

A Tentative Analysis of the Trophic Levels of North Sea Fish

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ABSTRACT: Trophic levels of basic food items, feeding habits and trophic levels of various North Sea fishes have been derived from historical references and the MAFF North Sea Groundfish Survey data in 1977, 1978 and 1980. There is an obvious progression in the mean trophic levels from planktophagic (3.5) to benthophagic (3.9) and ichthyophagic (4.5). The mean trophic level of 34 species for the period 1947–77 is 3.67. While the total catch and the catch of some species were fluctuating widely, the mean trophic level of the nominal catch of fish (excluding several less important species) showed almost no changes (3.62–3.76) from 1947 to 1977. Generally speaking, the catch should approximately reflect the abundance in a well exploited sea. Assuming that the trophic levels of 34 species were similar during 1947–77, fishing does not appear to have upset the fundamental ecological balance of the North Sea. In other words, the influence of fishing has not yet surpassed the self-regulatory capacity of the North Sea ecosystem.

INTRODUCTION

The trophic level of fish can be described in relation to their level of productivity and food consumption, and forms an important part of the structure of food webs in an ecosystem. The study of the trophic levels of fishes is of practical and theoretical significance.

The present work attempts to make an analysis of trophic levels of North Sea fishes using the many studies of their dietary habits that have been conducted since the last century.

DATA SOURCES AND METHOD

The trophic levels of basic food items of North Sea fishes as shown in Table 1 are derived from the literature. Following the usual practice the trophic level of algae is taken as 1. Similarly, the trophic level of pure

herbivorous animals is equal to 2, and those of the first, second and third carnivores are 3, 4 and 5, respectively. In fact most marine animals feed on more or less mixed diets, so that their mean trophic levels will not be exactly whole integers. For example, *Temora longicornis* is recorded as a mixed diet feeder. It feeds chiefly on diatoms and copepods, the proportion of diatoms in its stomach contents being slightly more than that of copepods (Lebour, 1922), and therefore the trophic level of *T. longicornis* is taken as 2.4 on a point basis. The trophic levels of the other animals are estimated on a similar basis (Table 1).

The feeding habits (based on food composition) of various fishes in the North Sea are derived from the literature on fish food studies (Smith, 1889, 1890; Scott, 1902; Todd, 1905, 1907; Bullen, 1912; Lebour, 1918, 1919; Hardy, 1924; Savage, 1937; Hartley, 1940; Rae, 1956, 1963, 1967; Raitt and Adams, 1962; Ryland, 1964; Macer, 1966, 1977; Zilanov, 1966, 1968; Braber and de Groot, 1973; Daan, 1973; Wyatt, 1974; Shuvaev, 1977; Last, 1978a, b, 1980), and in addition unpublished stomach contents data (about 7,000 fish) were made available to the author from the MAFF North Sea Groundfish Survey during 1977, 1978 and 1980. All the above data were reanalysed by the Points Method (Hynes, 1950) and ignored unimportant food items.

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Table 1. Trophic level of basic food items of North Sea fishes (based on the sources indicated)

Food item	Trophic level	Sources
<i>Calanus finmarchicus</i>	2.3	Lebour (1922), Raymond (1963), Marshall & Orr (1972)
<i>Paracalanus parvus</i>	2.1	Lebour (1922), Raymond (1963)
<i>Pseudocalanus elongatus</i>	2.1	Lebour (1922), Raymond (1963)
<i>Pseudocalanus minutus</i>	2.1	
<i>Temora longicornis</i>	2.4	Lebour (1922), Raymond (1963)
<i>Eurytemora</i> spp.	2.4	Kaestner (1967)
<i>Metridia lucens</i>	2.1	Raymont (1963)
<i>Centropages</i>	2.4	Lebour (1922)
<i>Acartia clausii</i>	2.1	Lebour (1922)
<i>Oithona similis</i>	2.1	Lebour (1922)
<i>Oithona helgolandicus</i>	2.1	
Copepoda nauplii	2.1	
<i>Balanus nauplii</i>	2.1	Raymont (1963)
Cladocera	2.1	Raymont (1963)
<i>Thysanoessa inermis</i>	2.4	Raymont (1963)
<i>Nyctiphanes couchii</i>	2.3	Lebour (1922)
Hyperiididae	3.0	Lebour (1922), Kaestner (1967)
Mysids	2.4	Raymont (1963)
Decapods larvae	2.5	Lebour (1922)
<i>Crangon</i>	3.2	Allen (1960), Kaestner (1970), Tiews (1970)
<i>Eupagurus (= Pagurus)</i>	2.6	Kaestner (1970)
<i>Pandalus</i>	3.2	Simpson (1970), Kaestner (1970)
<i>Portunus</i>	3.3	Kaestner (1970)
<i>Nephrops</i>	3.3	Oakley (1978)
<i>Hyas</i>	3.3	Kaestner (1970)
<i>Appendicularia</i>	2.1	Davis (1955)
<i>Nereis</i>	2.4	Kaestner (1967)
<i>Pectinaria</i>	2.3	Kaestner (1967)
<i>Terebella</i>	2.3	Kaestner (1967)
<i>Sabella</i>	2.1	Kaestner (1967)
Polychaeta larvae	2.1	Lebour (1922)
<i>Scrobicularia</i>	2.1	Kaestner (1967)
<i>Solen</i>	2.1	Kaestner (1967)
<i>Tellina</i>	2.1	Kaestner (1967)
Lamellibranch larvae	2.1	Raymont (1963)
<i>Ophiura</i>	3.0	Campbell (1976)
<i>Ophiothrix</i>	3.0	Campbell (1976)
<i>Sagitta</i>	3.5	Lebour (1922), Lebour (1924)
Detritus feeders	2.1	Steele (1974)

The values of the trophic levels of various fish were then calculated from those of the basic food items (Table 1) and the food composition of the fish.

An example of the calculation of the trophic level of a fish (the herring) is given in Table 2. The principal and secondary food items of the herring are derived from Savage (1937), unimportant items being ignored. Points are allocated to each food item according to its relative importance in the stomach contents of the fish (Column I). The trophic level of each food item, taken from Table 1, is entered in Column III. The relative contribution of each food item (Column IV) is the product of Columns II and III, divided by 100. The sum of the individual values in Column IV is the weighted mean trophic level of the food (= 2.450); that of the fish is obtained by adding 1 to this value to represent the fish itself, giving 3.450 or about 3.5.

The mean trophic level of the nominal catch in the North Sea (Table 4, Fig. 1) is computed from 34 of the species listed in the ICES 'Bulletin Statistique' for the years 1947-77 (ICES, 1951-81), long rough dab, poor cod and bib were excluded because there are no catch data for these species; tunas, garfish, seabream, ratfish and unsorted and unidentified teleost fishes were also excluded because they contributed altogether less than 1 % to the total catch of fish in 1968-77.

The accuracy of the values in Table 3 will clearly be influenced by the fact that many different methods have been used by individual authors to analyse the food contents of animals, and the Points Method of Hynes (1950) is itself not a precise one.

The percentages of herring and other plankton-feeding fishes in the nominal total catch of fish from the North Sea in the period 1947-77 are computed from

Table 2. Calculation of weighted mean trophic level of the food of herring

Food item	I Points given	II % of total points	III Trophic level of basic food item	IV Value of trophic level (III × II ÷ 100)
<i>Calanus finmarchicus</i>	27	27	2.3	0.621
<i>Paracalanus parvus</i>	2	2	2.1	0.042
<i>Pseudocalanus elongatus</i>	1	1	2.1	0.021
<i>Temora longicornis</i>	9	9	2.4	0.216
<i>Metridia lucens</i>	1	1	2.1	0.021
<i>Centropages</i>	1	1	2.4	0.024
Other copepods	1	1	2.6	0.026
<i>Thysanoessa inermis</i>	3	3	2.4	0.072
<i>Nyctiphanes couchii</i>	9	9	2.3	0.207
<i>Meganyctiphanes</i>	3	3	2.4	0.072
Hyperiidæ	8	8	3.0	0.240
Decapoda larvae	1	1	2.5	0.025
<i>Ammodytes</i> larvae	6	6	3.2	0.192
Other fish larvae	1	1	3.5	0.035
<i>Sagitta</i>	3	3	3.5	0.105
<i>Oikopleura</i>	21	21	2.1	0.441
Other organisms	3	3	3.0	0.090
Total	100	100		2.450

Table 3. Feeding habits and trophic levels of various North Sea fishes

Fish species		Feeding habit	Trophic level
Sprat	<i>Sprattus sprattus</i>	Planktophagic	3.3
Raitt's sandeel	<i>Ammodytes marinus</i>	Planktophagic	3.3
Norway pout	<i>Trisopterus esmarkii</i>	Planktophagic	3.4
Herring	<i>Clupea harengus</i>	Planktophagic	3.5
Scad	<i>Trachurus trachurus</i>	Planktophagic	3.5
Mackerel	<i>Scomber scombrus</i>	Planktophagic	3.5
Greater sandeel	<i>Hyperoplus lanceolatus</i>	Planktophagic	3.5
Blue whiting	<i>Micromesistius poutassou</i>	Planktophagic	3.7
Witch	<i>Glyptocephalus cynoglossus</i>	Benthophagic	3.7
Plaice	<i>Pleuronectes platessa</i>	Benthophagic	3.7
Sole	<i>Solea solea</i>	Benthophagic	3.7
Lemon sole	<i>Microstomus kitt</i>	Benthophagic	3.7
Flounder	<i>Platichthys flesus</i>	Benthophagic	3.8
Dab	<i>Limanda limanda</i>	Benthophagic	3.7
Grey gurnard	<i>Eutrigla gurnardus</i>	Benthophagic	3.8
Long rough dab	<i>Hippoglossoides platessoides</i>	Benthophagic	4.0
Haddock	<i>Melanogrammus aeglefinus</i>	Benthophagic	3.9
Tub gurnard	<i>Trigla lucerna</i>	Benthophagic	4.0
Catfish	<i>Anarhichas lupus</i>	Benthophagic	4.0
Starry ray	<i>Raja radiata</i>	Benthophagic	4.1
Poor cod	<i>Trisopterus minutus</i>	Benthophagic	4.0
Bib	<i>Trisopterus luscus</i>	Benthophagic	4.2
Red gurnard	<i>Aspitrigla cuculus</i>	Benthophagic	4.1
Roker	<i>Raja clavata</i>	Benthophagic	4.0
Pollack	<i>Pollachius pollachius</i>	Ichthyophagic	4.4
Cod	<i>Gadus morhua</i>	Ichthyophagic	4.4
Whiting	<i>Merlangius merlangus</i>	Ichthyophagic	4.3
Halibut	<i>Hippoglossus hippoglossus</i>	Ichthyophagic	4.4
Spurdog	<i>Squalus acanthias</i>	Ichthyophagic	4.4
Skate	<i>Raja batis</i>	Ichthyophagic	4.6
Saithe	<i>Pollachius virens</i>	Ichthyophagic	4.5
Megrim	<i>Leipidorhombus whiffiagonis</i>	Ichthyophagic	4.5
Hake	<i>Merluccius merluccius</i>	Ichthyophagic	4.6
Turbot	<i>Scophthalmus maximus</i>	Ichthyophagic	4.6
Brill	<i>Scophthalmus rhombus</i>	Ichthyophagic	4.7
Ling	<i>Molva molva</i>	Ichthyophagic	4.8
Angler	<i>Luphius piscatorius</i>	Ichthyophagic	4.8

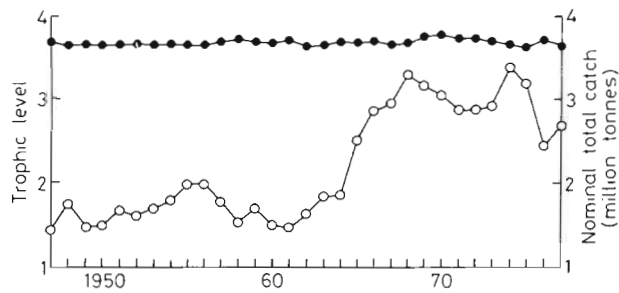


Fig. 1. Mean trophic level of nominal catch (filled circles) and nominal total catch (open circles) of North Sea fish during 1947–77

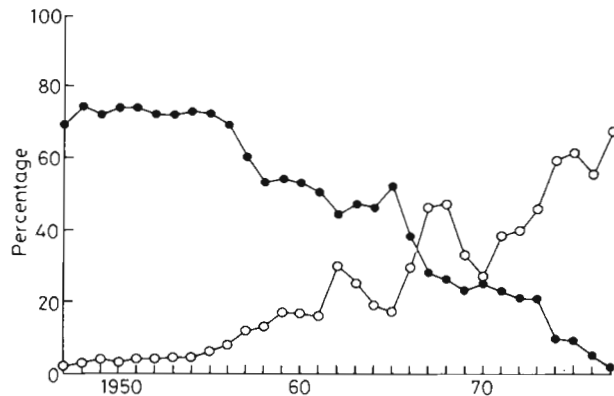


Fig. 2. Percentage of herring (filled circles) and of other plankton feeding fishes (open circles) in the nominal total catch of fish from the North Sea during 1947–77

ICES 'Bulletin Statistique' (ICES, 1951–81), again excluding the same less important fishes as mentioned above.

RESULTS

Feeding Habit and Trophic Level of Various Fishes

As may be seen from Table 3, the feeding habits of 8 species – sprat, Raitt's sandeel, Norway pout, herring, scad, mackerel, greater sandeel and blue whiting – are planktophagic with a mean trophic level of 3.5 (range 3.3 to 3.7). The feeding habits of 16 species such as witch, plaice, sole, dab, grey gurnard, haddock, starry ray, poor cod and bib are benthophagic, with a mean trophic level of 3.9 (range 3.7 to 4.2). The feeding habits of 13 other species, whiting, cod, spurdog, skate, saithe, hake, brill, angler and so on, are ichthyophagic, with a mean trophic level of 4.5 (range 4.3 to 4.8). There is an obvious progression in the mean trophic levels from planktophagic (3.5) to benthophagic (3.9) and ichthyophagic (4.5). The overall mean trophic level of fishes for the period 1947–77 is 3.67 (Table 4).

Long-Term Changes of Mean Trophic Level of Nominal Catch of Fish

As shown in Table 4 and Fig. 1, the mean trophic level of nominal catches of North Sea fish during 1947–77 ranged from 3.62–3.76, showing almost no change during this period.

DISCUSSION

Since 1947 the total catch of fish excluding several less important species (see section 'Data Sources and Method') from the North Sea has fluctuated widely. During the period 1947–60 the total catch of fish was 1.43 to 1.97 million tonnes. From 1961 to 1968 there was a sharp increase to 3.28 million tonnes, and thereafter the level of catches has varied between 2.44 and 3.38 million tonnes.

For many individual species, the fluctuations of catch are even more evident than that of the total. The best known example is the herring, catches of which reached a peak level of 1.3 million tonnes in 1965, followed by a sharp decline to 44,000 tonnes in 1977. Mackerel shows a history similar to herring. Whilst some species are in a period of decline, others have increased, for example sandeels (mainly *Ammodytes marinus*), the catch of which has greatly increased since 1965 (130 thousand tonnes) reaching 786 thousand tonnes in 1977. Similarly, the catch of Norway pout varied in the period 1962–77, being 53 thousand tonnes in 1966 and 823 thousand tonnes in 1974 (ICES 'Bulletin Statistique' for the years 1947–77) (ICES, 1951–81).

Although the herring declined between 1947 and 1977 (from 69.1 % in 1947 and 74.8 % in 1948 to 1.7 % in 1977), the percentage of plankton-feeders in the total catch of fish remained steady (average 69.8 %, range 51.6–77.3 %), apparently by virtue of the replacement of herring by other plankton-feeding fishes (from 1.6 % in 1947 to 67.3 % in 1977) (Table 4, Fig. 2). It is therefore of considerable interest to find that, despite these and other changes in the total catch or the catches of individual species, the mean trophic level of the nominal catch showed almost no change from 1947 to 1977, varying only between 3.62 and 3.76.

Generally speaking, the catch should approximately reflect the abundance in a well-exploited sea. Assuming that the trophic levels of the 34 species were similar during 1947–77, fishing does not appear to have upset the fundamental ecological balance of the North Sea. In other words, the influence of fishing has not yet surpassed the self-regulatory capacity of the North Sea ecosystem.

Table 4. North Sea fish: mean trophic level of nominal catch, nominal total catch*, and plankton feeders as % of total catch during 1947–1977

Year	Mean trophic level of nominal catch	Nominal total catch (tonnes)	Plankton feeders as % of total catch		
			All species	Herring	Others
1947	3.68	1431061	70.7	69.1	1.6
1948	3.64	1726524	77.1	74.8	2.4
1949	3.65	1460944	75.7	72.4	3.3
1950	3.64	1489777	77.2	74.3	2.8
1951	3.64	1655838	77.3	73.7	3.7
1952	3.65	1590943	75.7	72.0	3.7
1953	3.64	1677671	76.3	72.2	4.0
1954	3.65	1783586	76.9	72.7	4.1
1955	3.64	1973448	77.3	71.5	5.8
1956	3.64	1971920	76.8	69.2	7.6
1957	3.68	1752539	71.1	59.8	11.3
1958	3.71	1506256	66.3	53.4	12.9
1959	3.68	1677000	70.6	53.9	16.7
1960	3.67	1479337	69.9	53.5	16.5
1961	3.70	1450900	66.3	50.6	15.7
1962	3.62	1621683	74.1	44.4	29.7
1963	3.64	1824794	72.1	47.3	24.8
1964	3.68	1842527	65.3	46.5	18.8
1965	3.68	2499462	69.0	51.9	17.1
1966	3.69	2841482	66.8	37.6	29.2
1967	3.65	2944329	73.8	27.9	45.8
1968	3.66	3275535	73.0	26.0	47.0
1969	3.74	3147632	55.7	23.1	32.7
1970	3.76	3039113	51.6	24.7	26.9
1971	3.73	2867992	60.7	22.5	38.2
1972	3.73	2858888	60.8	21.2	39.7
1973	3.69	2910990	66.0	20.6	45.4
1974	3.65	3379222	68.7	9.7	59.1
1975	3.62	3190710	70.8	9.0	61.8
1976	3.70	2438713	60.1	5.0	55.1
1977	3.63	2674831	68.9	1.7	67.3
Average	3.67	2193085	69.8	45.6	24.2

* Calculated from ICES Bulletin Statistique and nominal landings officially reported to ICES

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