FAO Fisheries Synopsis No. 84
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FIRM/S84
SAST - Haddock - 1,48(04),010,01

SYNOPSIS OF BIOLOGICAL DATA ON HADDOCK

Melanogrammus aeglefinus (Linnaeus) 1758

Prepared by

R.W. Blacker

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 1971

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et

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MFS Provisional editions of " FAO Manuals in Fisheries Science."

Des catégories spéciales de documents techniques sont identifiées à l'aide des symboles suivants:

RE Listes indexées d'experts et institutions tirées des registres tenus à jour par la Division des ressources halieutiques.

CB Listes de périodiques, des sections spéciales de la « Aquatic Sciences and Fisheries Abstracts (ASFA) », des bibliographies particulières et des articles sur les problèmes de documentation.

MFS Editions provisoires des « Manuels FAO de science halieutique ».

Grupos especiales de documentos técnicos se identifican por las siglas siguientes:

RE Listas índices de expertos y de instituciones tomadas de los registros que se llevan en la Dirección de Recursos Pesqueros.

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SYNOPSIS OF BIOLOGICAL DATA ON HADDOCK

Melanogrammus aeglefinus (Linnaeus) 1758

Prepared by

R.W. Blacker
Fisheries Laboratory
Lowestoft
England

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, December 1971

PREPARATION OF THIS SYNOPSIS

The present synopsis was prepared as a follow-up of the recommendation of ICES at its 54th Statutory Meeting (Copenhagen 1966) that FAO should extend its Species Synopses Series to cover some of the species of major commercial importance from Arctic and Sub-Arctic regions.

The details set out in this paper are based on data collected by the author in the course of his personal research work on the species and also, on information received from various sources, most of which are listed in the bibliography.

Distribution

FAO Department of Fisheries
FAO Regional Fisheries Officers
Regional Fisheries Councils and Commissions
Selector SM
Author

Bibliographic Reference

Blacker, R.W. (1971)
FAO Fish.Synop., (84):pag.var.
Synopsis of biological data on haddock
Melanogrammus aeglefinus (Linnaeus) 1758

Nomenclature, taxonomy, morphology, distribution, bionomics, life history, nutrition and growth, behaviour, population dynamics, exploitation, fishing gear, fishing areas, protection and management, ANE, ANW.

CONTENTS

* As no information was available to the author, these items have been omitted from the text.

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Melanogrammus aeglefinus (Linnaeus) 1758

1.12 Objective synonymy

Gadus aeglefinus L., 1758
Morhua aeglefinus Fleming, 1828
Morhua punctatuo Fleming 1828
Aeglefinus linnei Malmgren, 1877

1.2 Taxonomy

1.21 Affinities

– Suprageneric

Phylum Vertebrata
Subphylum Craniata
Superclass Gnathostomata
Series Pisces
Class Teleostomi
Subclass Actinopterygii
Order Gadiformes
Family Gadidae
Subfamily Gadinae

– Generic

Melanogrammus Gill, 1863.
Type *Gadus aeglefinus* L., 1758.

The generic description given by Svetovidov (1948) is:

"Dorsal and anal fins separated by interspaces. First anal fin short, beginning beneath the origin of the second dorsal fin or slightly behind it. Caudal fin slightly notched. Barbel on chin weakly developed, shorter than the diameter of the eye. Mouth small, rear end of lower jaw beneath the centre of the eye, upper jaw extending beyond the lower. Teeth in 1–2 rows on the dentary, in several rows on the premaxillary, a group of a few teeth at the apex of the vomer. Lateral line dark, in the shape of a shallow arch, to the beginning of the third dorsal fin, placed above the central axis of the body, extending without interruption to the end of the body. There are pores along the lateral line canal on the head: 13 pores in the preopercular-mandibular canal, 7 pores in the infraorbital canal, 1 pore in the supraorbital canal and 1 pore in the supraorbital commissure. Mucous cavity on the skull closed in front. Prootic with a notch in front on the sides of the skull. Crests over the foramen of the recurrent dorsal branch of the facial nerve scarcely developed. Supraorbital with a high crest. Bones of the pectoral girdle greatly thickened. The opercular process of the hyomandibular somewhat shorter than the lower process."

– Specific

Melanogrammus aeglefinus (Linnaeus) 1758 (Fig. 1)
Type *Gadus aeglefinus* L., 1758

I D 15–16, II D 19–21, III D 19–22, I A 23–24, II A 22–23, gill rakers 24–27, vertebrae 52–57. First dorsal fin high and sharp tipped. Jaw bones greatly shortened, length of the upper jaw 28.6–33.1, lower jaw 35.3–39.1 percent of head length. In percent of body length: anteanal distance 41.7–45.5, antedorsal distance 26.1–28.2, length of pectoral fin 14.1–16.6, length of pelvic fin 8.9–10.9, base of first dorsal fin 12.2–13.8, base of second dorsal fin 19.7–23.5, third 13.6–16.4, base of first anal fin 21.1–22.8, base of second anal 13.8–16.5, height of first dorsal fin 13.4–18.5, height of first anal fin 9.6–10.6, length of caudal peduncle 4.3–5.3, its depth 10.4–12.4, head length 24.6–25.7. In percent of head length: length of snout 34.5–38.9, lateral diameter of eye 20.0–28.2, width of forehead 17.9–22.8. Upper part of body and head dark grey with violet shading, sides lighter, belly and lower part of head milky white. Lateral line black. A large black spot under the lateral line in the region of the pectoral fins on each side. Pectoral and dorsal fins same colour as the dorsum. Maximum length about 1 m (After Svetovidov, 1948)

Only one species.

1.22 Taxonomic status

Morpho-species

1.23 Subspecies

None

1.24 Standard common names, vernacular names (from ICES, 1966)

English	Haddock
Danish	Kuller
Dutch	Schelvis
Faroese	Hýsa
Finnish	Kolja
French	Eglefin
German	Schellfisch
Icelandic	Ýsa
Norwegian	Hyse, Kolje
Polish	Plamiak, łupacz
Portuguese	Arinca
Spanish	Eglefino
Swedish	Kolja
Russian	Piksha

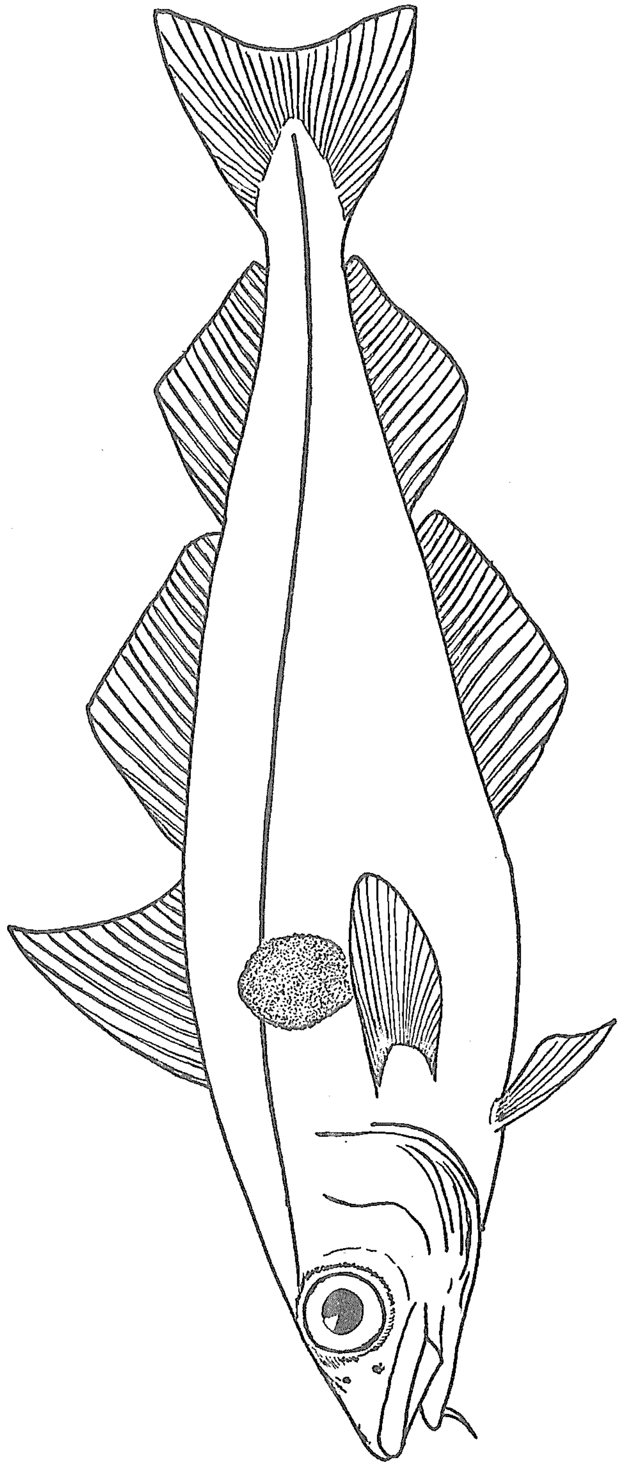

Fig. 1 Haddock

1.3 Morphology

1.31 External morphology (see 1.21 and Figure 1).

1.32 Cytomorphology

Chromosome number: 2n = 46, 6 or 7 pairs metacentric, 16 or 17 pairs telocentric (Purdom, personal communication).

1.33 Protein specificity

Individual differences in transferrin types in haddock have been located, but as yet definite transferring type determinations have not been possible (Møller and Naevdal, 1967). Intraspecific variations in haemoglobin components have been detected in haddock from the Norwegian coast, but the full significance of these variations has not been determined (Møller and Naevdal, 1969).

2 DISTRIBUTION

2.1 Total area (Fig. 2)

The haddock is a continental shelf species of the north-east Atlantic (ANE) and north-west Atlantic (ANW).

In the north-east Atlantic it ranges from the northern part of the Bay of Biscay to the north of west Spitsbergen, including the Irish Sea, the North Sea, the western part of the Baltic and the banks off the continental shelf - Porcupine Bank, "Farm" area, Rockall Bank (Blacker, 1962 and 1963), Lousy Bank (Pawsey and Davis, 1924), Faroe Bank and Faroe Plateau. In the Barents Sea it occurs as far east as Goose Bank and the shores of southern Novaya Zemlya; some dead ones have been found in the Kara Sea in recent years (Svetovidov, 1948). At Spitsbergen, juvenile haddock have been taken as far north as 80°30'N (Berger, Popov and Cheremisina, 1962). In the southern part of its range the haddock at present makes only sporadic occurrences in the southern North Sea and the English Channel and it is doubtful if it occurs in northern Biscay nowadays.

The haddock is abundant at Iceland except in the colder areas of the north and north-east (Saemundsson, 1949), but at Greenland it is comparatively rare on the west side, and very rare on the east coast (Konstantinov, 1968).

In the north-west Atlantic the haddock ranges from Cape May (38°N) to the Strait of Belle Isle (52°N). It is most abundant from Cape Cod to the southern part of Grand Bank. Haddock are much less abundant in the Gulf of St. Lawrence, off the west coast of Newfoundland (Bigelow and Schroeder, 1953) and off the east coast of Newfoundland (Leim and Scott, 1966).

2.2 Differential distribution

2.21 Spawn, larvae and juveniles

- Spawning areas and seasons (see Table I)

The eggs are pelagic, mainly from 0-20 m (Colton, 1965).

- Larvae

Larvae are pelagic and late stage larvae may perhaps be associated with jellyfish (e.g. *Cyanea*) (Svetovidov, 1948; Colton and Temple, 1961).

The larvae are usually most concentrated between 10 and 40 m depth (Colton, 1965).

- Juveniles

According to Svetovidov (1948) in the Barents Sea O-group juveniles are pelagic until autumn cooling starts; then they take to the bottom. In the following spring they become pelagic again and move inshore. In the next autumn they move offshore again and become wholly bottom-living. In their third year they start seasonal migrations, moving to the western Barents Sea when autumn cooling begins and back to the eastern Barents Sea during the feeding season. In these migrations, the largest fish move furthest east (Maslov, 1939).

Thompson (1929) gives the areas of distribution of North Sea haddock at successive ages from hatching.

In the north-west Atlantic juveniles seem to occur on the same grounds as the adult stock (Schuck, 1948; Colton, 1965).

2.22 Adults

Mainly bottom-living but known to be pelagic at times (see 3.5).

Seasonal migrations are undertaken between spawning and feeding grounds: from the shallower parts of the Barents Sea to the north-west and north Norway coast for spawning. At Iceland spawning is concentrated off the south-west and west coasts and feeding grounds are off these north-west, north, south and south-east coasts.

In the north-west Atlantic migrations are not extensive. In the Gulf of Maine there is a movement into shallower water in spring and summer and again in autumn. These haddock withdraw from shallow water when the temperature rises above 10°C in summer and when it falls in winter (Bigelow and Schroeder, 1953; Colton, 1955; Needler, 1930; Schroeder, 1942; Vladykov, 1935).

In the North Sea, adults spawn in deep water in the northern North Sea and migrate to shallower water to the west and south for feeding. Haddock probably also spawn off the Scottish north-west coast, in the Butt of Lewis region (R. Jones, personal communication). Largest fish migrate furthest (Thompson, 1929). In years of high stock abundance movements are greater; for example, the very abundant 1962 year-class spread into the southern North Sea and the English Channel, where haddock do not usually occur.

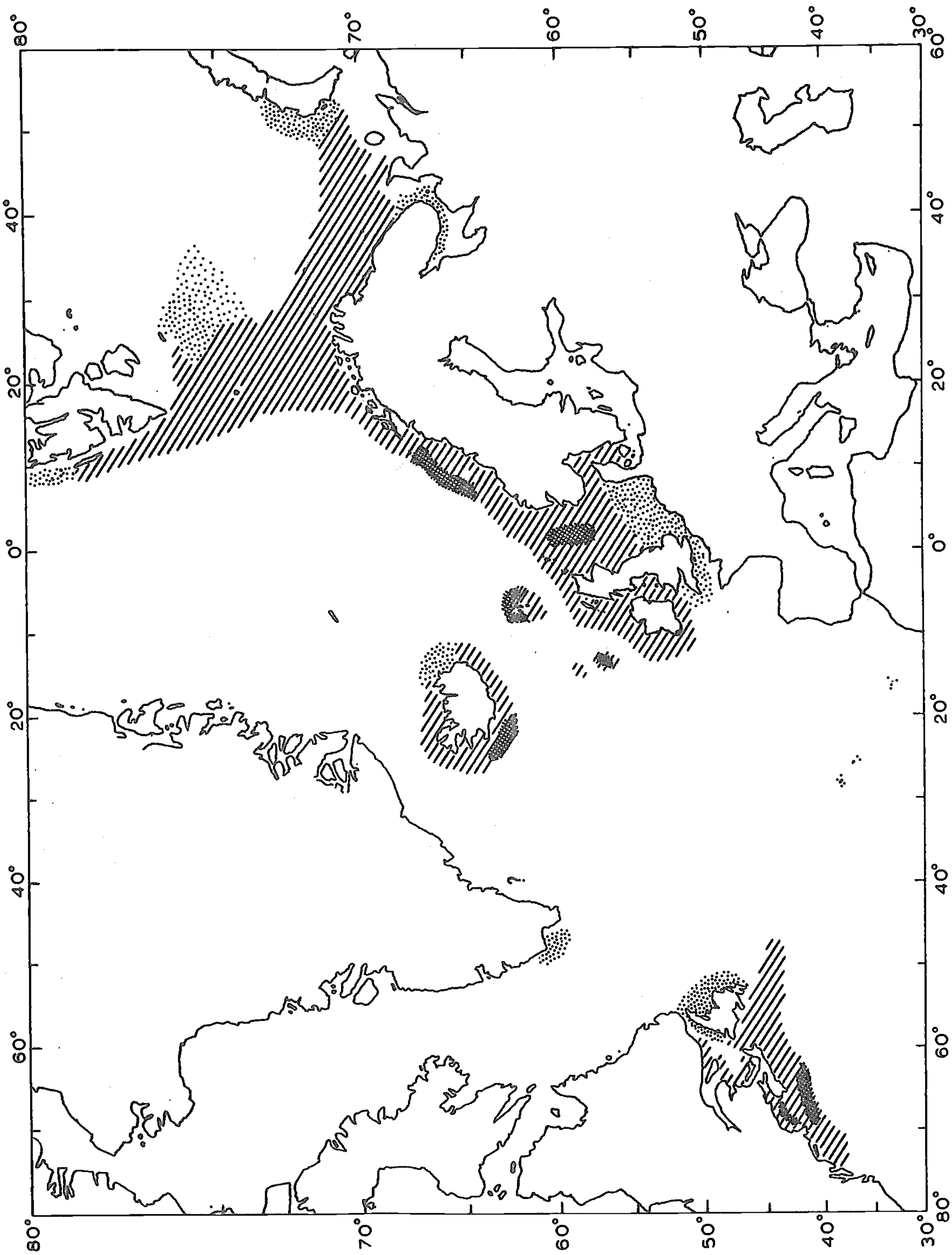

Fig. 2 The distribution of haddock

TABLE I

Haddock spawning areas and seasons

Stock	Spawning area(s)	Spawning season	Peak season	Authority
1. North Sea and N Scotland	Northern North Sea and shelf W of Orkney and Shetland	March to mid-May	Late March to first half April	Saville (1959, 1965)
2. Rockall	Rockall Bank	?	May	Schmidt (1909) MAFF (unpublished data)
3. Faroe	NW, N and NE of Faroe	Late February to mid-May	Early April	Saville (1956)
4. Barents Sea	NW Norway, 63–68°N*	Late January to June	March to April	Dragesund (1970)
5. Iceland	SW and W Iceland	May to June		Saemundsson (1949)
6. NW Atlantic	(a) Georges Bank, Browns Bank, coastal water of Gulf of Maine	February to May	March to April	Bigelow and Schroeder (1953); Walford (1938); Colton and Temple (1961)
	(b) Scotian Banks		April	Leim and Scott (1966)
	(c) Grand Bank	May to June	June	Hodder (1965)

* According to Svetovidov (1948) haddock also spawn off the Finmark and W. Murman coasts, but there appears to be no recent evidence of this.

2.3 Determinants of distribution changes

Like the cod (Gadus morhua) the haddock is closely associated with the Gulf Stream and its branches where mixing with Arctic currents and other waters takes place in shallow depths.

Generally haddock occur in water temperatures between 1 and 10°C.

In the north-west Atlantic the salinity range of haddock is from 31.5 to 34.5‰ (Bigelow and Schroeder, 1953), but in the Barents Sea the salinity range is higher, 34-35‰ (Svetovidov, 1948)

The usual depth range is 10–450 m. Svetovidov (1948) gives the depth range as 10–1 000 m, but the latter depth probably refers to a record of Goode and Bean (1895) which is open to doubt.

Sonina (1969) describes changes in the distribution and migrations of haddock in the Barents Sea from 1927 to 1965. She attributes these to variations in the hydrographic conditions and a change of feeding habits.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

The sexes are separate.

Hermaphroditism may occur as in other gadoids, but from the absence of published records it must be very rare.

There are no external sexual characters.

3.12 Maturity

The ages and sizes at first maturity for various populations are given in Table II.

3.13 Mating

Probably polygamous and promiscuous (see also 3.16).

3.14 Fertilization

External.

3.15 Gonads

- Relation of gonad size and egg number to body length and weight and to age

The relation of fecundity to length is shown in Figure 3. The low values of Earll (1880) compared with those of Raitt (1933) and Hodder (1965) suggest that some eggs may have been released before his samples were obtained, although Earll was aware that spawning of individuals was spread over a long period.

The relation of fecundity to age is given in Table III.

TABLE II

Haddock size and age at first maturity

Stock	Age (years)	Size (cm)	Authority
North Sea	3–5	23–29	Thompson (1924, 1929)
Rockall	? 4	about 30	Personal observation
Faroe	2–	27–42	Thompson (1924)
Barents Sea	4–7	37–73	Personal observation; Sonina (1969)
Norwegian coastal	2–4	28–32	Personal observation
Iceland	4–5	50–55	Saemundsson (1949); Thompson (1929a)
NW Atlantic	3–6	36–54	Thompson (1939); Bigelow and Schroeder (1953);
Georges Bank	2–3	30–50	Clark (1959)

TABLE III

Relation of fecundity to age (thousands of eggs)

Stock	Age (years)										Authority
	3	4	5	6	7	8	9	10	11	12	
North Sea*	31	100	159	224	278	–	–	–	–	–	Raitt (1933)
Grand Bank	–	48–154	195–298	198–298	514	481–550	496–514	742	805–1148	846	Hodder (1965)

* Ages adjusted to 1 January birthday

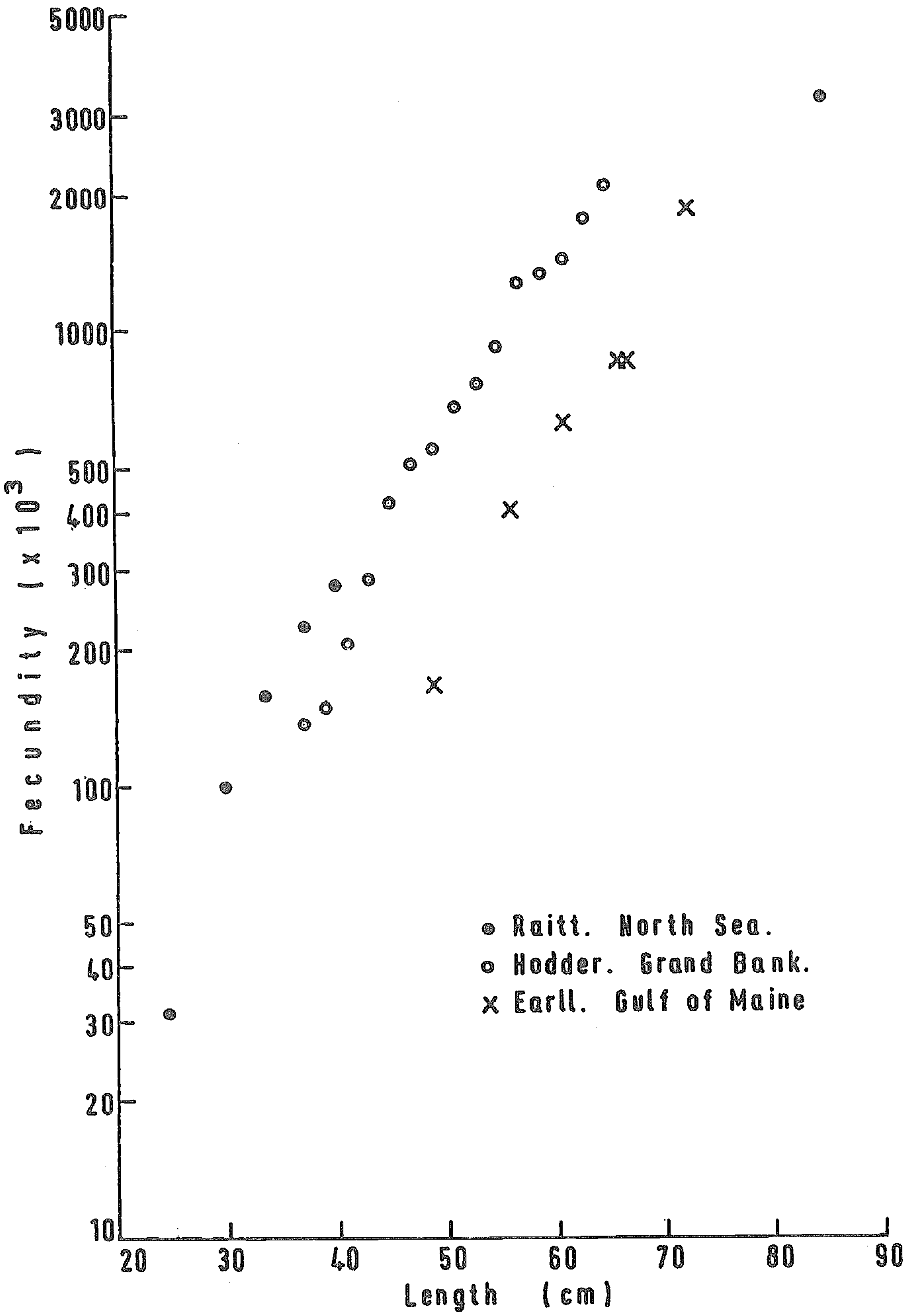

Fig. 3 The fecundity/length relationship for some haddock

- Coefficient of fecundity

For North Sea: $F = 0.2032 \times L^{3.84}$ (Raitt, 1933)

For Grand Bank: $F = 0.001391 \times L^{5.110}$ (Hodder, 1965)

- Number of eggs produced by an individual

- In a year

See above.

- In a lifetime

A haddock may survive to spawn in six or more successive years after reaching maturity, in which case the total egg production would be in excess of 3 million.

- Variation in fecundity with health or condition

No information.

- Correlation between the number of eggs produced and the nature of environment

Hodder (1965) discusses the possible effects of temperature on the fecundity of Grand Bank haddock.

3.16 Spawning

- Number of spawnings per year

Only one spawning per year, but observations of spawning in an aquarium show that the eggs are released at intervals over a period of about three weeks (Hawkins, Chapman and Symonds, 1967). Earll (1880) and Raitt (1933) had already suggested repetitive spawning.

- Spawning seasons

See Table I and 2.21.

- Spawning time of day

No particular time of day from aquarium observations (Hawkins, Chapman and Symonds, 1967).

- Sequence of spawning of individuals in a population

No information.

- Factors influencing spawning time

Closely related to temperature changes on Georges Bank (Colton, 1968).

- Relation of time of breeding to that of related species

Usually three weeks or so later than cod in the same area, with an overlap between late-spawning cod and early-spawning haddock (Saville, 1956; Walford, 1938; Marak and Colton, 1962).

- Location and type of spawning ground

For location see 2.21.

Type of ground: in the North-west Atlantic, spawning takes place over broken ground where sand, gravel, mud and rocks intermingle (Bigelow and Schroeder, 1953).

- Variations and causes of variations of spawning grounds

No information.

- Ratio and distribution of sexes on spawning grounds

No information (see 4.11).

- Nature of mating act

Courtship and mating have been observed in the aquarium (Hawkins, Chapman and Symonds, 1967). A male and female paired off and sperm and eggs were released with the two fish in close contact, belly to belly, swimming vertically upwards.

- Variation in mating behaviour

No information.

- Nesting habits

No nest produced.

- Reproductive isolation

None.

- Induction of spawning

No information.

3.17 Spawn

Eggs buoyant, transparent, without oil globule and with a narrow perivitelline space. Diameter 1.19-1.72 mm. In early stages indistinguishable from eggs of cod and witch (Glyptocephalus cynoglossus) (Bigelow and Schroeder, 1953; Walford, 1938).

3.2 Pre-adult phase

3.21 Embryonic phase

McIntosh and Masterman (1897) describe the development of haddock eggs and larvae, but no temperature details are given. According to them, gastrulation, the formation of the notochord and the appearance of the first pigment spots take place on the fifth day; the blastopore closes on the eleventh day; embryonic fin rays and eye pigment appear on the seventeenth day; and hatching occurs after 20 days.

The rate of development varies with temperature. The rates given by different observers are shown in Table IV. The figures given by Dannevig (1895) and Walford (1938) agree closely, but those of Bigelow and Schroeder (1953) differ considerably from those of the other authors.

3.22 Larvae phase

Post-larval and young stages are illustrated in Figure 4.

Newly-hatched larvae are 3.5-4.1 mm long (McIntosh and Masterman, 1897). The yolk-sac is absorbed in about ten days at 5°C when the larvae reache a size of 5.5 mm (Bigelow and Schroeder, 1953).

Haddock larvae are distinguished from those of cod, saithe (Pollachius virens), pollack (P. pollachius) and polar cod (Boreogadus saida) by the absence of medio-lateral pigmentation. They are distinguished from those of other gadoids without medio-lateral pigment by their pigmentation and the position of the anus. Schmidt (1905) gives keys for the identification of larvae of different sizes.

The black shoulder patch is readily seen in larvae of 45-50 mm.

- Effect of environment on rates of development and survival

The variation in survival of haddock broods in relation to wind strength and direction and currents has been studied by Carruthers, Lawford and Veley (1951), Carruthers, Lawford, Veley and Parrish (1951), Chase (1955), Rae, K.M. (1957), Saville (1959, 1965) and Walford (1938). Carruthers, Lawford, Veley and Parrish (1951) found a correlation between year-class strength of North Sea haddock and wind direction and strength, poor year-classes during the period 1920 to 1949 being associated with predominant south-west winds during the spawning season. Saville (1959, 1965) found no such correlation for the period 1952 to 1957, and Gulland (1965) pointed out the difficulties of attempting to correlate the survival of young stages of fish with environmental conditions.

3.23 Adolescent phase

Development of the basic adult colouration is complete at a size of 45-50 mm. At this stage the juveniles are still pelagic.

See 2.21 for distribution of juvenile stages.

- Rates and periods of development and survival and factors affecting these

The growth rates of various populations are shown in Figure 5. The adolescent phase may last from two years (Faroe and North Sea) to seven years (Barents Sea) (see Table II).

0-group, 1-group and occasionally larger haddock are preyed upon by cod, saithe, whiting and other predatory fish (Bigelow and Schroeder, 1953; observations from MAFF routine research vessel samples). See also 3.34.

TABLE IV

Hatching time (days) of haddock eggs at various temperatures (°C)

Authority	3°	4°	5°	6°	8°	10°	12°	14°
Dannevig (1895)	23	20½	17¾	15½	13	10¾	9⅔	8¾
Walford (1938)		21	18½	16¾	13½	10¾		
Bigelow and Schroeder (1953)	15		13					

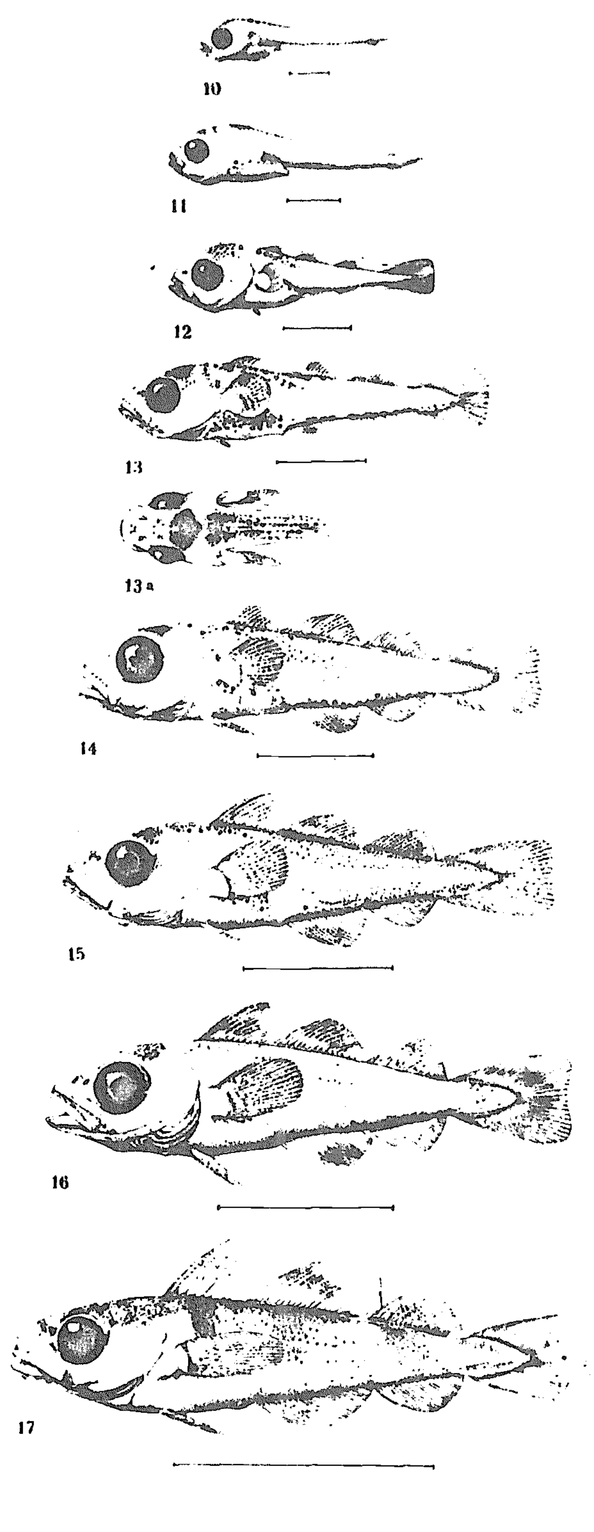

Fig. 4 Post-larval and young stages of haddock (from Schmidt, 1905)

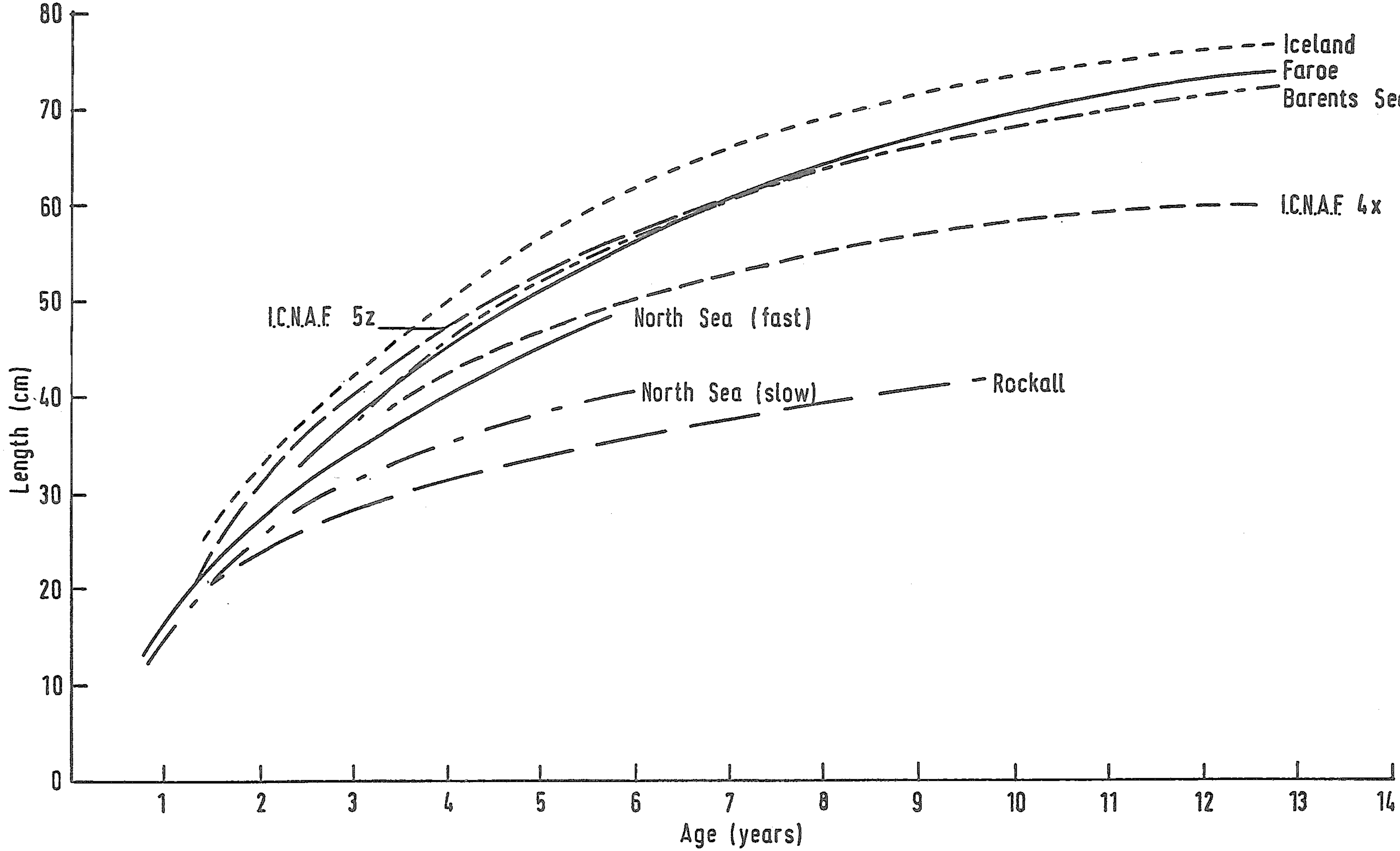

Fig. 5 Growth curves for various haddock stocks

<u>Data sources:</u>

North Sea
Jones and Jermyn, 1968;

Rockall
Blacker, unpublished;

Faroe
Jones, 1962;

Barents Sea, Iceland
MAFF market sampling data for 1969, unpublished;

Browns Bank etc. (ICNAF 4X)
Hennemuth, Grosslein and McCracken, 1964;

Georges Bank (ICNAF 5Z)
Jensen and Wise, 1962.

- Effects of environment, sub-populations, density, on rates of development and survival

Growth rates of different populations vary (Fig. 5) and there are also variations within populations (Thompson, 1929; Jones, 1962). These may be environmental effects. See also 3.43.

- Differences from adults in diet, feeding methods, etc.

Basically there is no difference between the diet and feeding methods of adolescent and adult haddock as both feed mainly on benthos (see 3.42), but the smaller adolescents (0- and 1-group) feed on smaller species and specimens than the large adults.

3.3 Adult phase

3.31 Longevity

- Average life expectancy

Varies with different populations.

- Maximum age

22 years in the Barents Sea (personal observation).

14 years in the north-west Atlantic (Bigelow and Schroeder, 1953).

16 years at Iceland (from routine otolith samples, Fisheries Laboratory, Lowestoft).

11 years in the North Sea (Thompson, 1923).

3.32 Hardiness

Temperature range 1-12°C, salinity range 31.5-34.5 °/oo in the North-west Atlantic, up to 35.2 °/oo in the North-east Atlantic (Bigelow and Schroeder, 1953).

Haddock rarely occur in water colder than 1°C and colder temperatures cause large mortalities (Templeman, 1965). In aquaria haddock survived at 14-20°C for several months (Bigelow and Schroeder, 1953), but such high temperatures are not normal in areas where haddock occur.

3.33 Competitors

There is, perhaps, a certain amount of competition between cod and haddock (Brown and Cheng, 1946; Kohler and Fitzgerald, 1969; Petrova-Grinkevich, 1944). Petrova-Grinkevich found that competition between cod and haddock was greatest in spring and early summer in the western and central Barents Sea, when both fish were feeding on capelin or krill. Templeman (1965a) also recorded cod and haddock both feeding on spawning capelin on the South-east Shoal of the Grand Bank in July and August, but the haddock contained a greater percentage of capelin eggs than the cod. At Iceland both species sometimes feed on sandeels (Brown and Cheng, 1946) and this also occurs in the North-west Atlantic (Kohler and Fitzgerald, 1969). In all these instances the extent of competition is probably small because of the great abundance of the food organisms at the time when cod and haddock are both feeding on them.

3.34 Predators

Fish up to about 30 cm are eaten by cod, coalfish (Bigelow and Schroeder, 1953) and other carnivores. Larger fish are taken by seals (Rae, B.B., 1968), but man is the principal predator at this stage.

3.35 Parasites, diseases, injuries, and abnormalities

- Parasites and diseases

The following parasites of haddock are listed by Reichenbach-Klinke (1966).

Protozoa:

Myxosoma aeglefini	in cranial bones
Nosema branchiale	on gills
Myxobolus aeglefini	
Eimeria gadi	in swimbladder
Haemogregarina aeglefini	in blood
Leucocytozoon sp.	in blood

Platyhelminthes:

Diclidophora gadi	on gills
Bucephalopsis gracilescens	
Lepidapedon rachion	
Derotrema abyssorum	
Cryptocotyle lingua	metacercaria in the skin
Grillotia erinacea	larvae (adults in sharks and rays)
Parabothrium bulbiferum	
Abothrium gadi	
Bothriocephalus scorpii	

Nematoda:

Cucullanus cirratus	in gut
Contracaecum clavatum } *C. aduncum* }	in liver, gut, mesentaries, stomach and abdominal wall
Ascarophis morrhuae	in gut

Crustacea:

Bomolochus soleae	on gills
Caligus curtus	on skin and fins
Lernaeocera lusci	on gills
[L. branchialis][1]	on gills
Epibrachiella impudica	
Clavella dubia[2])	in mouth cavity and
C. brevicollis[2])	pharynx

To this list should be added: Tripartiella melanogrammi (Protozoa, Ciliata), found on the gills and fins by Stein (1961), and Ascarophis filiformis (Nematoda) and Pyramicephalus phocarum (Cestoda), recorded on haddock by Dogiel, Petrushevski and Polyanski (1958).

Few of these parasites have been studied in detail in the haddock, but the effects of Lernaeocera obtusa have been described by Kabata (1958). Infection is by a planktonic stage from the intermediate phase in the lemon sole (Microstomus). Adults reduce the weight of the host by 10 to 30 percent.

- Injuries and abnormalities

Xanthochroism occurs occasionally. Apart from the golden colour there appears to be no adverse effect on the fish.

3.4 Nutrition and growth

3.41 Feeding

- Time of day

Unknown.

- Place

Anywhere in the geographic range.

- Manner

The method of feeding has been observed in aquaria by Tseeb (1962, 1962b). Mouthfuls of the bottom are "sieved" in the mouth; some particles are passed out through the gills and others spat out of the mouth, thus reducing the intake of mineral particles.

- Frequency

Unknown.

- Variation of feeding habits with availability, season, etc.

Larvae and juveniles are planktonic feeders.

Adults feed less intensively in the spawning season. Usually they are benthic feeders, but at times haddock concentrate on spawning shoals of capelin, feeding on the fish and eggs (Templeman, 1965a), on herring spawning grounds (Bowman, 1923), and on sand-eels (Bigelow and Schroeder, 1953; Brown and Cheng, 1946). Sonina (1969) described long-term changes in the feeding habits of Barents Sea haddock: a change from feeding mainly on benthos in the east and south-east Barents Sea to feeding on euphausiids and capelin further west. Wigley (1956) described food habits on Georges Bank.

3.42 Food

- Types

Planktonic copepods during pelagic larval and juvenile stages (Olgilvie, 1938; Marak, 1960). Adults feed on a vast variety of benthic animals, especially Crustacea, Polychaetes, Lamellibranch molluscs, and Echinoderms (Ophiuroids and Echinoids in particular) (Brown and Cheng, 1946; Ritchie, 1937; Bigelow and Schroeder, 1953; Hertling, 1940; Kohler and Fitzgerald, 1969; Wigley, 1956).

Fish eaten by haddock include herring, capelin, sandeels, small mackerel, young eels and silver hake (Bigelow and Schroeder, 1953). Cannibalism has also been recorded (Wigley, 1956). Capelin spawn and herring spawn are also eaten (see 3.41).

- Volume of food eaten

Ritchie (1937) gives the volume of each of the constituent groups in the diet for various size groups of haddock from the North Sea. Thompson (1939) gives the following average volumes of food per 100 stomachs:

Nova Scotian Banks	590 cc (average haddock length 49 cm)
Newfoundland Banks	934 cc (average haddock length 56 cm)
North Sea	562 cc (average haddock length over 40 cm).

1/ Kabata (1958) separated L. obtusa, found only on haddock, from L. branchialis.

2/ Kabata (1963) reviewed the systematics of Clavella spp. in European waters and concluded that the many species described are all ecotypes of Clavella adunca.

3.43 Growth rate

- Relative and absolute growth patterns and rates

The growth rate varies according to area. Curves given in Figure 5 show that growth is rapid at Iceland, at Faroe, in the Barents Sea, and on Georges Bank and slow in the deep central North Sea and at Rockall. Growth of different populations in the North-west Atlantic is given by Hennemuth, Grosslein and McCracken (1964).

Andersson (1938) noted variations in the growth rate of different year-classes of haddock entering the Skagerrak.

Jones (1962) illustrated considerable annual variations in growth in the North Sea and compared the growth rates found by Thompson (1929) with more recent data (Table V). He also found considerable variations for Faroe haddock.

The following parameters of the Bertalanffy growth curve have been obtained:

	L_{∞}(cm)	K	
North Sea, slow growth area	48.3	0.28	Jones (1962)
North Sea, fast growth area	58.1	0.24	
Faroe	77.9	0.22	
ICNAF Subarea 3 (Grand Bank)	55-60	0.22	Beverton (1965)
ICNAF Subarea 4 (Scotian Shelf)	65-70	0.17-0.22	
ICNAF Subarea 5 (Georges Bank)	73	0.28	

- Condition factors

0.85-1.2 (R. Jones, personal communication; Tytler, 1969).

- Relation of growth to feeding, spawning, etc.

The slow growth rate in the deep central North Sea and at Rockall is probably due to poor feeding conditions.

Templeman and Squires (1956) showed that in the Grand Bank area the growth rates differ for males and females: males grow faster at first and mature earlier than females, but after maturity is reached their growth slows down. Jones (1962) also showed that female haddock were significantly larger than males of the same age in the North Sea and at Faroe in 1950 and 1951.

- Relation of growth to population density

The growth rate of the extremely abundant North Sea 1962 year-class was significantly lower than average in its earlier years (Jones and Jermyn, 1968). This may have been caused by the great density of this year-class.

Beverton and Holt (1957) and Raitt (1939) discussed the effects of haddock population density on growth rate for various areas in the North Sea and showed that the growth rate decreases with increasing population in some areas.

An inverse relationship between the growth rate and population density of the Barents Sea haddock population has been described by Sonina (1965, 1967, 1969). She also showed a relationship between growth rate and changes in feeding habits which have happened at the same time as the present decrease in population density in the Barents Sea.

TABLE V

The variation in growth rate of North Sea haddock, shown as mean lengths in centimetres. (After Jones, 1962)

Age (years)	Slow growth area			Fast growth area		
	1926-30	1936-39	1947-57	1926-30	1936-39	1947-57
0.75	14.5	15.3	15.7	17.0	16.9	17.8
1.75	21.4	23.5	23.9	24.2	25.8	27.1
2.75	25.9	29.4	29.4	29.4	31.9	34.6
3.75	29.3	34.0	33.9	33.7	36.4	40.7
4.75	32.9	37.8	37.3	37.6	39.9	45.8

- Food-growth relations

No information.

3.44 Metabolism

- Metabolic rates

The following values have been obtained by Tytler (1969, and personal communication).

- Standard

At $10^{\circ}C$, 59 ± 12 mg O_2/kg/hour; at $15^{\circ}C$, 150 ± 40 mg O_2/kg/hour.

- Active

Mean rate at a swimming speed of two body lengths per second: at $10^{\circ}C$, 268 ± 48 mg O_2/kg/hour; at $15^{\circ}C$, 289 ± 66 mg O_2/kg/hour.

- Endocrine systems and hormones

No information.

- Osmotic relations

No information.

3.5 Behaviour

3.51 Migrations and local movements

In most areas there are migrations to and from the spawning grounds. These may be extensive as in the Barents Sea (Saetersdal, 1956, Sonina, 1969) and at Iceland (Saemundsson, 1949; Thompson, 1929a), or short movements as in the North-west Atlantic (Bigelow and Schroeder, 1953; McCracken, 1965). See also 2.22.

Thompson (1929) described the differences in migration distances and direction with increasing age of haddock in the North Sea.

3.52 Schooling

- Extent of schooling habits

At spawning time and when feeding on concentrations of capelin or sandeels, haddock form dense schools, but Jones (1963) suggests that it is not normally a shoaling fish.

- Composition of stocks by size, age and sex

See 4.1

- Mixing of stocks

No evidence of mixing of stocks anywhere.

- Mixing between species

In the catches haddock often occur mixed with cod and coalfish, but there is no evidence to prove that they are not in separate shoals on the sea-bed.

- Patterns of schools

No information.

- Vertical movements

At times haddock are known to be pelagic and well off the sea bed (Trout, 1962; Woodhead, 1964, 1965). In the North Sea they have been caught and observed on television at 27-36 m where the depth was 128 m (Margetts, 1966).

- Size, density and behaviour of schools in relation to time of day, geographic location, season, oceanographical factors, physiological conditions

Diurnal vertical migrations take place in some areas (Woodhead, 1964, 1965; Colton, 1965). There are seasonal variations in catchability which are presumably due to changes in the behaviour of the fish, for example the change from "dark" to "daylight" fishing at Faroe in the spring.

- Aggregation (local concentration of several separate schools of some species or various species)

No information.

3.53 Responses to stimuli

- Environmental stimuli

- Mechanical (pressures, currents, sound)

Haddock produce sounds (Hawkins and Chapman, 1966) so presumably they can respond to sound stimuli.

- Chemical (olfactory, gustatory, salinity gradients)

No information.

- Thermal

No information.

- Optical

No information.

- Artificial stimuli

- Fishing gear components, model gear

Observations on the behaviour of haddock in the trawl have been made by Clark (1958) and Livingstone (1962). Haddock in the funnel of the cod-end swam mainly in the direction of the tow, making some side-to-side movements without touching the net at the sides. A small percentage swam straight into the cod-end. The majority of fish seen escaping from the cod-end went through the meshes easily, but some escaped only after a struggle.

Blaxter and Parrish (1966) described tank experiments with nets etc. and found that haddock responded to visual stimuli in daylight and some undetermined stimuli at low light levels.

Photographs taken with cameras mounted on the trawl show haddock swimming in the direction of the tow in front of the trawl as well as when they are under the netting (Blacker, unpublished).

- Electrical

Haddock respond in the same way as other fish, swimming toward the anode. In high currents paralysis or death occurs (McRae and French, 1965).

- Variations in reactions occurring with age, size, etc.

No information.

4 POPULATION

4.1 Structure

4.11 Sex ratio

Research vessel samples off the north-west Norway coast in 1963 gave a ratio of 58 percent males to 42 percent females; 95.4 percent of the fish were mature (MAFF, unpublished data).

According to Thompson (1924) in the overall population the numbers of each sex are about equal. He found variations in the sex ratios on different grounds with females predominating in the shallower inshore areas and males in the offshore grounds, but this is probably not generally true.

4.12 Age composition

The age of haddock may be determined from scales (Thompson, 1923; Jensen and Clark, 1958; Jensen and Wise, 1962) or otoliths (Saetersdal, 1953). Comparison of age determinations from scales and otoliths shows that up to the age of eight years or so agreement is good, but after this the scale ages become increasingly unreliable (Kohler and Clark, 1958; Saetersdal, 1958).

- Age composition of the population as a whole

There is little information for the populations as a whole because O- and I-group haddock are not sampled adequately by commercial gear, but data are available for the northern North Sea from Scottish research vessel surveys made annually since 1919 (except for the war years 1939-45) (Raitt, 1939; Jones, 1962), and for the north-west Atlantic from U.S., U.S.S.R., and Canadian research vessel surveys made since 1948 (Grosslein, 1969; Richter and Vinogradov, 1969; Lux, Richter and Grosslein, 1969). Results from surveys of the North Sea since 1947 and of the Barents Sea since 1958, have been published annually in Annales Biologiques (ICES, Copenhagen).

- Age distribution of the catch

Data for various areas are given in Table VI.

Additional information for some stocks is given each year in Annales Biologiques (ICES, Copenhagen) and the ICNAF Sampling Yearbooks. Age distributions of catches at Iceland from 1960 to 1966 are given in ICES, 1969.

- Variations with depth, etc.

No data.

- Age at first capture

This varies with the growth rate and the mesh size in use. In the North Sea, at Faroe and Georges Bank, haddock usually enter the fishery late in their second year; at Iceland the Barents Sea and off Nova Scotia the age of entry into the fishery is usually 3-4 years, but a few fish are caught when 2½-3 years old.

- Age at first maturity

See 3.12, Table II

- Maximum age

Twenty two years recorded from the Barents Sea (personal observation).

- Density of age-groups

Highly variable. In the North Sea the 1962 year-class was the most abundant ever recorded, whereas the 1956 year-class was the poorest recorded since 1916 (when records began). The results of annual surveys of the northern North Sea made by Scottish research vessels are published in Annales Biologiques.

The results of Russian surveys of the Barents Sea for O-, I-, II- and III- age-group haddock have been published annually since 1959 by Baranenkova (1961, 1962, 1963), Baranenkova and Baranova (1964), Nizovtsev and Baranova (1965) and Baranova (1966, 1967, 1968, 1968a). These surveys and the international O-group fish surveys of the Barents Sea (Dragesund, 1970; ICES, 1969b) show wide variations in the density and distribution of young haddock.

Surveys of the distribution and abundance of young fish have also been made at Faroe in some years (Joensen, 1956, 1957, 1959).

For the north-west Atlantic, data on the abundance and age and size distribution for the distribution for the following ICNAF subareas have been published:

Subareas	3O and 3N	(Grand Bank)	Templeman and Hodder (1965) Hodder (1966)
Subarea	3Ps	(St. Pierre Bank)	Templeman and Hodder (1965a)
Subarea	4W	(Emerald and Sable Island Banks)	McCracken (1968)
Subarea	4X	(Browns and Le Havre Banks)	Hennemuth, Grosslein and McCracken (1964)

TABLE VI

Age distribution (numbers per thousand fish) of haddock landings, total catch and effort for 1968

	Subarea	Age (years) 1	2	3	4	5	6	7	8	9	10	11	12 and older	Total catch (metric tons)	Total hours' fishing	
I	Barents Sea	-	0.2	14.2	390.6	376.4	38.6	120.0	50.0	6.3	1.2	0.8	1.7	9 554	84 762	1/
IIa	Norway coast	-	-	0.2	82.4	331.5	91.1	357.7	117.8	14.6	1.1	1.4	1.9	20 842	69 806	1/
Va	Iceland	-	73.5	352.6	401.1	82.8	42.3	19.3	20.9	2.4	2.1	2.6	1.1	9 628	212 427	1/
Vb	Faroe	1.6	522.3	232.9	80.6	60.2	57.9	31.2	9.4	3.2	0.9	-	-	5 578	53 617	2/
IV	Northern North Sea															
	1. Trawl	13.3	446.9	45.7	5.7	2.4	483.5	1.7	0.6	-	-	-	-	11 907	96 913	3/
	2. Seine	17.5	426.5	42.0	4.5	0.7	506.2	2.0	0.6	-	-	-	-	10 069	88 175	3/
	North Central North Sea															
	1. Trawl	18.1	531.7	226.9	-	-	222.7	-	-	-	-	-	-	904	10 615	3/
	2. Seine	10.9	702.2	56.6	5.6	0.3	223.5	0.7	0.1	-	-	-	-	12 864	133 598	3/
5Z	Georges Bank	-	121.4	28.6	71.7	566.2	137.8	27.2	17.9	29.2	-	-	-	25 445	9 096*	4/

* Days fished.

1/ English landings (MAFF, unpublished data)

2/ Scottish landings (Jones and Jermyn, 1969)

3/ Scottish landings (ICES, 1970)

4/ U.S. landings (ICNAF, 1970)

Subarea 5Z (Georges Bank) Colton (1955); Hennemuth (1969); Zukowski (1968)

The bounderies and subareas of ICES, ICNAF and NEAFC are shown in Figure 6.

0-group surveys of Georges Bank and the Gulf of Maine have been made in most years since 1948 (Colton, 1955; Grosslein, 1969, 1969a; Graham, 1969).

4.13 Size composition

- See Table VII for length composition of the catch for various areas.

Wells (1968) gives factors for the conversion of standard, fork and total lengths for haddock from St. Pierre Bank, ICNAF subarea 3Ps.

Additional information for north-east Atlantic stocks is published annually in ICES "Annales Biologiques", and for the north-west Atlantic in ICNAF Sampling Yearbooks.

- Size at first capture

Varies with the mesh regulations for each area.

- Size at first maturity

See 3.12.

- Maximum size

112 cm, 14.5 kg gutted weight, from Iceland (Thompson, 1929a).

- Density of size groups

Varies with the success of year-classes but the actual density of any particular size group is difficult to determine for any stock. See 4.2.

- Length and weight relationship

See Table VIII.

4.2 Abundance and density (of population)

4.21 Average abundance

In the north-east Arctic the estimated available population of Arcto-Norwegian haddock has averaged 823 million during the period 1949-1968. The highest figure was 1 859 million in 1952 when the outstanding 1950 year-class entered the fishery. The lowest was 388 million in 1968, after a succession of poor or moderate strength year-classes. These estimates do not include 0- and I-group fish (Garrod, personal communication).

According to Hennemuth (1969) the available population of Georges Bank haddock from 1935-1960 was 132 million, but in 1968 it was reduced to 47 million. The estimated average number of recruits (age 2) for the period 1935-1960 was 49 million. The numbers of 0- and I-group haddock would each be greater than this figure, so the total population for the period 1935-1960 probably averaged about 300 million.

4.22 Changes in abundance

See 3.22 for the effects of environmental conditions on brood strength, the variation of which is one of the main causes of fluctuations in abundance of haddock in all areas.

The effects of food competition and predation on the abundance of haddock are negligible compared with the effect of fishing. Hennemuth (1969) describes the decline in abundance of haddock on Georges Bank, Raitt (1939) and Parrish and Jones (1953) show the effect of fishing on North Sea haddock, and Gulland (1961) gives data for the Iceland stock. Recent changes in the Barents Sea and Iceland stocks have also been studied (ICES, 1969, 1969a).

4.23 Average density

- Annual mean density

See 4.24.

4.24' Changes in density

- Landings per unit of fishing effort

For the period 1917-1968, landings from Georges Bank (ICNAF subarea 5Z) varied from the peak of 22.6 metric tons per day's fishing in 1927 to 2.9 metric tons per day's fishing in 1968 (Hennemuth, 1969).

TABLE VII

Length distribution of English haddock landings for 1968 (MAFF, unpublished). Number of fish per 100 hours' fishing

Subarea		Length-group (cm)													Total
		30–4	35–9	40–4	45–9	50–4	55–9	60–4	65–9	70–4	75–9	80–4	85–9	90–4	
I	Barents Sea	6	126	734	1 938	2 539	1 928	1 093	300	63	19	11	3	0	8 760
IIa	Norway coast	2	67	446	1 640	5 046	7 048	4 040	942	219	71	41	4	1	19 567
Va	Iceland	58	209	665	1 073	857	419	256	132	77	27	8	2	0	3 783

TABLE VIII

Length and weight relationship of haddock from various areas, shown as the weight (g) of fish of lengths 20–80 cm

Area	Authority	Length (cm)												
		20	25	30	35	40	45	50	55	60	65	70	75	80
Gulf of Maine	Earll (1880)	–	–	–	–	–	–	1 077 (49 cm)	1 815 (56 cm)	2 145 (61 cm)	2 950 (66 cm)	4 335 (72 cm)	–	–
North Sea	Russell (1914)	67	134	242	418	629	902	1 220	1 650	2 200	–	–	–	–
North Sea	Raitt (1933)	72	138	238	388	586	843	1 169	1 570	–	–	–	–	–
NW Atlantic	Schuck (1947), Clark and Dietsch (1959)	–	198	339	508	763	1 073	1 440	1 892	2 400	2 965	3 700	4 490	–
North Sea	MAFF and DAFS (1969)	–	–	253	–	619	–	1 266	–	2 194	–	3 430	–	5 120

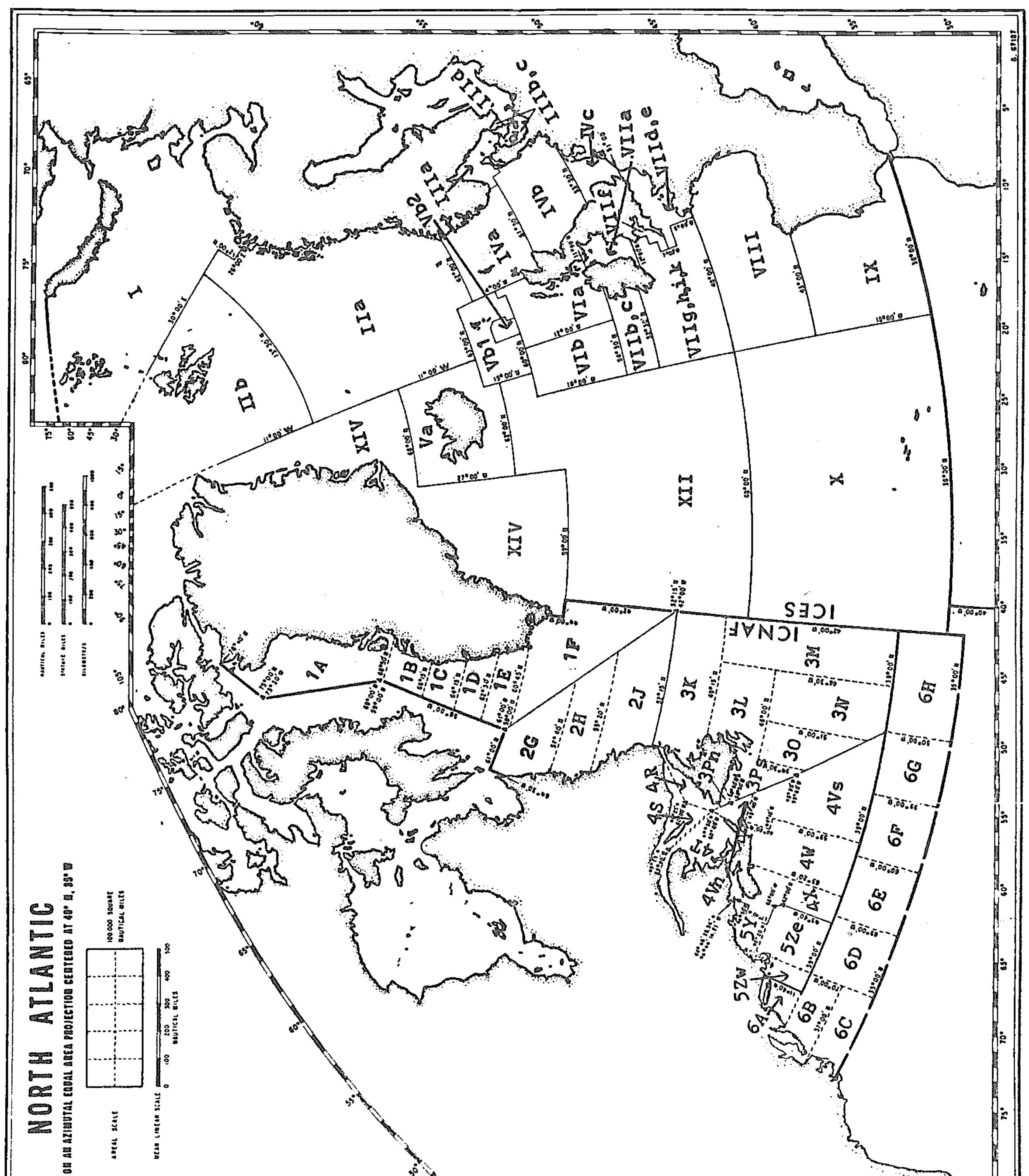

Fig. 6 Areas and Subareas of ICES, ICNAF and NEAFC
(from ICNAF Statistical Bulletin)

In the Barents Sea (ICES subarea I) the catch per unit effort for English trawlers during the period 1946-1967 varied from 170 to 970 tons per million ton-hours. For the Norway coast fishery (subarea IIa) the figures for the same period were 180 to 7 900 tons per million ton-hours. The peak figures were for 1946 when fishing was resumed after the 1939-45 war. For the period 1950-1967 the highest catch-rates were 420 tons per million ton-hours in the Barents Sea and 1 100 tons per million ton-hours off the Norway coast (ICES, 1969a).

At Iceland (subarea Va) English trawler catches declined from 757 tons per million ton-hours in 1946 to 74 tons per million ton-hours in 1966 (ICES, 1969).

Haddock catch-rates in the northern North Sea during the period 1947-1967 varied from about 3.81 tons per 100 hours' fishing to a peak of 14.07 tons per 100 hours in 1966. These are the catching rates of Aberdeen trawlers fishing the most important distributional area of the haddock in the North Sea. Catch-rates in the middle North Sea are very much lower.

At Faroe the British catch per unit effort since 1947 has varied from 780 tons per million ton-hours (1947) to 250 tons per million ton-hours (1961) (B.W. Jones, personal communication).

- Variations with depth

Haddock undertake seasonal migrations in most areas, usually from deep water in winter to shallow feeding grounds in summer (McCracken, 1965; Templeman and Hodder, 1965b; Schuck, 1952), but there may be local variations in the pattern of movement, as in the Gulf of Maine (see 2.22).

- Seasonal variations in available stock

Trout (1962) described the variations in catches associated with the seasonal migration patterns.

In the northern North Sea and in other areas the available stock increases toward the end of the year and the end of the growth season, when the recruit year-class usually reaches saleable size (see 3.43).

Schuck (1949) describes seasonal changes in relation to fishing in New England waters.

4.3 Natality and recruitment

4.31 Reproduction rates

- Annual egg production

From eggs and larvae surveys at Faroe, Saville (1956) estimated egg production as 58×10^{11} in 1950, 70×10^{11} in 1951, 67×10^{11} in 1952 and 49×10^{11} in 1953.

Walford (1938) estimated the number of eggs produced by the spawning stock on Georges Bank in 1932 as 80×10^{11}.

Beverton and Holt (1957) estimated the mean annual egg production for North Sea haddock as 37.5×10^{12} for the period 1922-1937, the range being from 7.9×10^{12} to 65.5×10^{12}.

- Survival rates

Saville (1956) found no clear relationship between the number of eggs produced and the number of surviving larvae at Faroe. Beverton and Holt (1957) also showed that there is no direct relation between the number of eggs produced and the subsequent annual recruitment to the stock. Herrington (1944) stated that large spawning stocks usually result in poor year-classes, because the survival of larvae from large broods is reduced by competition for food.

- Forecasting of potential yields

Indices of year-class strength have been obtained from surveys of 0-group fish in the north-east Arctic and in the north-west Atlantic (see 4.12 - Density of age-groups). Forecasts of yield have been based on these in recent years for New England waters (Graham, 1967).

4.32 Factors affecting reproduction

- Density dependent factors

Sonina (1965, 1967) and others (see 3.43) have shown that growth of haddock may be density-dependent. As fecundity is related to the size of the fish, the potential reproduction rate is obviously affected by any factor which reduces the growth of the fish.

Predation is no doubt a cause of larval mortality; the extent is unknown.

- Physical factors

Failure of year-classes in some areas has been attributed to water movements caused by wind carrying eggs and larvae into unfavourable areas (see 3.22).

Rollefsen (1930) showed that rough seas may be directly responsible for the damaging and death of eggs of cod. Presumably haddock eggs would be susceptible in the same way.

4.33 Recruitment

- Mean recruitment to the fishable stock

For the North Sea the mean annual recruitment for the period 1922-1937 was calculated as 849.5×10^6 (Beverton and Holt, 1957).

Hennemuth (1969) calculated the mean annual recruitment of 2-year-old fish on Georges Bank as 49×10^6 for the period 1935-1963.

- Factors determining recruitment

The age at which haddock attain marketable size is probably the main factor in determining recruitment to the fishery (see 4.12).

- Seasonal pattern of recruitment

In the North Sea recruits usually enter the fishery in the autumn and winter of their second year (age 1½ years), but before that large quantities of the pre-recruitment stage of abundant year-classes may be caught and rejected. This is also true of Georges Bank haddock (Bigelow and Schroeder, 1953; Graham, 1952) and probably applies to other stocks as well.

- Variation in annual recruitment

For the North Sea during the period 1922-1937 the calculated numbers of annual recruits varied from 39×10^6 to $2\ 807 \times 10^6$ (Beverton and Holt, 1957).

Estimated annual recruitment of 2-year-old haddock on Georges Bank varied from 1×10^6 to 502×10^{-6} for the 1956-68 year-classes. The decline in recruitment has been most marked since 1965. The estimated recruitment as 2-year-olds from the 1965-68 year-classes is: 1965, 2×10^6; 1966, 16×10^6; 1967, 1×10^6; 1968, 16×10^6. This is to be compared with the mean annual recruitment of 49×10^6 for the period 1935-63 (Hennemuth, 1969).

Estimates of total numbers of recruits are not available for other areas or periods, but indications of the variation in year-class strength can be obtained from a number of sources (see 4.12).

- Relation of recruitment to stock size and reproductive rate

See 4.31.

4.4 Mortality and morbidity

4.41 Mortality rates

- Annual mean mortality rates

For all areas the annual mortality rate lies between 40 and 75 percent (see Table IX for authorities).

- Instantaneous mortality coefficients

See Table IX.

- Variations in mortality

Most of the authorities quoted in Table IX show the year-to-year variations in mortality coefficients, and the variation of mortality rate with age.

McCraken (1968) also shows seasonal changes in the mortality rate of haddock of the central Scotian Shelf.

Jones (1966) gives a range of total mortality coefficients in the North Sea, from 0.8 to 1.0 in the northernmost part to 1.5 to 1.6 in the heavily fished area off the Scottish east coast.

- Density dependence of natural mortality

No information.

4.42 Factors causing or affecting mortality

- Predators

There are no data on the extent of mortality caused by predation, but larvae and fish up to 30 cm long are eaten by a variety of predators (see 3.34).

- Food of larvae and post-larvae and its availability

Food availability may be one of the causes of the variation in year-class strength (Herrington, 1944; Saville, 1956) (see 4.31).

- Physical factors

See 4.32.

TABLE IX

Estimates of haddock mortality coefficients (M, F and Z) for various areas

Area		Mortality coefficient: Natural mortality (M)	Fishing mortality (F)	Total mortality (Z)	Authority
1. North Sea	1922–1939	0.20	1.00	1.20	Beverton and Holt (1957)
	1947–1950	–	–	1.02	Parrish and Jones (1953)
	1947–1965	–	–	1.00	Jones (1966)
	1958–1965	–	–	1.20	Jones (1966)
2. Faroe	1926–1950 (excluding 1941–46)	0.15	0.59–1.41	0.74–1.56	Parrish and Jones (1953)
	1941–1946	0.18	0.21–0.45	0.39–0.63	Parrish and Jones (1953)
	1951–1968	–	–	0.32–1.28	Jones, B.W. (personal communication)
3. Iceland	1960–1966	0.15	0.04–1.02*	0.19–1.17*	ICES (1969)
		0.30	0.03–0.98*	0.33–1.28*	ICES (1969)
4. Arcto-Norwegian stock	1956–1963	0.20	0.65**	0.85**	ICES (1969a)
	1964–1965	0.20	0.80	1.00	ICES (1969a)
5. Georges Bank (5Z)	1935–1963	0.20	0.50	0.70	Hennemuth (1969)
	1965–1966	0.20	0.80	1.00	Hennemuth (1969)
6. Scotian Shelf (4W, 4X)	1948–1965	–	–	0.60–0.73	Hennemuth, Grosslein and McCracken (1964); McCracken (1968)
7. Grand Bank (3)	1955–1964	–	–	0.75–1.00	Hodder (1966)

* For age-groups 2–9

** For age-groups 6–9

- Direct effects of fishing

Fishing is the main cause of mortality (see Table IX).

- Indirect effects of fishing

No information.

4.43 Factors affecting morbidity

- Parasites and diseases

See 3.35.

4.44 Relation of morbidity to mortality rates

No information.

4.5 Dynamics of population (as a whole)

Because the haddock is one of the most important demersal species in the North Atlantic the dynamics of all the major stocks have been studied in recent years. Beverton and Holt (1957) used pre-war data on the North Sea haddock to demonstrate methods of population assessment. Parrish and Jones (1953) describe the methods they applied to the North Sea stock (1946-50) and to the Faroe stock (1914-50).

Recent assessments of the Arcto-Norwegian stock (ICES, 1968, 1969a), of the Iceland stock (ICES, 1969), and of the Georges Bank stock (Hennemuth, 1969) have used the method of virtual population analysis described by Gulland in ICES (1965). An earlier assessment of the Iceland stock, showing the effect of changes in mesh size and fishing effort, was made by Gulland (1961).

The method of virtual population analysis reduces the variance of mortality estimates compared with those estimates obtained from the ratio of the catches per unit effort of the same year-class in successive years, because it is based on the numbers of fish of each year-class and furthermore it does not assume that the fishing mortality is constant with age.

4.6 The population in the community and the ecosystem

- Physical features of the biotope of the community

The haddock is normally a bottom-living fish at moderate depths in areas where the predominant hydrographic feature is the mixing of Atlantic water with another water mass, e.g. Arctic water in the Barents Sea.

- Species composition of the community

A wide variety of other fishes are caught with haddock, but the relative sizes of their populations are unknown.

- Interrelations of the population of the species in the community and ecosystem

The haddock is mainly a benthos feeder, but sometimes feeds on pelagic fish or plankton in midwater (see 3.41). Adult fish are the final link in the marine chain:

Diatoms → planktonic herbivores → planktonic carnivores → benthic detritus feeders → haddock

planktonic carnivores → fish → haddock

Juvenile stages are often the prey of carnivorous fishes such as cod.

- Type of fluctuations (cyclic and non-cyclic)

There are no data which suggest cyclic fluctuations of haddock populations, but there are great variations in population density, the reasons for which are not fully understood (see 4.22 and 4.24).

- Changes in environmental factors and their effect on the population

See 2.3, 3.22 and 4.32.

5 EXPLOITATION

5.1 Fishing equipment

5.11 Gears

- Present gear

Haddock are caught by a wide variety of gears; the most important is probably the otter trawl, but seine nets, lines and traps are also used, and midwater trawls take haddock on occasion.

- Changes in types of gear during the development of the fishery

Changes reflect the growth of otter trawling in the twentieth century.

- Use of echo sounding or fish detectors

Haddock give good echoes, but these are indistinguishable from those of cod and many other species with the gear and techniques at present available.

5.12 Boats

- Type

Otter trawlers, seine-netters, small and large lineboats are used, depending on the geographic area of the fishing grounds.

- Size, power

All sizes from rowing boats to the largest factory trawlers.

5.2 Fishing areas

5.21 General geographic distribution

Fished throughout its geographic distribution (see 2.1 and 2.2) apart from the extreme limits of larval distribution.

5.22 Geographic ranges

- Distance from coast

Rarely caught close to coast (see 5.23) except in deep fjords as at Faroe, and in some lochs on the Scottish west coast.

- Areas of greatest abundance

ANE, Atlantic NE: Barents Sea, Norwegian Sea, North Sea and off Iceland.

ANW, Atlantic NW: Georges Bank and Browns Bank.

- Differential abundance associated with hydrographic features

Atlantic subarctic regions: 5.1.2. Barents Sea and North Atlantic intermediate boreal regions; 5.2.1 Newfoundland waters; 5.2.2 Irminger Gyral; 5.2.3 Norwegian Sea and Faroes; 5.2.4 North Sea and Irish Sea. Limited to areas influenced by the Gulf Stream.

5.23 Depth ranges

- Bathymetric contour

Rare waters shallower than 10-18 m (Bigelow and Schroeder, 1953) and most fisheries take place in less than 100-360 m.

- Variations of density with depth

No information.

5.24 Conditions of the grounds

Probably feeding grounds are mainly sand or sandy mud with a rich fauna of molluscs and echinoderms (Blacker, unpublished photographs).

5.3 Fishing seasons

5.31 General pattern of seasons

Fished at all seasons of the year.

5.4 Fishing operations and results

5.41 Effort and intensity

In most areas haddock and cod occur together and it is impossible to give separate estimates of effort for each species.

- Units of effort

Catch per 100 hours, catch per 10 hours, catch per day's fishing, catch per day's absence.

- Landings per unit of fishing effort

Georges Bank 2.9-22.6 metric tons per day's fishing	Hennemuth (1969)
Barents Sea/Norway Coast Barents Sea: 11.1 tons Norway Coast: 29.4 tons - per 100 hours' fishing, English landings, 1968	MAFF and DAFS (1969)

Iceland	
4.5 tons per 100 hours' fishing, English landings	MAFF and DAFS (1969)
Northern North Sea	
9.6 tons per 100 hours' fishing, Scottish trawlers	MAFF and DAFS (1969)
6.0 tons per 100 hours' fishing, Scottish seine-netters	MAFF and DAFS (1969)

– Fishing effort per unit area, and total fishing intensity

Where cod and haddock ranges overlap, separate estimates of effort for each species are unobtainable. Data on fishing effort for some areas and some countries are given in Table VI. Further data on total fishing effort are available from Bulletins Statistiques (ICES, Copenhagen) and ICNAF Statistical Bulletins. No figures are available for fishing effort per unit area.

– Causes of variation in fishing effort and intensity

Fishing effort in particular areas varies with season, weather and economic factors. For example, heavy fishing on Norway coast grounds may result in diversion of trawlers from Iceland and the North-west Atlantic. Poor yields in the Barents Sea in some years have resulted in increased effort by British and Soviet vessels in the North-west Atlantic.

Prolonged spells of bad weather and ice conditions may close some grounds such as those off North-west and North Iceland.

5.42 Selectivity

– Selective properties of gear

Selection factors for haddock:

Double-braided manila cod-end	3.0-4.1	Blacker (1967); Pope and Hall (1966); Bohl (1966); McCracken (1963); Clark (1963)
Double-braided polypropylene (ulstron)	3.2-3.4	Hylen (1967); Olsen (1966, 1967)
Double-braided polyamide (Kapron)	3.6 compared with 3.1 for manila	Treshev and Stepanov (1968)

Experiments with topside chafers show that the approved ICNAF chafer ($1\frac{1}{2}$ times the width of the cod-end), and chafers with meshes about twice the cod-end mesh, have little effect on selectivity (Blacker, 1967; Bohl, 1967; Hylen, 1967; Olsen, 1967).

– Changes in the mesh size and their effects

Gulland (1961) and ICES (1969) discuss the effects of increasing mesh sizes for the Iceland stock. The effects of mesh changes on the yield of the Arcto-Norwegian haddock have also been estimated (ICES, 1969a).

Graham (1952) and Beverton and Hodder (1962) estimate the effects of mesh changes in ICNAF subareas 3, 4 and 5.

– Other selection factors

In some areas and some seasons there may be considerable rejection of fish just above the legal minimum size, because of difficulty in selling them. This is particularly likely in the North Sea when a very abundant year-class first enters the fishery.

5.43 Catches

– Total annual yields from different fishing grounds

Annual yields from the major haddock fishing areas are given in Table X. Figure 7 illustrates the yield from the more important areas.

(Data from ICES Bulletin Statistique, ICNAF Statistical Bulletin.)

The total catch of haddock from all areas, in metric tons, live weight for some recent years was:

1962	1963	1964	FAO (1967, 1968)
549 000	513 000	589 000	
1965	1966	1967	
747 000	729 000	483 000	

– Maximum equilibrium yield

Parrish and Jones (1953) gave estimates of the maximum yield for North Sea and Faroe haddock for two levels of natural mortality. Assuming an instantaneous natural mortality coefficient (M) of 0.11, the maximum yields per recruit are 0.31 kg for the North Sea and 0.73 kg for Faroe. Assuming M = 0.22 the corresponding yields are 0.21 kg and 0.37 kg. These yields could be attained with an effort of about 75 percent of the 1950 level, when the minimum trawl mesh size was 70 mm. Increases in the minimum mesh size would give an increased yield without the same reduction in effort. Since then the minimum mesh sizes for these and other areas have been increased (see 6.12).

TABLE X

Haddock landings from the major fishing areas (1938–1968) in metric tons, round fresh

Subarea	1938	1945–6	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
North Sea (IVa, b, c)	71 482	156 759	93 777	71 068	55 231	56 429	56 478	52 372	60 380	70 135	87 656	93 917
NW Scotland (VIa)	13 076	2 802	7 548	7 329	4 839	2 867	3 975	8 039	18 313	20 076	23 164	28 469
Rockall (VIb)	3 787	2 350	3 903	1 792	1 840	1 959	3 257	1 641	1 402	1 375	134	–
Barents Sea (I)	61 972	59 166	94 329	79 423	115 574	90 517	86 735	103 662	105 416	125 681	157 098	163 720
Norwegian Sea (IIa)	32 161	26 799	36 258	37 785	24 953	30 010	27 758	20 334	15 605	22 096	34 693	40 935
Faroe Plateau and Bank (Vb_1, Vb_2)	14 739	16 356	12 531	10 079	9 805	11 983	14 409	14 271	15 012	15 403	16 573	17 515
Iceland (Va)	24 948	42 122	32 984	51 905	66 537	60 373	54 351	44 952	53 295	62 056	64 341	61 898
ICNAF Subarea 3	823	26 719	23 710	57 035	78 511	61 741	23 360	27 883	37 583	55 335	104 471	80 436
ICNAF Subarea 4	–	–	–	–	–	–	42 325	53 433	44 379	50 295	43 100	51 444
ICNAF Subarea 5	–	–	–	–	–	–	53 248	48 659	44 641	53 539	50 525	58 451

Subarea	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
North Sea (IVa, b, c)	105 304	96 191	79 670	66 424	67 238	52 419	59 398	198 706	221 700	268 958	167 408	139 469
NW Scotland (VIa)	30 053	27 394	18 165	14 719	10 845	8 431	13 791	26 835	32 467	29 881	20 302	20 469
Rockall (VIb)	8	5	12	2	1 547	2 301	3 073	2 416	548	1 935	874	903
Barents Sea (I)	86 986	78 112	58 734	121 160	159 728	159 172	123 356	79 056	98 505	123 438	104 005	–
Norwegian Sea (IIa)	24 658	29 391	26 415	26 302	25 642	25 189	21 471	18 993	19 108	35 417	30 668	–
Faroe Plateau and Bank (Vb_1, Vb_2)	20 995	23 871	20 239	25 727	20 709	27 149	27 569	19 491	18 407	18 762	13 372	17 857
Iceland (Va)	76 413	70 152	63 699	86 427	108 344	119 603	102 562	99 247	99 127	60 141	60 482	51 227
ICNAF Subarea 3	68 086	44 337	35 040	67 000	79 000	35 145	14 431	12 353	8 612	9 854	12 000	6 393
ICNAF Subarea 4	47 657	48 908	53 400	46 000	47 000	44 046	51 337	59 996	85 240	66 092	49 000	45 948
ICNAF Subarea 5	54 727	44 689	40 711	46 000	52 000	59 114	59 635	69 539	154 725	126 978	57 000	44 066

Data for ICES subareas from Cons. perm. int. Explor. Mer Bulletins Statistiques 1938–1966; and FAO Fisheries Circulars Nos. 211 and 243 for 1967 and 1968 data, except for Regions I and IIA which are obtained from ICES, 1969.

Data for ICNAF subareas from Int. Commn NW Atlant. Fish. Res. Doc. 69/21 and Statistical Bulletins.

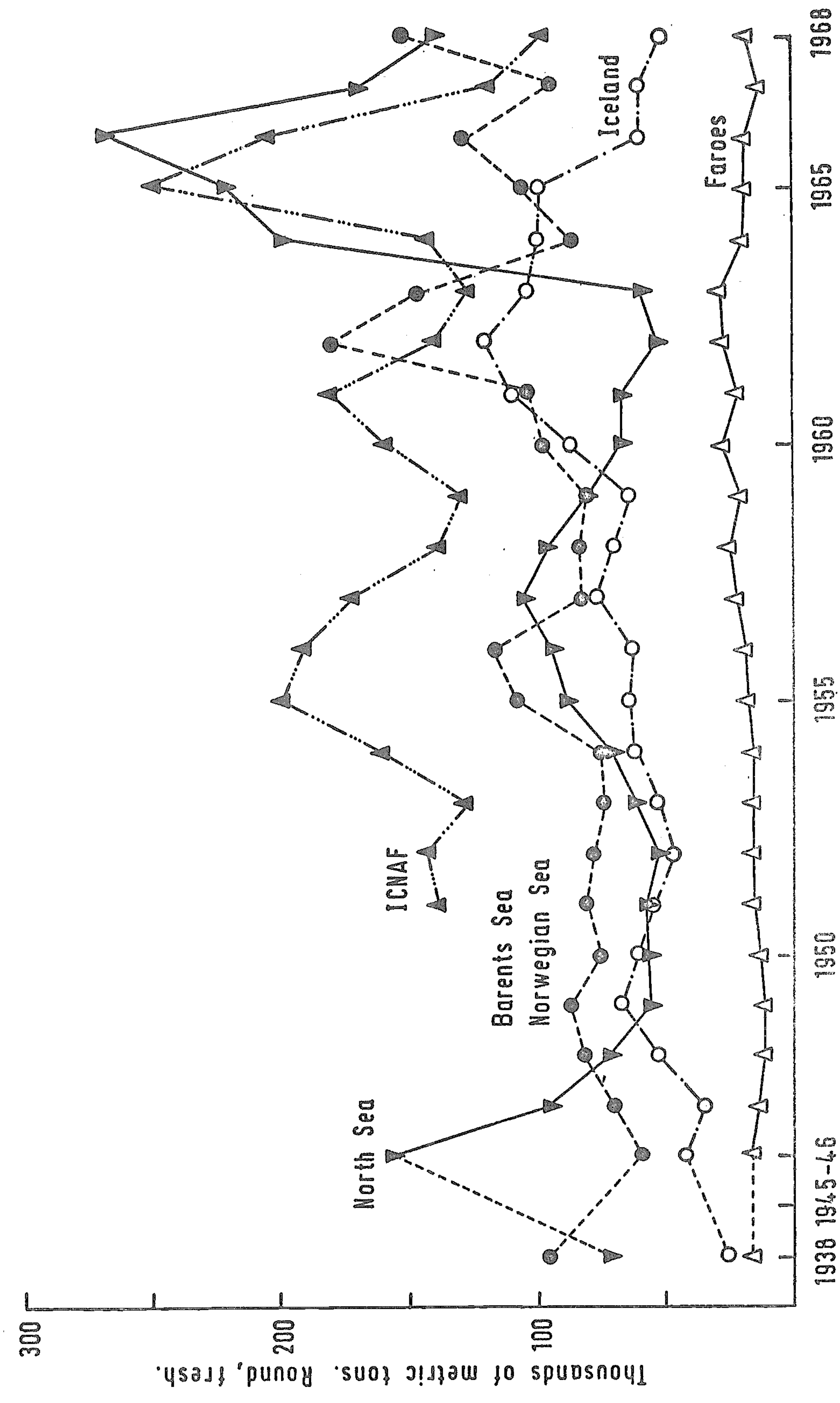

Fig. 7 Haddock landings from the main fishing areas for the period 1938 to 1968 (see also Table X)

For the Arcto-Norwegian stock a yield of 0.578 kg per recruit should be attainable at 33 percent of the present fishing level, which yields 0.456 kg per recruit (ICES, 1969a).

Hennemuth (1969) calculated a maximum sustainable yield of about 50 000 metric tons per year for the Georges Bank stock at a level of about 7 000 standard days' fishing (approximately 50 percent of the 1967 and 1968 fishing effort).

6 PROTECTION AND MANAGEMENT

For the purposes of regulation of the fisheries the North Atlantic is divided into two areas: the north-east Atlantic comes under the North-East Atlantic Fisheries Commission (NEAFC) and the north-west Atlantic is under the jurisdiction of the International Commission for the Northwest Atlantic Fisheries (ICNAF).

6.1 Regulatory (legislative) measures

The problem of management of fish stocks, including haddock in the North Atlantic, is reviewed in ICNAF, 1968. Subsequently the regulations outlined below were brought into force in 1970 (ICNAF, 1969).

6.11 Limitation or reduction of total catch

- Limitation on the efficiency of fishing units

None to date.

- Limitation on the total catches

ICNAF regulations impose the following total catch limits each year during 1970, 1971 and 1972:

Division 4X of subarea 4:	18 000 metric tons
Subarea 5 (which includes Georges Bank):	12 000 metric tons

Details of the method of reporting catches to be used by the Contracting Governments are also given (ICNAF, 1969, p. 26-28).

6.12 Protection of portions of population

- Closed areas

ICNAF regulations prohibit fishing with gear capable of catching demersal species during March and April 1970, 1971 and 1972 in the following areas:

1. That part of division 4X of subarea 4 that lies between 42°00'N latitude and 43°00'N latitude and between 67°00'W longitude and 64°30'W longitude.

2. In areas of subarea 5 bounded by straight lines connecting the following coordinates in the order listed:

(a)	70°00'W	42°10'N	
	69°10'W	41°10'N	
	68°30'W	41°35'N	
	69°20'W	42°30'N	
(b)	67°00'W	42°20'N	
	67°00'W	41°15'N	
	65°40'W	41°15'N	
	65°40'W	42°00'N	(ICNAF, 1969,
	66°00'W	42°20'N	p. 27-28)

- Closed seasons

Fishing is prohibited in the above areas during March and April 1970, 1971 and 1972. (ICNAF, 1969, p. 27-28)

- Limitations on size or efficiency of gear or craft

The mesh size of trawls, and other nets used for catching demersal fish, is regulated in both the ICNAF and NEAFC areas.

The minimum mesh sizes are given in Table XI. Mesh sizes are measured from knot to knot stretched, and apply to both wet and dry nets.

In the ICNAF area and Region 1 of the NEAFC area topside chafers are permitted on trawl cod-ends, provided that their specifications and attachments are in accord with one of the following:

1. the chafer is rectangular, of a mesh size not less than that of the cod-end, and is at least one and a half times the width of the cod-end. It must be attached to the cod-end only along the forward and lateral edges, so that if there is a splitting strop the chafer is attached not more than four meshes forward and ends at least four meshes forward of the cod-line mesh. If there is no splitting strop the chafer must not be more than one third the length of the cod-end; or

2. flap-type chafers of the same mesh and width as the cod-end, attached only along the forward edge and not more than ten meshes long. The aggregate length of such pieces must not exceed two-thirds the length of the cod-end; or

3. a rectangular chafer, the same material and width as the cod-end, but with mesh dimensions twice that of the cod-end, fastened only along the forward and lateral edges so that each mesh coincides with four meshes of the cod-end.

- Restrictions based on sex or condition

None.

TABLE XI

Minimum mesh sizes (St. Inst. 1968, 1969)

Net	Minimum mesh size, width of flat gauge (mm)				
	ICNAF Subareas		NEAFC area		
	1	2, 3, 4 and 5	Region 1*	Faroe (subarea Vb)	North Sea (subarea IV)
1. Seine net	110	100	110	105	70
2. Any trawl made of cotton, hemp, polyamide fibres or polyester fibres	120	105	120	105	75
3. Any trawl made of manila, sisal or any other material not mentioned in 2	130	114	130	110	80

* NEAFC region 1 includes subareas I, IIa, IIb, Va, XII and XIV.

- Restrictions on use of fish

In industrial fisheries in the NEAFC area and certain fisheries in the ICNAF area, in which the use of small-meshed nets is legal, the catch of haddock must not exceed 10 percent by weight of the total catch.

In all countries within the NEAFC area there are legal minimum sizes for haddock; the landing of haddock less than 27 cm total length from near-water fisheries, or 31 cm from distant-water fisheries, is illegal.

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SYNOPSIS OF FISHERIES BIOLOGICAL DATA

This is one of a series of documents issued by FAO, CSIRO and USFWS concerning species and stocks of aquatic organisms of present or potential economic interest. The primary purpose of this series is to make existing information readily available to fishery scientists according to a standard pattern, and by so doing also to draw attention to gaps in knowledge. It is hoped that synopses in the series will be useful to other scientists initiating investigations of the species concerned or of related ones, as a means of exchange of knowledge among those already working on the species, and as the basis for comparative study of fisheries resources. They will be brought up to date from time to time as further information becomes available either as revisions of the entire document or their specific chapters.

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FAO:

Fishery Resources Division
Marine Biology and Environment Branch
Food and Agriculture Organization
of the United Nations
Via delle Terme di Caracalla
00100 Rome, Italy

USFWS:

Chief, Scientific Publications Unit
National Marine Fisheries Service
Bldg. 67, Naval Support Activity
Seattle, Washington 98115,
U.S.A.

CSIRO:

Scientific Editor
CSIRO Division of Fisheries and Oceanography
Box 21
Cronulla, N.S.W.
2230 Australia

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