volunteer may be incorrect, aggregated answers of multiple volunteers give reliable data. In a large-scale study with 1.51 million African wildlife images, the aggregated answers of 28,000 volunteers were correct in 98% of the images when compared to the consensus answers of experts.[46] In fact, aggregated answers of volunteers were more reliable than that of a single expert.[47] Although labelling African wildlife may be easier than labelling fish species, this difficult task is suitable for citizen science as well. When untrained volunteers were asked to label fish species from video footage, the agreement between aggregated volunteer answers and the expert ratings was equal to the agreement between expert ratings (He et al. 2016).[48]

If species in artwork are labelled and the data are shared in open access databases or publications, scientists from various disciplines may use the information for their research.

44 He J. – Spampinato C. – Boom B.J. – Kavasidi I., "Data Groundtruthing and Crowdsourcing", in Fisher R.B. – Chen-Burger Y.-H. – Giordano D. a.o. (eds.), *Fish4Knowledge: Collecting and Analyzing Massive Coral Reef Fish Video Data* (n.p.: 2016) 207–227.

45 Swanson A. – Kosmala M. – Lintott C. – Packer C., "A Generalized Approach for Producing, Quantifying, and Validating Citizen Science Data from Wildlife Images", *Conservation Biology* 30 (2016) 520–531.

46 Swanson a.o., "A Generalized Approach".

47 Swanson a.o., "A Generalized Approach".

48 He a.o., "Data Groundtruthing and Crowdsourcing".

5 Results and Discussion

From the original set of 2272 subjects (RKD and Rijksmuseum combined), 1676 subjects (74%) were positively judged to contain identifiable fish and entered into the fish identification task. The subjects that were retired concerned, according to the volunteers, artwork with fish that lacked the amount of detail necessary for identification (16%), fantasy fish (7%), or artwork in which no fish could be found (4%).

The reliability of the identifications made by the crowd in the current data set does not allow for labelling individual artwork on the species level (see ANNEX). Nevertheless, when compared with expert identifications, the fish species identified by the crowd were correct in more than half of instances. Therefore, if the Zooniverse project is continued for a longer period, increasing the number of classifications per object it is possible to make a selection of artworks with a certain level of reliability based on Pielou's index and the fraction of support (see ANNEX). With the current data set only a fraction of the artwork is reliably labelled. For the majority of artwork, the volunteers' answers are not reliable enough to say whether a pictured fish was cod or pollock, but if the consensus species is that it is a cod, it is very likely a species from the Gadidae family and almost certainly a marine fish. Therefore, it is still possible to look at larger trends, such as differences between centuries, or comparing groups of fish species, such as freshwater versus marine fish.

6 Which Species Are Depicted in Early Modern Art?

Consensus species per artwork are reported in the online available data set https://doi.org/10.6084/m9.figshare.19501324. There were 66 different species identified as consensus species from the artworks. The species that was most often identified was cod (*Gadus morhua*) (186 works), followed by pike (*Esox lucius*) (175 works), carp (*Cyprinus carpio*) (149 works), European perch (*Perca fluviatilis*) (123 works), and European flounder (*Platichthys flesus*) (110 works).

From 1485 until 1900 the proportion of artwork with only freshwater or only marine fish was almost equal, with a slightly higher number of marine species, and stayed constant over time [Fig. 9.1]. After 1900 the proportion of purely freshwater fish paintings increased, while that of purely marine species decreased. The proportion of artwork that depicted both marine and freshwater species in one work decreased throughout the early modern period [Fig. 9.2].

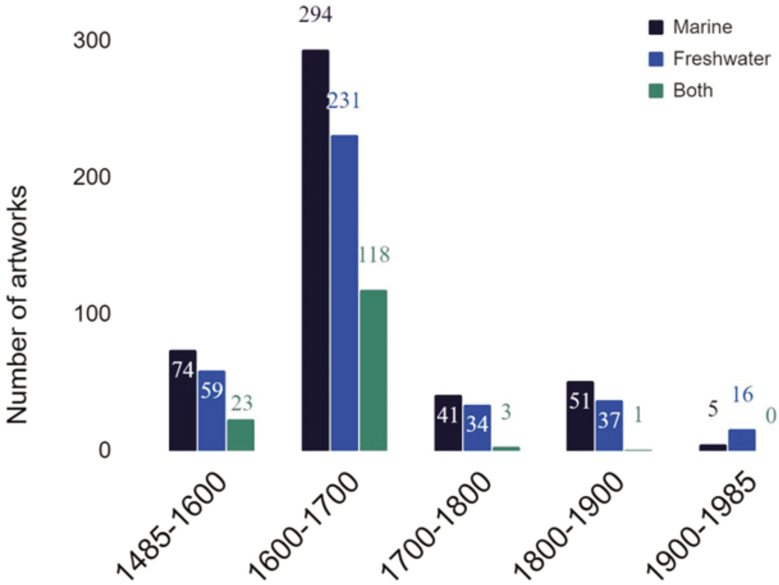

FIGURE 9.1 The number of pieces of artwork that pictured freshwater fish species only, marine fish species only, or both types of fish in one work. Numbers above bars indicate the exact number of paintings in each category

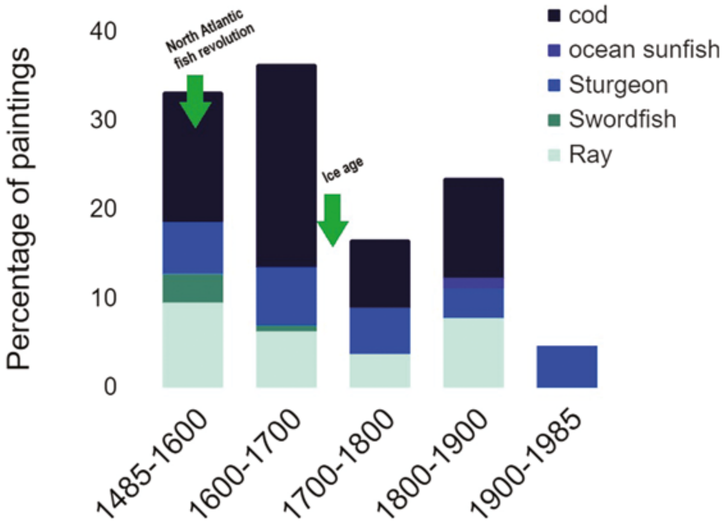

FIGURE 9.2 The proportion of artwork (calculated as the number of paintings depicting a certain species divided by the total number of artworks with fish in that period) that pictured large higher trophic level species

After the discovery of the Newfoundland cod stock in 1500, the proportion of cod in artwork increased from the 15th to the 16th century (see Fig. 9.2). After the Little Ice Age around 1700, the proportion of large-sized fish decreased from 36% in 17th-century art to 17% of 18th-century art (see Fig. 9.2). After the 19th century large higher trophic level species were seldomly pictured except for the sturgeon. The decline of larger fish species in 20th-century art coincides with the global drop in the average trophic level of fishery catches visible from 1950,[49] and it comes after the drop in Dutch fisheries in the 19th century.[50] This indicates that the depiction of these species in art was related to the availability in the markets of that time. Surprisingly, the proportion of sturgeons stays relatively constant throughout the centuries compared with the other large fish species, varying from 3.4% in the 18th century to 6.5% of the works in the 16th century. This was not expected because European sturgeon (*Acipenser sturio*) populations declined from the mid-19th century and disappeared from the Netherlands starting in 1952.[51] Also the morphologically identical *A. oxyrinchu* became extinct in the North Sea from the 19th century.[52] This indicates that artists from the Low Countries were less restricted by what was available at local markets than was expected when judging from the conclusions from the Utrecht exhibition. Various explanations are possible. First, artists may have used specimens from overseas markets or collections that they visited or that were sent to them. Second, they may have been inspired by sources other than real specimens, such as fish books, older works, etc. Third, there may be a bias for appealing species in art. Sturgeons are remarkable for the osseous plates on their skin, which is an interesting study object for artists.

When looking at artwork in a food-related context there is a clear visible shift in the proportion of freshwater and marine species [Fig. 9.3]. In the 15th and 16th centuries, freshwater fish are pictured in a food-related context in 40% of the artworks involving freshwater fish, compared to 20% of the marine fish artworks. This is in contrast with the low importance of freshwater fish in the Low Countries reported by Coenen.[53] But in line with other sources[54] and

49 Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

50 Bennema – Rijnsdorp, "Fish Abundance".

51 Williot P. – Rochard E. – Castelnaud G. – Rouault T. a.o., "Biological Characteristics of European Atlantic Sturgeon, *Acipenser sturio*, as the Basis for a Restoration Program in France", *Environ Biol Fish* 48 (1997) 359–372.

52 Spikmans F. – Kranenbarg J. – Veenvliet P. – van Emmerik W. a.o., *Standaardlijst namen zoetwatervissen van Nederland en Vlaanderen anno 2019. Achtergronddocument. Stichting* RAVON (Nijmegen: 2019).

53 Bennema – Rijnsdorp, "Fish Abundance".

54 van der Woude – de Vries, *Nederland 1500–1815*.

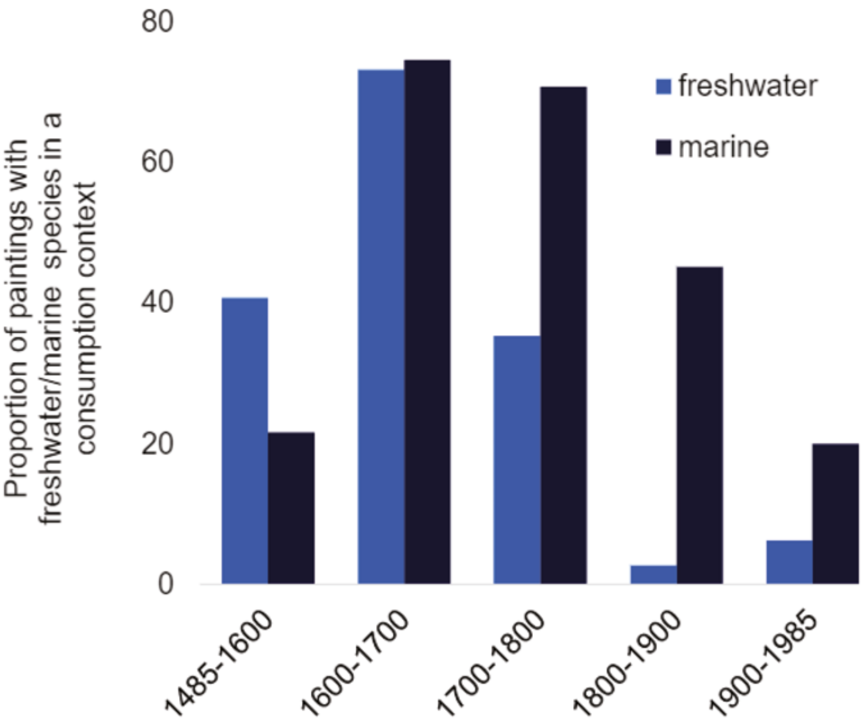

FIGURE 9.3 Proportion of freshwater/marine fish in a consumption-related context

the trends in other parts of Europe where freshwater fish formed an important part of the diet in the 15th and 16th centuries.[55] This suggests that the fish consumption trends in Holland were more similar to the rest of Europe than it appears from Coenen's fish book. The proportions of artwork in a food context increased for both freshwater and marine fish after 1600. This rise may be caused by a growing number of consumption-related artworks in general or a rise in the popularity of fish in the human diet. Not much is known about the fish consumption in the Low Countries in the 17th century. Comparisons with other food items in artwork, such as meat or cheese, may reveal whether there was a change in diet or a general increased interest in producing food-related art. In the 18th to the 20th century marine fish is more often depicted in a food context than freshwater fish. This is in line with the shift in the human diet from freshwater to marine fish. Remarkably, in the 20th century fresh fish were more often seen in artworks than marine fish were, but when looking at the proportion of paintings in a food context, that of marine fish is larger.

55 van der Woude – de Vries, *Nederland 1500–1815*.

Therefore, we can conclude that the overall proportion of fish species in artwork is not merely a representation of the species that were consumed at that time. Only when taking the context into account do the trends in artwork reflect the trends in the human diet.

7 Conclusion

Identification of fish species in artworks by the general population is not as reliable as the identification of, for example, African wildlife from wild traps. There is not much agreement about fish species between volunteers who scored the same artwork. With the current data set, only a fraction of the subjects is reliably labelled.

Nevertheless, when looking at the larger picture, such as the presence of marine, freshwater, or larger higher trophic level species in the artwork, some interesting trends are noticeable. These trends in fish art correspond with major environmental changes and changes in the human diet. Freshwater species in paintings increased after the 19th century. Large fish species are less often depicted after the second Little Ice Age; most of these species are no longer seen in art after 1900. Sturgeons remain constant in paintings throughout the centuries. When looking at artwork involving a consumption-related context, the proportion of freshwater/marine fish changes over time from mostly freshwater in the 15th and 16th centuries to mostly marine in the 18th to the 20th century.

This Zooniverse project not only shows the dependence of the visual arts on the fluctuating ichthyological biodiversity through the centuries – thanks to the online database,[56] this project also provides a tool for motif research in art history. The database makes it possible to localize fish species in a large body of artwork. How important species identification – both botanical and zoological – can be for interpretating works of art is apparent from recent studies.[57] Moreover, crowdsourcing projects like this, where volunteers identify species in art, have a general recruiting function in the context of interdisciplinarity. It makes art historians aware of the importance of flora and fauna

56 Overduin Anne, Results for the Zooniverse Fishing in the past project. figshare. Data set. 2022. 10.6084/m9.figshare.19501324.

57 See, for instance, Segal S. – Alen K., *Dutch and Flemish Flower Pieces. Paintings, Drawings and Prints up to the Nineteenth Century* (Leiden – Boston: 2020), and Rikken M. – Smith P.J., "Jan Brueghel's *Allegory of Air* (1621) from a Natural Historical Perspective", *Netherlands Yearbook for History of Art* 61 (2011) 87–115.

and biologists aware of the importance of visual arts. Lastly, but importantly, it brings the non-specialized crowd in contact with both art and nature.

ANNEX: Methods and Reliability of the Data[58]

Methods

Within this study we selected artwork depicting fish from Dutch and Flemish artists and labelled the species by means of an online Zooniverse[59] citizen science project.

Selection of Artwork

The two major sources of information on Dutch and Flemish art are the collection of the Rijksmuseum, Amsterdam and the online database of the RKD. From the RKD database all the works with the standardized keyword ("onderwerpstrefwoord") labelled "vis" (Dutch for "fish") were selected by Reinier van 't Zelfde, connected as information architect at the RKD. This resulted in 1961 hits. After a quick visual scan of the images by Anne Overduin, most irrelevant pictures were removed, and 1895 subjects from RKD were added to the list of subjects in the Zooniverse project "fishing in the past". Rijksmuseum subjects were selected by Anne Overduin using the Application Programming Interface (API) from the Rijksmuseum, which enables users to make a selection of artwork based on certain criteria. The following selection criteria were used: time frame, 1500–1880; type of work, painting, drawing, etching, or engraving; origin, Dutch; keywords, fishes, bony fishes, other fishes, deep sea fishes, eels, cartilaginous fishes, fishes (with NAME), and the Dutch keyword "vissen" (plural for fish). This resulted in 606 records from the Rijksmuseum database. These hits included some photographic duplicates from the same artwork as well as some artwork not from the Low Countries (since selection on origin was not possible for paintings and drawings), and irrelevant pictures with, for example, fantasy creatures or market scenes without clearly distinguishable fish. After a visual scan of the images, these irrelevant records were removed and 377 unique pieces of artwork were entered as subject in the Zooniverse project. In total there were 2272 subjects added to the project, including 1594 paintings, 301 drawings, 294 etchings or engravings, and 83 other types of work. Each piece of art was represented by 1–5 (mean: 1.1 ± SD 0.4) pictures. All pictures

58 The innovative nature of our Zooniverse project makes it necessary to provide in this Annex an extensive report on the project's method and execution.

59 https://www.zooniverse.org/about.

that belonged to a single artwork were presented to the volunteers in a single subject, which received a single classification per volunteer.

Selection of Common Species

The main task for the volunteers was to identify species from a predefined species list. Facultatively, they could also manually add other species in a second task (see next paragraph). We expected that most of the fish painted by Dutch and Flemish painters were species that have commercial value and that occur in European waters. Therefore, we composed a list of fish species based on the list of European commercial fish species from the EUMOFA (European Market Observatory for fisheries and aquaculture).[60] A total of 59 species from the EUMOFA list were selected.

The number of freshwater species on the EUMOFA list is minimal, probably because currently these fish are less interesting with regard to commercial use. Therefore, 12 freshwater species that are common in European waters were added. In order to include species that were present in the early modern time, we added species that were abundant in the Netherlands in the 16th century. We added the 14 species that were not yet in our list and that were reported as "common" or "plentiful" around 1600.[61] After a first trial period (21-11-2019 until 31-03-2020), 549 pieces of art were successfully classified by 155 volunteers, with 1–5 (mean 1.28 ± SD 0.59) classifications per subject. The 20 species that were only chosen for one painting or less in this trial period were removed from the choice list for consequent classifications.[62] Moreover, the 8 species that were added manually during this trial period and occurred on more than one painting were added to the list.[63]

In order to make identification of the species easier for the volunteers, pictures of the species were added to the citizen science project. For every species at least one picture depicted the entire lateral (or in case of angler and ray sp., dorsal) view of each fish. These pictures were also used as a thumbnail within the species list. The background of these pictures was removed such that even in the small-scaled thumbnails the outline of the fish was obvious. Additional pictures were provided for most species (N = 53), from other angles, with details or with another appearance of the species (e.g. juvenile). Apart from a short description of each species, easily confused species were listed.

60 EUMOFA. 2018. European market observatory for fisheries and aquatic products. Metadata 2 – Data management. ANNEX 1 List of Commodity groups and Main commercial species.

61 Bennema – Rijnsdorp, "Fish Abundance".

62 See the species table at https://doi.org/10.6084/m9.figshare.19497548.

63 See the species table at https://doi.org/10.6084/m9.figshare.19497548.

These included mostly species with the same body shape. Details were given on how to distinguish between each pair of often confused species. In order to enable untrained, non-expert volunteers to make a deliberate choice, all the species from the list could be filtered according to a number of characteristics. In the trial period these included overall body shape, colour, pattern, caudal fin shape, mouth shape, scale size, first dorsal fin shape, and number of dorsal fins. After the first trial period the characteristics "first dorsal fin shape" and "scale size" were removed, because scale size is not clearly defined, and fish are often pictured in their typical out-of-water appearance with clamped fins obscuring fin shape. A characteristic of a given species was not restricted to one option. For example, if a species is brown on the back and silver on the flanks, both colours applied to that species.

Workflow on Zooniverse

Selection of Subjects with Identifiable Fish

In the first trial period, volunteers first had to indicate whether the presented pictures included fish that could be identified. If they answered "yes", they could immediately identify the species; otherwise, they were taken to the next image.

After the first trial period, this first question was split off as a separate "fish or no fish" task. This allowed for the quick retirement of artworks. This task was completed by 392 volunteers from 13-3-2020 until 04-05-2020, when all subjects had been classified by at least two independent volunteers as picturing identifiable fish, or they received three negative classifications and were retired from the project.

Identification of Fish

The identification of fish species was done in two steps. In the first step, volunteers had to select which species of the preselected species list[64] were present on a particular subject. They could click on the species name from an alphabetically sorted list, or they could filter the species list based on their characteristics (body shape, colour, number of dorsal fins, colour pattern, shape of the mouth, shape of the caudal fin). Traditionally, identification of species is done according to a dichotomous key, where a series of questions in a predefined order leads to the correct species. The disadvantage of this system is that the order of questions is fixed and if one does not know the answer to one

64 See the species table at https://doi.org/10.6084/m9.figshare.19497548.

of the first questions, for example, because a crucial part of the animal is not visible, the determination is impossible. Therefore, we used a multi-entry key where users could decide for themselves which characteristic to start with and how many choices they made, before they started comparing the images of the species.

Once a species was chosen, volunteers could click on the name of an often confused species, which displayed the picture of the often confused species with details on how to discriminate between the two. For each of the selected species volunteers had to indicate how many individuals were present and whether they saw any indication of commercial use (whether the fish were cut, cooked, dried, or otherwise prepared; in a market; consumed (on a plate/ dining table); or none of the above). In the second step, volunteers could identify species that were not on the list, by marking a fish and entering a species, genus, or family name manually.

Selection of Volunteers

The higher the number of volunteers that rate a single picture, the higher the accuracy. With 28 volunteers per image 98% of correct labelling was achieved in the *Snapshot Serengeti* project.[65] With 5 volunteers per image already 90% of correct labelling was found in the same data set.[66] Common or easily recognizable species can be reliably labelled with only 2 or 3 volunteers, but rare, difficult, or undetailed pictured species may need 10 or more volunteers to achieve acceptable reliability values.[67] Similarly to automatically taken photos from camera traps, the paintings from our selection often depict only a piece of the fish, and there are also a lot of bad-quality images and roughly painted fish, which made identification difficult. Therefore, we expected the difficulty of labelling species in our project to be comparable to that of the *Snapshot Serengeti* project. We set the number of volunteers that rated each artwork to 14, and we expected the aggregated labels to be correct at values between 90% and 98%. Moreover, we calculated an evenness score for every single piece of art. That way we could select subjects with sufficient evenness scores from our data set to obtain a set of reliably labelled artworks. In the *Snapshot Serengeti* project, when discarding images with evenness higher than 0.5, 97% of images were correctly labelled when considering the answers of 5 volunteers per subject.

65 Swanson a.o., "A Generalized Approach".
66 Swanson a.o., "A Generalized Approach".
67 Swanson a.o., "A Generalized Approach".

Volunteers consisted of the general group of Zooniverse users that were already present at the Zooniverse community. Additionally, groups of people with interest in fish were attracted by using Instagram, Facebook, and articles in Dutch general journals (*Trouw* and *Nederlands Dagblad*)[68] and journals of specialized Dutch communities (RAVON, a conservation organization for Dutch reptiles, fish, and amphibians) and Sportvisserij Nederland (the Dutch sport fishing organization), *Vroege Vogels* (a popular Dutch public radio program),[69] and a presentation at Naturalis Biodiversity Centre, Leiden.

Aggregation of the Data

For subjects where at least 10 volunteers had selected at least one species from the list (N = 1029) the answers of the volunteers were combined in an aggregated answer. First, the number of consensus species N was calculated, as the median number of chosen species. For each of the species that was mentioned by the volunteers, the proportion of volunteers that recognized it was calculated. For each subject the species with the highest proportion of volunteers that recognized it were selected as a consensus answer from the top answer until the Nth species (rounded up in cases of a tie).

Calculation of Reliability

For individual subjects, two values are calculated: evenness and fraction support.[70] Evenness was calculated for all the subjects where at least 10 volunteers had selected at least one species from the list (N = 1029). For the calculation of evenness we used Pielou's evenness index:[71] $-(\sum_{i}^{S}=p_i \ln p_i)/\ln S$, where S is the number of different species reported by all volunteers, and p_i is the proportion of classifications received by species *i*. When all classifications were in agreement, we assigned a value of zero. The maximum value for this index is 1.0, indicating high disagreement among classifications.

For practical reasons, fraction support was calculated only for the pictures where the median of the number of species was equal to 1 (N = 565). It was calculated as the fraction of classifications that supported the aggregated answer.

Additionally, we have a selection of subjects that have been identified by specialists. We have a selection of subjects that were already identified by Lex

68 K. Moons in *Trouw*, 12 January 2020, and *Nederlands Dagblad*, 20 January 2020.

69 https://www.nporadio1.nl/nieuws/binnenland/08f664b8-e982-4c30-85d4-026b74b7a3d8/vissen-van-de-geschiedenis-herken-jij-de-vissen-op-het-schilderij.

70 Conform with Swanson a.o., "A Generalized Approach".

71 Pielou E.C., "Species-Diversity and Pattern-Diversity in the Study of Ecological Succession", *Journal of Theoretical Biology* 10 (1966) 370–383.

Raat for the 2004 Utrecht *Fish* exhibition.[72] Additionally, specialists from Ravon and Sportvisserij Nederland were asked to judge a selection of paintings within our Zooniverse project. For a total of 56 pieces of artwork we compared the identification of the specialists with the aggregated answer of the volunteers.

Reliability

Pielou's evenness index ranged from 0 (full agreement) to 1 (Fig. 9.1, mean, 0.90 ± 0.11; N = 1029), indicating that there was little agreement between volunteers about the identification of fish species [Fig. 9.4].

The fraction of support for the artwork with only one consensus species (N = 565) ranged from 0.1 to 1 (all supported the consensus species) (see Fig. 9.4) (mean, 0.43 ± 0.21), indicating that there was little support for the consensus answer.

When comparing the consensus answers from the volunteers with the identifications made by the experts (N = 56), the consensus answers agreed in 50% of the cases with the experts' answers. In 27% of the cases only some of the species from the volunteers corresponded with the expert identifications, and in 23% of the cases none of the species from the volunteers corresponded with the experts' annotations.

Therefore, we conclude that the classification of fish species from paintings by the general crowd is more complicated than we thought. Compared to the *Snapshot Serengeti* project, one would need more volunteers per subject in order to get an acceptable reliability (with an evenness <0.5) of the consensus

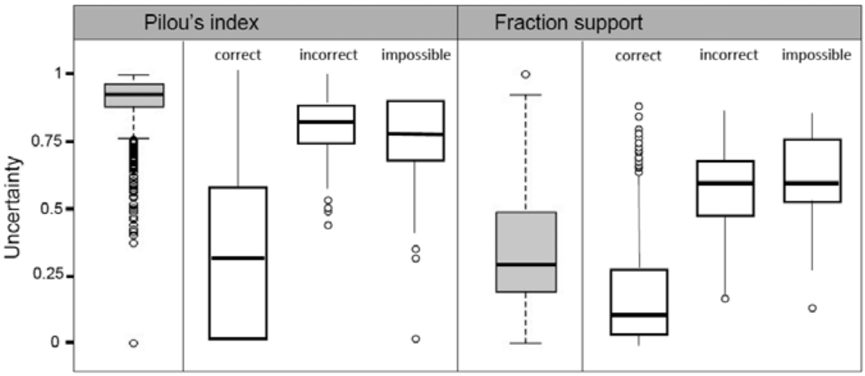

FIGURE 9.4 Boxplots of Pielou's evenness and Fraction Support in the current study (grey) compared to those in the *Snapshot Serengeti* project (white). Note that the inverse of fraction support is plotted in order to correspond with the direction of Pielou's evenness, i.e., a low number corresponds with low uncertainty

72 Raat, "Determinatie van de vissen op schilderijen".

answers. Therefore, with the current data set, identifications on the species level are only reliable for a fraction of the paintings (N = 20). For the other paintings with an evenness of >0.5 the identifications by the crowd cannot be used to label individual artworks. Nevertheless, when comparing the consensus answers of volunteers with those of the experts, the majority of species identifications made by the volunteers are correct. Probably, the volunteers recognized some of the fish, but it was often difficult to discriminate between several similar-looking species. However, if we look at the larger picture, focussing on averages across centuries and differences between particular groups of fish species, such as freshwater and marine fish, a certain margin of error is acceptable, and trends could be interesting. For example, the volunteers' answers are not reliable enough to say whether a pictured fish was cod or pollock, but if the consensus species is a cod, it is very likely a species from the Gadidae family and almost certainly a marine fish.

Acknowledgements

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