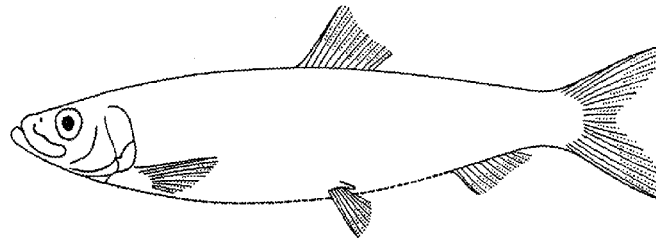


**Herring***Clupea harengus*
Family ClupeidaeMax size: 40 cm
Max age: 10 years**Introduction**

Taxonomy: Atlantic herring *Clupea harengus* Linneus, 1758 (Order: Clupeiformes, Family: Clupeidae) is one of five clupeids occurring in the North Sea [1,2]. Herring stocks comprise many races that may be reproductively isolated through specific spawning grounds and specific spawning seasons (e.g. autumn vs spring spawners), but the taxonomic status of the various sub-populations has remained unclear.

common names			
<i>Danish</i>	Sild	<i>Icelandic</i>	Síld
<i>Dutch</i>	Haring	<i>Latvian</i>	Siļķe (Atl.) / Reņģe (Baltic)
<i>English</i>	Herring	<i>Norwegian</i>	Sild
<i>Estonian</i>	Heeringas (Atl.) / Rääm (Balt.)	<i>Polish</i>	Sledz
<i>Faeroese</i>	Sild	<i>Portuguese</i>	Arenque
<i>Finnish</i>	Silli (Atl.) / Silakka (Balt.)	<i>Russian</i>	Сельдь (Atl.) / Салака (Baltic)
<i>French</i>	Hareng	<i>Spanish</i>	Arenque
<i>German</i>	Hering	<i>Swedish</i>	Sill (Atl.) / Strömming (Baltic)

General: Herring is numerically one of the most important pelagic species in several North Atlantic ecosystems and intensive exploitation goes back several centuries. Stocks have fluctuated enormously in the past - as have many stocks of pelagic teleosts - in response to both natural variations in the environment and human exploitation. Herring lay their eggs in dense beds on the sea bed and need specific gravelly substrates to spawn. In the Baltic herring also spawn on vegetation. This makes herring particularly susceptible to anthropogenic activities affecting the sea bed such as offshore oil and gas industries, gravel extraction and eutrophication causing oxygen depletion. Herring scientists are also special because herring is the only species that must be measured in half cm!

Minimum Landing Size: 20 cm in the North Sea; 18 cm in the Skagerrak.

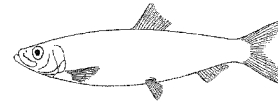
Herring and sound

Herring are physostomous, i.e. they have an open swimbladder where a duct connects the swimbladder to the oesophagus. Additionally, clupeid fish have connections between the swimbladder and the inner ear, whereby the diverticula of the swimbladder extend into the skull. Here they form otic bullae and press against the labyrinth wall, helping propagate vibrations from the swimbladder to the ear. Hence, herring is regarded as a species that will be sensitive to anthropogenic noise disturbance [3].



Herring

Clupea harengus
Family Clupeidae



Distribution

Biogeographical distribution: Atlantic herring is widely distributed in the Northwest and Northeast Atlantic. Within the Northeast Atlantic, they are distributed from the northern Bay of Biscay to Greenland, and east into the Barents Sea. In the Northwest Atlantic they are distributed from South Carolina to Labrador [1,2].

Adult fish are pelagic and are found mostly in continental shelf seas to depths of 200 m deep [1]. However, the Atlanto-Scandian herring disperses widely over the abyssal plains during its feeding migrations between Norway, Iceland and Greenland. Especially for the autumn spawners, the larval stage may be extended and passive drift may bring them to nursery areas that are far away from the spawning grounds. Juveniles tend to occur in shallower water, quite separate from the adults, and they move into deeper waters after two years. Herring form large shoals, with diurnal vertical migration patterns through the water column. During the day, herring shoals tend to remain close to the sea bottom or in deep water to a depth of 200 m, and they move towards the surface at dusk and disperse over a wider area during the night. These diurnal vertical movements may be related to the availability of prey items, or to the stage in their maturation cycle [4].

Spatial distribution in North Sea: Within the North Sea, herring may be found everywhere, but 1-group herring are virtually restricted to within the 100m depth contour and are most abundant in the southeastern part, in the Kattegat and in a band along the British coast. The 2-group is much more dispersed over the northern North Sea. The mature 3+ herring has largely withdrawn from the eastern half of the North Sea and is found in a westerly band running from the Southern Bight to the northern North Sea. Only the Kattegat remains an area of high concentration for all age groups (Fig. 1).

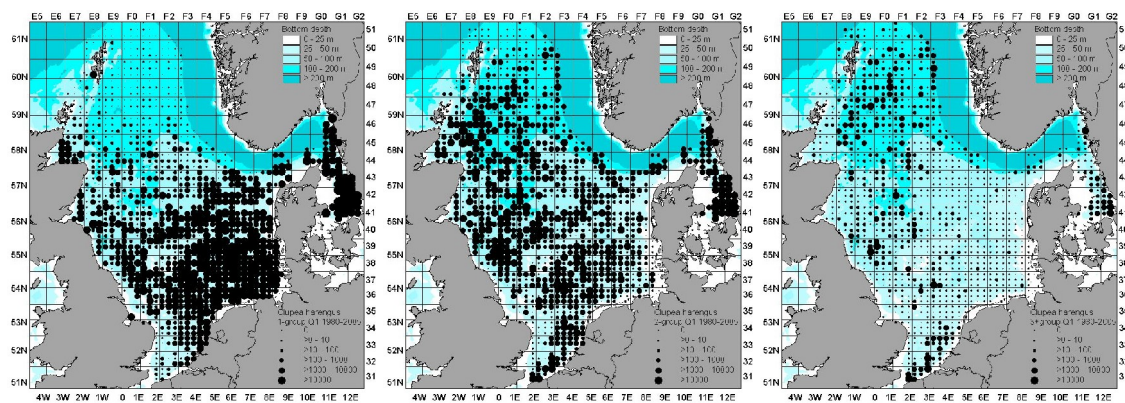


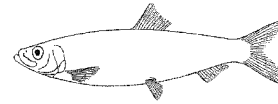
Figure 1. Average annual catch rate (number per hour fishing) for 1-group and 2-group and 3+ group herring in the quarter 1 IBTS survey, 1977-2005.

Habitat characteristics: Herring deposit their egg masses on gravel and maerl habitats, and geographically the spawning grounds tend to be well-defined, although the intensity of spawning varies and over time some areas may be deserted and new ones be occupied. The habitats of juveniles and adults are primarily pelagic, and many hydrographical features (e.g. temperature, depth of the thermocline, degree of mixing, proximity of frontal systems), as well as abundance and composition of the zooplankton on which they feed affect the distribution [5,6,7].



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Clupea harengus
Family Clupeidae



Life history

Age, growth rates, longevity, length-weight relationship: Although herring can attain a maximum length of 40 cm, most adult fish in the North Sea are in the range of 20–30 cm. On average, more than 60% of the 2-year-olds and 95% of the 3-year olds are mature [8]. Although the maximum lifespan exceeds 10 years, most North Sea herring are less than 7 years [9]. Growth is fairly rapid until reaching maturity and then slows down as the fish start reproducing. Recent estimates of the mean length and weight at age, and proportion of catch at age (2004, all quarters) are given below [9]. The mean length and proportion mature at age of autumn spawners (as observed in IBTS surveys are illustrated in Figure 2.

Age:	0	1	2	3	4	5	6	7	8	9+
Mean length, cm:	13.4	16.1	24.1	25.3	27.7	28.7	29.2	29.9	30.3	31.5
Mean wt, g:	13	26	120	137	182	206	221	229	241	265
Proportion, %	15.8	3.4	6.9	33.6	13.0	18.1	4.3	2.5	1.8	0.6

The concepts of age and year class are a bit problematic in herring, because of the extended spawning season of autumn spawners from September to January. Herring scientists generally refer to the number of rings seen in otoliths, which means that all autumn spawners and spring spawners from one spawning season are combined in one cohort of 0-ringers, 1-ringers, etc. Using the convention of January 1st as the birthday, 0-ringers or 0-group refer to fish born between between 3 and 18 months ago, but 0-ringer autumn spawners belong to a different year class from 0-ringer spring spawners.

The relationship between weight (W) and total length (L) is [10]: $W = 0.00603 * L^{3.0904}$

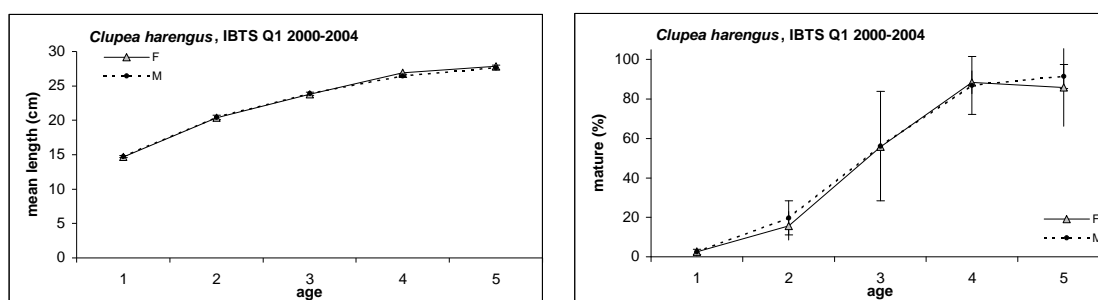
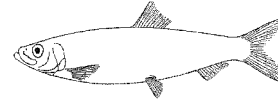


Figure 2. Mean length (left) and proportion mature (right) at age for autumn spawning herring in the North Sea and Skagerrak/Kattegat, based on IBTS data 2000–2004.

Reproduction: Herring are demersal spawners, depositing their sticky eggs on coarse sand, gravel, shells and small stones, all the members of a shoal spawning over a relatively short time period. The fish congregate on traditional spawning grounds, many of which are on shoals and banks and in relatively shallow water, approximately 15-40 m deep. Outside the North Sea, some spawning grounds of Atlanto-Scandian herring have been found on gravel banks in deep water (ca. 200 m) off the western coast of Norway [1]. Each female produces a single batch of eggs per year, releasing a ribbon of eggs that adheres to the substratum, and the male sheds milt while swimming a few centimetres above the female [11]. The resulting egg carpet, which can be 4–9 layers thick, may cover an area of up to one hectare [12].



Herring

Clupea harengus
Family Clupeidae

The number, size and weight of eggs produced by an average sized female vary between stocks [9]. For example, an average sized female (27.5 cm, 175 g) from the Downs stock (see below under stock structure) produces 42 000 eggs per annum (240 eggs per gram body weight) whereas a comparably sized fish from the Buchan stock may produce 67 000 eggs (380 eggs per gram) [13]. It may take up to two weeks for the eggs to hatch, depending on sea temperature [14], and, after hatching, the pelagic larvae rise to surface waters where they are transported by the prevailing water currents [15]. Most autumn spawned herring larvae drift in an easterly direction, towards the important nursery grounds in the coastal waters of the eastern North Sea, and they metamorphose in the spring at a length of approximately 4.8–5.0 cm [14]. There are also nursery grounds in the Moray Firth and Firth of Forth. Larval drift is however variable, and in some years many larvae may not reach the traditional nursery areas [16,17]. Observed shifts in the position of some spawning areas may be related to changes in the abundance and distribution of their planktonic food resources, which in turn are affected by hydrographical and environmental changes [16].

Migrations: After spending their first few years in coastal nurseries, two-year-old herring move offshore into deeper waters [18], eventually joining the adult population in the feeding and spawning migrations to the western areas of the North Sea. These migration patterns, developed as juveniles, are generally regarded as being relatively constant over periods of several years despite environmental variation [19].

Food habits: The pelagic larvae, which are 8-10 mm at hatching, feed on copepods and other small planktonic organisms [14,21]. Calanoid copepods are the predominant prey items during the early juvenile (< 3 cm) stage of life [12], but euphausiids, hyperiid amphipods, juvenile sandeels, *Oikopleura* spp., and fish eggs are also eaten [20], with larger herring also consuming predominantly copepods with small fish, arrow worms and ctenophores as an aside. Although fish eggs are unlikely to represent an important food resource for the herring, the mortality induced may affect survival of the early stages of these species and thus recruitment [21].

Predation: Herring represent an important prey for many predators, including cod and other large gadoids, dogfish and sharks, marine mammals and sea birds.

Population structure

Age and length composition: Within the North Sea, the majority of herring are less than 7 years of age [9], with a greater proportion of 1 and 2-group fish in coastal areas.

Length composition: Herring of up to 38 cm length have been recorded in the IBTS surveys, though the vast majority of herring sampled are in either the 9–19 cm or 19–30 cm size classes (Fig. 3).



Herring

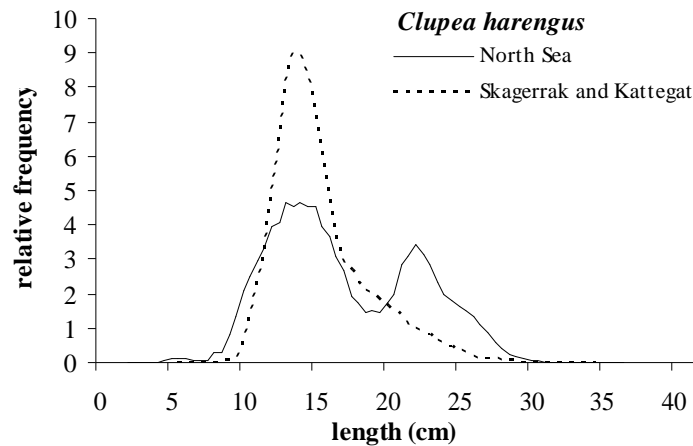
Clupea harengus
Family Clupeidae

Figure 3. Length-frequency distribution of autumn spawning herring caught in the North Sea, and Skagerrak/Kattegat in the quarter 1 IBTS surveys, 1985–2005.

Changes in abundance: Over the last 60 years, the North Sea herring has undergone huge changes. Following a period of heavy overexploitation, the stock of North Sea herring collapsed in the mid-1970s. After the fishery was stopped almost completely, the biomass has recovered and is approaching a level of 2 million tonnes. There has, however, been a succession of poor recruitments in recent years. In the Skagerrak/Kattegat area, the herring fishery has experienced periods of extremely large catches alternating with extremely poor catches over several centuries. These so-called Bohuslån herring periods are supposedly induced by environmental variations .

Stock structure: A number of 'races' are distinguished within the North Sea, which differ in spawning site, timing of the spawning season and in meristic characters such as the number of vertebrae. These latter variations are small and are at least partly influenced by environmental conditions, but may also have a genetic origin [22]. There are three major races of autumn spawners, which mix on the feeding grounds for the majority of the year, but then migrate to specific grounds to spawn [23]:

- Buchan / Shetland herring spawn off the northeast Scottish and Shetland coasts during August to September.
- Banks or Dogger herring spawn in the central North Sea off the northeast English coast during August to October.
- Southern Bight / Downs herring spawn in the Southern Bight of the North Sea and English Channel during November to January.

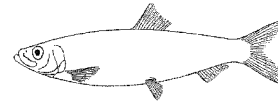
These three represent the bulk of the North Sea herring stock [23], but some spawning also occurs in spring (e.g. the Skagerrak spring spawners that are related to the Western Baltic stock and Thames Estuary stocks). Spawning grounds have also been described on a finer scale [9, 24]. At least one race, the former 'Zuiderzee' herring has become extinct after the closure of this Dutch estuary with a dam.

Because of the mixing of adult herring, landings cannot be disaggregated to the constituting races and North Sea autumn spawners are assessed as a single stock. Based on larval surveys however, the Dogger herring have largely disappeared, and the collapse of the Downs herring in the 1960s preceded the collapse in other races.



Herring

Clupea harengus
Family Clupeidae



Exploitation in the North Sea

Main métiers targeting the stock: There are several fleets that fish for North Sea herring [25], including directed herring fisheries using purse seine and various types of trawls (mid-water, pair and otter trawl), and industrial fisheries where herring is taken as a by-catch. The latter fisheries operate in the North Sea as well as in the Skagerrak and Kattegat [26]. Some inshore fisheries continue using drift nets. The two major components of the landings comprise North Sea autumn spawners and western Baltic spring spawners [26]. A small part is processed for fish meal and oil.

Landings: Landings increased after World War II to a peak of over 1 million tonnes in 1965 [27]. Subsequent over-fishing and recruitment failure caused a stock collapse and the fishery was closed during 1977-1981 to allow the stocks to recover. Another decline in the mid 1990s, led to the implementation of a recovery plan in 1996 (revised in 2004) and associated harvest control rules, which appears to have been effective [28]. Catches have been increasing in recent years (Fig. 4).

The stock is fished throughout the year, with peak catches between October and March. Landings of herring in the autumn are predominantly from off Orkney and Shetland, Buchan, off Peterhead, northwest of the Dogger Bank and from the coastal waters of eastern England. Landings in the spring are concentrated off the Lincolnshire and East Anglia coasts in the south-western North Sea. During the summer and early autumn, landings are greatest in the north-western North Sea, around Shetland and Orkney, and in the western central North Sea. The traditional Dutch fishery for ripening first-spawners ('maatjes') in westerly waters has been taken over by Danish and Norwegian fleets operating in more easterly areas, while in recent years a profitable fishery for herring roe has developed during the spawning season.

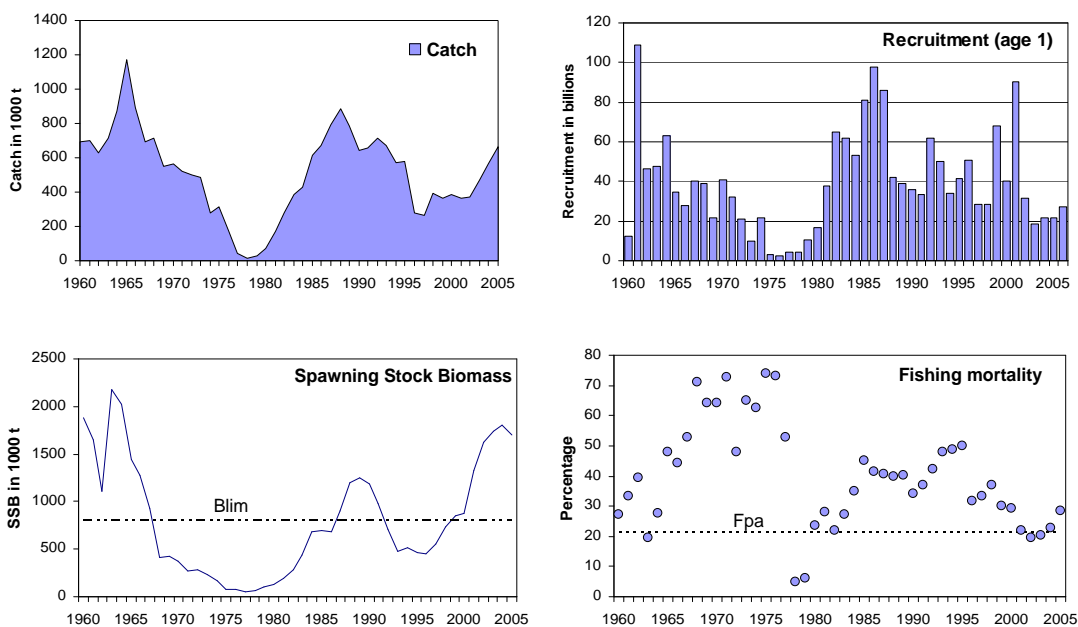


Figure 4. Time series of landings ('000 t), recruitment (billions of 1-year-olds), spawning stock biomass ('000 t) and fishing mortality (percentage per year of ages 2–6) of herring in the North Sea [30].



Herring

Clupea harengus
Family Clupeidae

Spawning Stock Biomass and fishing mortality: Following the implementation of the recovery plan in 1996 to reduce fishing mortality, and a series of years with high recruitment, the stock of autumn spawners recovered to a sustainable level. A series of four weak year classes (2002-2005) will soon enter the spawning stock and the spawning stock is expected to decrease again in the next years [30].

Stock status: After the record low in the mid-1970s, the spawning stock biomass has recovered to above the precautionary level of 1.3 million tonnes and is now considered to have full reproduction capacity and is being harvested sustainably.

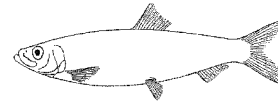
Protection and management: Herring boxes exist along the northwest Danish coast (1 July to 31 August; designed to protect juvenile herring from being caught in the industrial fishery), and along the North Yorkshire coast and Northumberland coast of England (15 August to 30 September; designed to protect vulnerable spawning grounds) [29]. The current management strategy is to maintain the stock within precautionary limits for spawning stock biomass and fishing mortality [27]. TACs are set on the basis of a harvest control rule agreed by the EC and Norway for herring in the Skagerrak, northern and central North Sea (Division IIIa, sub-area IV north of 53° 30'N) and for the southern North Sea and eastern Channel (Divisions IVc and VIId) separately.

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Herring

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