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Herring periods of Bohuslän: a cross-sectoral approach

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Herring periods have occurred in Bohuslän, on the west coast of Sweden, at least since the 16th century, probably even earlier. The first scientific description was given by Axel V. Ljungman, who arranged the occurrence of herring into periods which seemed to be related to sun-spot activities. The reappearance of herring by the end of the 1870s — the last herring period — inspired the oceanographers Otto Pettersson and Gustaf Ekman to ask for international cooperation in marine research, which eventually led to the Stockholm Conference in 1899. Pettersson and Ekman thought that movements of the upper water layers were related to the appearance of herring. Later, Pettersson was more in favour of large tidal forces as the cause for herring periods. K. A. Andersson had difficulty in finding a direct connection between oceanography and herring occurrence and emphasized that the herring stock had to be very large before any herring period could occur. For the successful identification of the type of herring which caused the period starting in the 18th century, Hans Höglund conducted excavations of herring waste deposits buried on land as a result of environmental protests of that time, thus adding archaeology to the efforts. Studies of climate and variations in herring populations by Jürgen Alheit and Eberhard Hagen pointed to the North Atlantic Oscillation (NAO) as the ultimate environmental driving force necessary for a herring period. A relationship between herring periods of Bohuslän and the medieval herring fishery farther south off Scania has not been found. An accumulated stock of large year classes of herring seeking shelter during the winter months in the archipelago of Bohuslän is the necessary precondition for a herring period, especially when there are low winter severity/mildness indices.

Keywords: Bohuslän, herring periods, NAO, Scania.

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Introduction

At the end of the 19th century, the leading personalities in oceanographic research (at that time "hydrographic" research) in Sweden were Otto Pettersson and his colleague Gustaf Ekman. Much of their work was inspired by the reappearance of herring at the coast of Bohuslän in 1877. In their capacity as members of the Hydrographic Commission, they stated in a letter to King Oscar II (Wijkander *et al.*, 1897, translated by Artur Svansson):

> All the fisheries of the Nordic Sea and particularly the behaviour of the migrating fishes are, as we know, related to the great movements of the upper layers of the sea as well as the variations of the fish food or 'plankton' available in these layers, which food consists of animal and vegetable organisms floating in the sea water. On the knowledge of the great movements in these levels of the ocean, and the quality and quantity of foodstuffs for the fishes contained in them, the rational carrying out of the fisheries as well as its legislation must be found in the future.

They continued, submitting the idea of scientific cooperation with other governments:

> The purpose of this investigation would be to analyse the state and movements in the upper moving water layers of the sea, from the surface down to a depth of about 800–1000 m …

Members of the Hydrographic Commission looked for oceanographic explanations, and Pettersson first thought the solution was the influx of "bank water", but it was soon evident that this was not the simple explanation. It was, however, the lively interest of those oceanographers in international scientific cooperation in northern waters, aiming at a combined biological and physical/chemical approach, which was one of the scientific issues that led to the exploratory meeting in Stockholm in 1899. Regarding the reappearance of herring, Pettersson and Ekman referred to the work of Axel V. Ljungman, who had reviewed the periodic historic

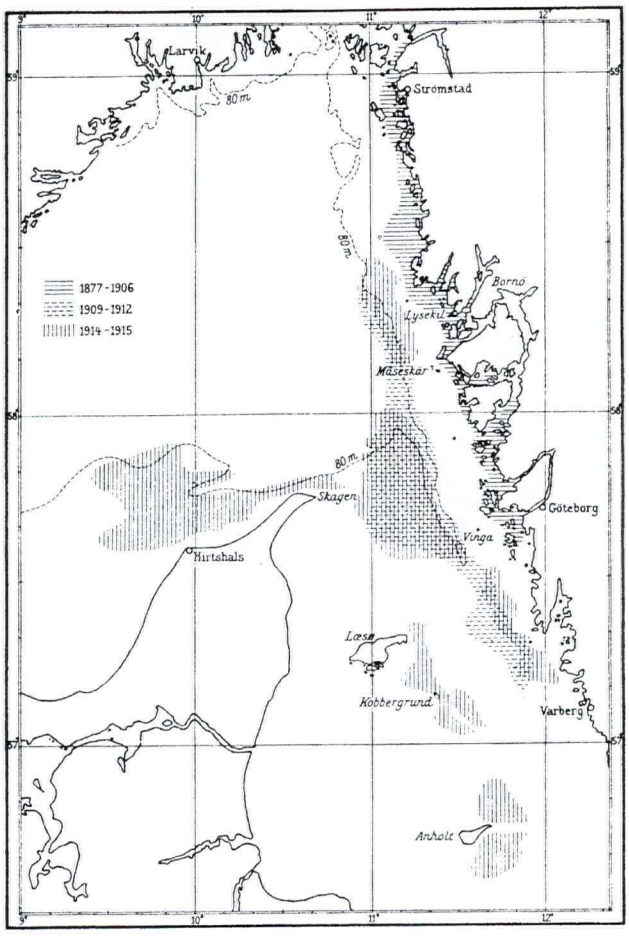

Figure 1. Swedish herring fisheries in the Skagerrak and Kattegat, 1877–1915. Fishing gear: 1877–1906 beach seines, 1909–1912 purse seines, and 1914–1915 purse seines and (bottom) trawls. After 1915, the fishery was similar to that of 1914–1915, except that over a period of years there was no fishery in the open sea north of Lysekil. From Andersson (1948).

occurrence of herring some twenty years earlier. Ljungman established a scheme starting around the year 1000 and related the occurrence of herring to sun-spot periodicity. He was, however, careful to point out that there were scarcely any historical records for herring fisheries in Bohuslän before 1300, a fact which later historical studies seem to confirm. Ljungman's scheme of a periodic appearance became, however, widely accepted in the literature, even including the time before 1300. Pettersson later favoured large tidal forces as the main factor and their variations in strength as the reason why herring appeared and disappeared. In this way, herring periods gave rise to cross-sectoral thinking: biology – oceanography – astronomy – tidal forces.

Lindquist (1983, 1999a, 1999b) has attempted earlier to update what is known about the herring periods of Bohuslän. The present paper adds further information and provides an overall review of the status of knowledge.

Historical records of the fishery

For at least 500–1000 years, the province of Bohuslän on the eastern side of the Skagerrak experienced many mass occurrences of herring. Each time, this phenomenon lasted for four or more decades, after which the herring disappeared for perhaps six or seven decades before returning. At the beginning of each herring period, shoals entered the archipelago of the central and northern part of the coast and stayed there during winter. This was repeated year after year until the end of a period.

There is no information to indicate whether there was any mass occurrence of herring outside the archipelago in the open Skagerrak or Kattegat because herring could not be fished in the open sea with the gear used in those days. Only since the 20th century has it been known that herring also occurred in great quantities in the open sea (Table 1 and Figure 1). It is interesting to note that no information exists about any "herring periods" off the

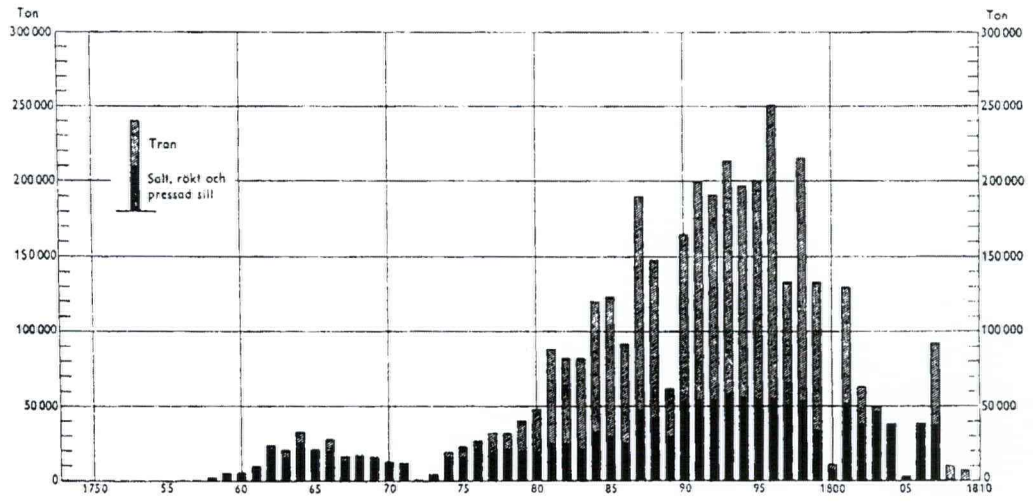

Figure 2a. Herring export from Sweden, 1750–1810. From Hasslöf (1949, Bild 33), who recalculated the number of barrels of herring oil and salted, smoked, and pressed herring into tonnes.

Danish coasts (see below for the medieval herring fishery off Scania). Regarding the Norwegian Skagerrak coast, the occurrence of herring has been studied by Hans Höglund (1976), but the quantities of herring caught off Østlandet, Norway, were never reported to be comparable to those in Bohuslän.

The catches of herring caught in the coastal area of Bohuslän have been quite remarkable (Andersson, 1960; Hasslöf, 1949; Höglund, 1978; Holmberg, 1963; Nilsson, 1963) (Figures 2a and 2b). As there are no direct landing figures for earlier years, exports of train oil produced from herring have been recalculated in terms of live herring. In the last two herring periods, annual catches in peak years were 200 000–300 000 t. In order to understand the magnitude of those quantities, it should be realized that they were higher than the present total Swedish herring catch taken with modern fishing vessels in the Skagerrak, Kattegat, and Baltic combined.

History of scientific studies

A. V. Ljungman, in his 1879 publication, first used the term "herring periods" for the great fluctuations in the herring fishery, and his paper is the source of all later quotations. Ljungman identified nine herring periods (Table 1). He started his scheme (based on periods of sun-spot activity) around the year 1000, but was careful to state that for "the time before the year 1300 we have scarcely any information regarding our Bohuslän fisheries" [1879, p. 263 (translation) and 1882, p. 500]. On critical historical grounds, only the last four herring periods in the archipelago are accepted. Dalén (1941), in his study about the fishing villages of Bohuslän, stated that there were only a few, if any, historical records supporting the concept of herring periods before the 16th century: "Of the five periods in the Middle Ages generally accepted without question, it appears that only one really existed, about the year 1300" (p. 340).

There are, however, several early sources which cannot be disregarded which refer to the mass occurrence of herring during the Middle Ages. For example, Aurigarius, in his 1588 atlas, mentions that "This catch of herring in the neighbourhood of Marstrand is for 100 and 30 and 40 years exceptionally large, thereafter it disappeared totally for 100 years, and went to Scania and Denmark, then within 30 years moved from Scania and again arrived at this place, and has been caught in great quantities" (quoted from Tomfohrde, 1914, pp. 23 and 29, translation).

One author with a profound knowledge of the Bohuslän fishery, Olof Hasslöf (1949, pp. 118–120), assumed that herring periods also existed during the Middle Ages. Although the existence of herring periods before the 16th century has not been documented, Lindquist (1999b), after reviewing earlier work, stated that from a biological point of view it is likely that herring periods existed before 1500.

Historically, one of the first attempts to explain the annual variations in the occurrence of herring in general in the North Atlantic was made by Johann Anderson, whose polar migration theory was published posthumously in 1746. He believed that there was only one herring stock which migrated every year from the Arctic Ocean to the North Sea. Anderson was not the first to advocate the polar migration theory. As Wegner (1996) clearly showed, the *Atlas maritimus et commercialis* of 1728 (published in London) by the astronomer Edmond

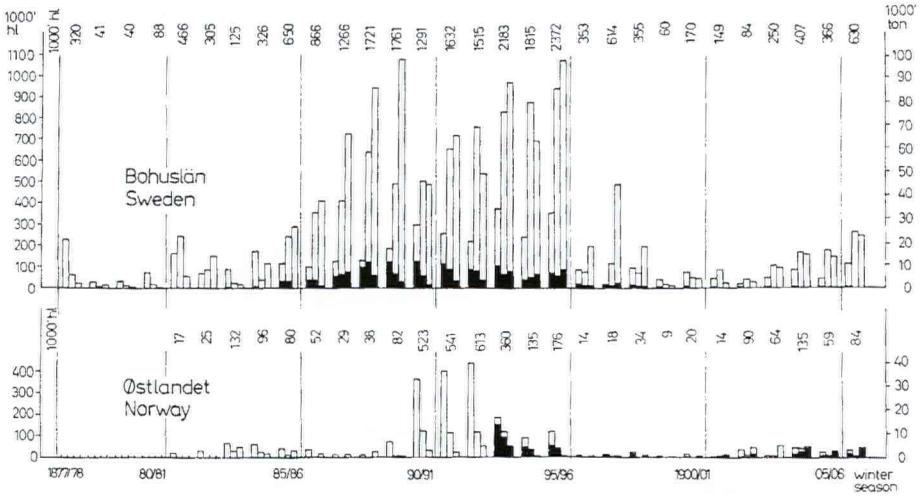

Figure 158. Yield of herring in the Skagerrak during the winters of 1877/1878 to 1906/1907.

The total catch for each season is divided into three groups according to the different regions on each side of the border between Norway and Sweden.

For Bohuslän:
Right-hand columns: South Bohuslän.
Centre columns: Central Bohuslän.
Left-hand columns: North Bohuslän.

For Østlandet:
Left-hand columns: Østfold.
Centre columns: Vestfold.
Right-hand columns: Telemark, Aust- and Vest-Agder.

Empty parts of columns: seine-caught herring. Filled parts of columns: net-caught herring. For Bohuslän the catches are credited to the district where the fishermen lived. For Østlandet the catches are credited to the stretches of coast where they were made.

Figure 2b. Yield of herring in the Skagerrak during the winters of 1877/1888 to 1906/1907. From Höglund (1978) (first published in 1976).

Halley already included this idea, on which Anderson, however, expanded. Therefore, according to Wegner, the theory should be called the Halley-Anderson Polar Migration Theory. Anderson's 1746 book influenced thinking until the end of the 19th century, since all facts known at that time agreed well with his theory. For other early theories on large-scale herring migrations, the reader is referred to Wegner (1993).

Recent studies in periodicity

Herring periods in Bohuslän are not a unique phenomenon. Periodic appearances of herring, sardines, and anchovies are well known from many seas, including the North Sea. Outstanding examples of fish with large natural fluctuations are the Pacific sardine and the northern anchovy in the Santa Barbara Basin. Fluctuations since about AD 300 have been documented by layers of scales deposited in anaerobic sediments (Baumgartner *et al.*, 1992; MacCall, 1996). Long-term variability in catches of Pacific herring, sardines in the Benguela Current, and anchovies in the Humboldt system have also been found.

Sun spots, extraordinary tidal forces, and the North Atlantic Oscillation (NAO) have all been proposed as responsible for the mass occurrence of herring. As mentioned above, Ljungman thought that herring periods were regular phenomena, probably of cosmic origin. He pointed to what he saw as a coincidence in regularity with the 55.5-year sun-spot cycle. Pettersson (1922; 1926, p. 317) felt that certain relative constellations of the sun, earth, and moon created extraordinary tidal forces which, in turn, resulted in a greater inflow of water from the Norwegian Sea. He found that an "absolute maximum should have occurred about 1433" (1922, p. 10, translation) when there was an exceptional constellation (see also Svansson, 1998 for the history of Pettersson's ideas).

Alheit and Hagen (1997) reported that a negative (low) index of the NAO implies severe winters in Europe with a decreased influence of southern waters, favouring a strong inflow of cold Siberian air masses. This situation is favourable or even necessary for a Bohuslän herring period. Not only are the herring in Bohuslän favoured under such conditions, but also the herring off Southwest England, in the English Channel, and in the Bay of Biscay. It is interesting to note that the "winter mildness/severity index" since the year 1100 in Figure 4 of Alheit and Hagen's paper shows a minimum at about the year 1440, i.e., the same time when Pettersson estimated that the greatest inflow of water from the Norwegian Sea had occurred. Using the same figures as Alheit and Hagen, the connection between herring periods and the NAO index is shown numerically in Figure 3. The conclusion from this material is that there is a higher frequency of low indices equating to severe winters during herring periods (both those which are documented and those which probably have occurred).

Table 1. Periodicity of the herring fishery of Bohuslän. Columns 3 and 4: A. V. Ljungman's scheme, published in 1879 (and taken from the version published in English in 1882); Columns 1 and 5: numbering of sun spot-cycles and herring periods by Höglund (1976, Figure 1); Columns 2 and 6: recent information about the beginning and end of periods and location of the herring fishery in the Skagerrak (modified from Andersson, 1948; Lindquist, 1983).

1	2	3	4	5	6
Sun-spot cycle	Years	Years	Herring in the archipelago of Bohuslän	Herring period	Herring in the open sea
					1963–1965
					1943–1954
19	1877–1906	1867–1922	Rich fisheries began in 1877	9	Purse seine fishery started 1903, trawl fishery 1911; for location see Figure 1
18	1810–1876	1811–1866	No good fisheries		For earlier years no information about open sea fishery
17	1755–1809	1755–1810	Rich fisheries 1748–1808, which, especially during the last quarter of the 18th century, assume enormous dimensions	8	
16	1699–1754	1699–1754	No specially good fisheries till near the end of the period from 1747 or 1748		
15	1643–1698?	1643–1698	Good fisheries, at least between 1660–1680	7	
14	1590–1642	1587–1642	No good fisheries		
13	1556–1589	1531–1586	Particularly good fisheries, at least between 1556 and 1587	6	
12	1475–1555	1475–1530	No good fisheries		
11		1419–1474	Good fisheries, at least about the middle of the century	5	
10		1363–1418	No good fisheries		
9		1307–1362	Particularly good fisheries, at least during the first thirty years of the century, which probably already commenced towards the end of the preceding century	4	
8		1251–1306	At the beginning and about the middle of the period no good fisheries, although probably the fisheries were good towards the end		
7		1195–1250	Probably there were good fisheries, judging from the fact that during this period Gullholmen, Öckerö, and other desert islands were colonized, and the convents of Marstrand and Dragsmark were founded	3	
6		1139–1194			
5		1083–1138	Probably there were good fisheries, during which Konungahella became the most important city in the north	2	
4		1027–1082			
3		971–1026	Good fisheries, at least during the reign of Olaf the Saint	1	
2		915–970	No good fisheries, at least during the beginning of the reign of Gunhild's sons		
1		859–914			

	00	10	20	30	40	50	60	70	80	90
19	0	6	4	-1	1	-1	-1			
18	-1	-3	0	-2	-2	-2	6	0	0	-1
17	1	1	-1	3	-1	-5	0	4	-4	-2
16	0	-3	-3	2	5	-7	-3	-6	-7	-5
15	-3	2	11	6	-1	-3	-3	-1	-5	-5
14	-2	-1	7	-18	-2	-3	-6	1	1	-12
13	1	-10	-1	-1	4	-4	2	-5	11	2
12	-5	-5	6	1	3	-5	-1	0	3	5
11	-2	-5	-3	-3	-9	-3	-2	2	5	5

A. Indices calculated for 12°E, 50°N

	Severe winters -																				+ Mild winters		
	1 8	..	1 2	1 1	1 0	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7 .. 1	Total
Within a period	1				1	1	2	2	7	2	6	3	4	2	2	1	1	2	2	2	1		42
Outside a period			1					2		5	5	9	5	5	4	2	1	2	2		2		45

	00	10	20	30	40	50	60	70	80	90
19	1	5.5	7	4	0	0.5	-2			
18	-1.5	-2.5	0	-2.5	-2.5	-1.5	7	0	-1	-2
17	0.5	-0.5	-2.5	6	-2.5	-2.5	-3	1.5	-4	-2
16	-5	-0.5	-5	-1.5	1	-8	-5	-3	-4.5	-6
15	2	0	6.5	1.5	-1.5	-2	-5	-2	-6	-5
14	-2.5	0.5	3.5	-15	3.5	-2	-7.5	2	-2.5	-9
13	0	-5.5	-0.5	-2.5	3	-3.5	1	-4	6.5	0
12	1	3.5	3.5	3.5	2	-1	-2	3.5	3	3.5
11	-1.5	-4.5	-3	-1.5	-6	-4.5	-1	2	5.5	6

B. Indices calculated for 0°E, 50°N plus 12°E, 50°N divided by 2 and rounded

	Severe winters -																		+ Mild winters		
	1 5	..	1 2	1 1	1 0	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6 7 8	Total
Within a period	1					2		3	4	4	5	7	3		4	2	3	1	2	1		42
Outside a period					1			4	1	7	6	4	9	1	2	3	1	1	3	2		45

Figure 3. Winter mildness/severity index 1100–1960, and herring periods in Bohuslän: a higher frequency of lower indices during herring periods (shadowed, see Table 1). A: 12° is at the longitude for Bohuslän. B: the figures which Alheit and Hagen (1997) used in their Figure 4.

Andersson (1960) found that "the great fluctuations... were in all probability not due to changes in the hydrographical conditions in the eastern Skagerrak during the winters but were due to changes in the strength in the stock of the North Sea Bank herring" (p. 53). Confirming the need for a sequence of very rich year classes, Lindquist (1999b) stated that herring periods will more likely occur when the oceanographic situation is associated with low NAO indices. Furthermore, the northern part of Bohuslän is different in its oceanography, which would explain why herring are found there at the beginning of each winter season.

Some consideration needs to be given to climate change in general. Rummukainen (1999) summarized what is currently known about global climate change (after a symposium arranged by the Royal Swedish Academy of Sciences in March 1999). The global surface air temperature has warmed by about 0.6°C over the past 140 years and "it is possible that the past 30–50 years have been the warmest during the past 500 000 years." A rise of global sea surface temperature by 0.5°C during the last 100 years has also been observed (Jones, 1991). It is not known if, and to what extent, this development is of importance to the NAO.

Scientific studies on herring stocks

There are, unfortunately, only a few biological samples that provide information about the kind of herring constituting the bulk of the latest herring period. From those observations and from information received from professional fishermen, it is very likely that it was autumn-spawning North Sea herring (Andersson, 1956, 1960; Höglund, 1978). The same also holds for the herring of the open sea "periods" during this century (Figure 1 and Table 1).

Andersson pointed out earlier (1948), without speculating about the causes of the periodicity of the Bohuslän herring (he was obviously referring to Otto Pettersson), that with modern fishing techniques there is no need to wait for herring to enter the archipelago of Bohuslän because present-day herring fisheries take place mainly in the open sea. Andersson thought that if oceanographic conditions were not the main cause of fluctuations, then it was the size of the herring stock. Both oceanography and year-class strength could act in one direction or the other (pp. 127–128).

A theory that a Norwegian branch of the Atlanto-Scandian herring entered Bohuslän was put forward by

Figure 4. Herring fisheries off Scania in the Middle Ages. Woodcut from Olaus Magnus (1555), Chapter 20: On the herring.

Finn Devold in 1950 and, five years later, was presented by Devold at a session of the ICES Herring Committee (Devold, 1955), creating a lively discussion. Höglund, in his 1972 paper, described how this theory had been immediately rejected by Andersson. Höglund, thereafter, started an investigation of the remnants from train oil factories from the period ending in 1809. With his paper presented at the 1960 session of the Herring Committee in Moscow, scientific discussions continued, with ICES as the only possible international forum for fishery science. Höglund had investigated sub-fossil deposits containing herring bones and found that the age composition and length distribution of the major part of the herring caught 200 years ago was similar, if not identical, to the autumn-spawning herring now fished in the North Sea. Höglund's (1972) conclusion was "that the main body of the herring that caused the eighteenth century herring period in Bohuslän cannot have been Norwegian winter herring." He thus definitely ruled out the alternative theory.

An early environmental matter

When the herring failed to return at the end of a herring period, the economy of the whole province collapsed. It was, therefore, quite natural to seek reasons for the apparent change in herring behaviour. During the period beginning in the middle of the 18th century and lasting until 1810, herring were salted and exported; later, train oil was produced. The waste from train oil production was dumped directly into the sea and became a concern for the coastal population. Sailors and pilots reported that anchor grounds were rendered useless; others said "that the water was poisoned, so that the herring was disturbed in their migrations, or even frightened away from the coast" (Höglund, 1972). During the height of that herring period, an investigation was commenced on orders of State authorities. Höglund gave a lively description of the background and results of this very first marine environmental issue in Sweden. No direct link between the disappearance of herring and waste dumped into the sea could be found.

A related issue: the herring fishery off Scania during the Middle Ages

There are two major studies of Danish fisheries in the Sound (Øresund) and off Scania by Mourier (1866–1868) and by Krøyer (1887) and Fiedler (1887). Mourier quoted sagas and a number of historical sources which all directly or indirectly referred to herring fish-

eries that gave rise to decrees and laws in Denmark. His early references to important herring fisheries in the Sound seem to be from the 11th century (1867, pp. 129–130).

Krøyer concluded that herring fisheries in the Sound were exceptional from the second half of the 12th century and lasted, with interruptions, until the middle of the 16th century (Krøyer, 1887, p. 21). Before and during that time, there was also a herring fishery in the Western Baltic off Rügen, but any relationship between this fishery and that in the Sound remains unclear.

Lundberg (1893) introduced a new element to the discussion. From available historical sources, he tried to estimate the quantities of herring barrels produced in 1494 and 1495 off Skanör and Falsterbo, namely 50 952 and 62 000 barrels, respectively (p. 8). He compared this with the figure for 1882 of 50 000 barrels in about the same area (p. 10), which is of the same order of magnitude as some 400 years earlier!

Lundberg concluded that "the difference between the old and contemporary catch quantities is by no means so large that one is entitled to speak about the disappearance of herring, based on the difference between before and now" (p. 10, translation). He also compared the catches in the Sound area with the 1877–1887 mean of the Bohuslän fishery, which was roughly five times larger, namely 246 017 barrels.

Further studies are needed before more reliable conclusions can be reached. Some preliminary calculations can, however, be made with the following factors: 1 barrel = 1.25 hl, 1 hl = 90 kg, which equals 5625 t for 50 000 barrels. Using the same calculation for the number of barrels in the Bohuslän fishery in 1877–1887 given by Lundberg, this would correspond to about 28 000 t, which is of the same order of magnitude as those specific years (e.g., Höglund, 1972, Figure 158).

Holm (1998, p. 14), independently of Lundberg, compared herring catches around 1900 with medieval catches. Medieval catches may have been as high as 36 000 t (export of 300 000 barrels plus 100 000 barrels for local sales and personal consumption), while catches around 1900 amounted to 28 000–29 000 t. He concluded, "After all we may conclude that the fishery in the Sound during the Middle Ages was somewhat larger than that known from present times, but still within the normal variation which may be expected from such a labile stock as that of herring" (p. 15, translated).

In this context, it should be noted that herring catches in the Belts, Sound, and Baltic west of Bornholm are presently fluctuating between 100 000 and 200 000 t (compared to the TAC recommended by ACFM of 60 000 t). These contemporary figures are much larger than those from the fishery off Scania in "good" years during the Middle Ages. Of course, fishing gear and craft have changed dramatically since then.

It is unknown whether herring fisheries off Scania during the Middle Ages were related at all to the same large-scale climatological changes which very likely governed herring periods in Bohuslän.

From this, it seems that the great quantities of herring taken during the Middle Ages off Scania were not so enormous when compared to modern-day catches. Herring in the Middle Ages, for some unknown reason, may have been closer to shore and more accessible to fishing boats, as illustrated in the famous woodcut in Olaus Magnus (1555) (Figure 4).

Further studies required

After finalizing this paper, my attention was drawn to the paper by Corten (1999), which arrived at a similar conclusion regarding the importance of NOA. An answer to the question of how many herring periods existed before the 16th century could perhaps be found in scales deposited in anaerobic sediments. Unfortunately, as pointed out earlier (Lindquist, 1999b), no places with a sufficiently long history of deposition of scales are known from Bohuslän.

Acknowledgements

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