Northwest Atlantic Fisheries Organization

Serial No. N743

NAFO SCR Doc.83/IX/77

FIFTH ANNUAL MEETING - SEPTEMBER 1983

Trophic Relationships Between some Fish Species of the North Sea

by

V. N. Feldman, V. I. Malyshev and I. P. Golubyatnikova
Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO)
5 Dmitry Donskoy Street, Kaliningrad, USSR

Absract

Length composition of fishes consumed by predatory gadoids in the North Sea between 1975 and 1977 is studied depending on peculiarities of their distribution and dynamics of abundance. The sprat older than 3-4 year was stated to be less available food for cod and especially for whiting. The absence of blue whiting above 17 cm in length (older than 1 year) and large Norway pout in the saithe stomachs in the period under study was not associated with selectivity of its feeding.

The size electivity in relation to sprat becomes apparent for whiting above 30 cm in length and for cod above 50-70 cm. The size electivity in relation to sand eel is manifested for cod of above 70 cm and for haddock of above 35 cm in length. Some preliminary data on age ratio between predatory gadoids and their preys for 1981 were obtained. These data may be used to calculate the food suitability coefficients in the multispecies VPA.

The amounts and type of the food may heavily vary with increasing length of the fish consuming this food. Adult predators may consume the species which are their major competitors at early development stages. These situations were considered within the framework of the problem concerning the relationships between populations of predators and their preys (Ursin, 1973; Werner, 1979).

To evaluate the impact of stocks of predators on that of preys it should first be known what portion of the latter is

subject to eating away and "who eats whom". For studying purposes the relationships between the length of predatory gadoids and the length of fishes consumed were analysed, and within the framework of the ICES program on multispecies assessment model testing (Anon., 1980) the relationships between the age of predatory gadoids and age of their preys were studied.

Materials and Methods

The materials for studying of the length relationship between predators and their preys used as a basis for this paper were collected in the North Sea during the 1975-1977 summer-fall (feeding) periods. The bulk of the material by species comprised of 2067 stomachs from whiting Odontogadus merlangus (L.), 973 stomachs from cod Gadus morhua (L.), 758 stomachs from saithe Pollachius virens (L.), 695 stomachs from haddock Melanogrammus aeglefinus. The materials were analysed according to the standard methods (Methodic manual for studying of feeding, 1974). The length of all the fish found in the stomachs was measured, if possible. If the total zoological length could not be measured, the length was reconstructured according to respective morphometric graphs for each prey species.

For a characteristic of length frequencies of prey fishes, statistical indices of diversity were used: length limits (L_{min}-L_{max}), weighted mean length (L_{mean}), mean square deviation (σ), coefficient of variance (C_v) (Plokhinsky, 1970). A comparison was made between length composition of consumed fishes and composition of catches of these species taken in the locations of sampling with trawls with small-meshed cover.

The sprat consumed by whiting and cod was taken from the ICES Divs IVb and IVc, the main sprat habitats in the North Sea. The saithe prey on Norway pout, Trisopterus esmarkii Nilsson, blue whiting, Micromesisteus poutassou Risso, haddock and sand eel, Ammodytes marinus Raitt, from the ICES Div. IVa where these species dwell on and are targets of the fishery.

Since measurements of sand eel consumed by cod were not numerous, the materials for the ICES Divs IVa and IVd were combined.

The materials used for examination of relative stomach contents of cod and whiting at a certain age consuming fishes of one or another age group were collected by SRTM "Korifena" in the first quater of 1981 in the course of the ICES international experiment in the North Sea. A total of 400 stomachs were examined. This material was analysed by means of the weight method and in accordance with methods adopted by the ICES (Anon., 1980). The age of consumed fishes was determined by otoliths*.

The individual weighing of fishes was made. When the fish remains were impossible to weigh individually due to heavy destruction, their weight was distributed by age in accordance. with otoliths found in the food mass and by number of annuli read. The species belonging of fish remains was identified by bones, vertebrae and otoliths.

Results

Rather complete length frequency series suitable for statistic processing were produced for sprat consumed by whiting and cod, and for Norway pout, sand eel and blue whiting consumed by saithe (table 1-3). As is evident from these tables, mean length of consumed fish increases regularly with increasing length of predator. So, the whiting below 21 cm (yearlings) did not practically feed on adult sprat whereas large amounts of fry were found in the stomach contents of this species. The fry by number constituted great percentage in the feeding of larger whiting (up to 25 cm in length) while their proportion by weight was of insignificant magnitude. Medium-sized and large whiting (above 30 cm) preyed on sprat of 10-13 cm in length (age 2-4). It is worth of noting that no sprat above 14 cm (age 5-6) was found in the whiting stomachs while the sprat accounted for 8 to 26% in the catches during this period.

No sprat of above 14 cm in length was also recorded in the cod stomach contents (table 2). N.Daan (1973) studied the cod feeding and reported similar data on consumption of sprat by

---

* The age of herring and gadoids was determined by A.F.Lysenko and Vasiljeva T.G., respectively.

cod. Based on the above-mentioned the sprat above 14 cm in length may be assumed to be less available food for whiting and cod.

The other two numerous species of commercial interest, namely Norway pout and blue whiting, are the major food items for saithe, however large specimens of these species are incidentally represented in the diet (table 3). Examination of catch composition during the trawl surveys and abundance indices of these species permit to conclude that such picture is observed owing to peculiarities of dynamics of their abundance and distribution and is not attributed to the availability as a prey for saithe. So, the abundance of Norway pout is practically depleted at the 2-3 year of life due to the high natural losses of the species. The recruitment (0-group) averaged 91.2% over 1971-1975, and just owing to this the 0-group Norway pout was frequently recorded in the stomachs of both large and small saithe.

The sampling location for saithe feeding is coincided with the area of growing of young blue whiting. Simultaneously older age groups of blue whiting inhabit the other areas where depths exceed 300 m.

A comparison between mean lengths of fishes consumed by haddock, cod and saithe showed that large cod (51-70 cm) ate the larger sand eel than saithe and haddock of similar sizes, and large saithe (51-100 cm) consumed the larger sand eel compared to haddock of similar sizes (table 4).

Statistic characteristics of distribution of fishes consumed by whiting, cod and saithe indicate a tendency towards regular increase in mean lengths of consumed organisms with increasing sizes of predator which is usually observed in natural environment.

However, the length range of consumed fishes, which is narrow in the beginning, is expanded with increasing size of predator due to increase in the maximum sizes of the food provided the invariable minimum sizes. When predators reach certain sizes, the length range of their preys decreases again due to elimination of small fishes from their feeding.

Using the coefficient of variance of sizes of consumed fishes as an index of size electivity of food the predator sizes

may be determined at which such electivity becomes apparent. So, as regards whiting, the increase in mean length of consumed sprat due to increasing maximum length and invariable minimum length is observed up to 30 cm (C_V increases). As to larger individuals the size electivity becomes apparent (C_V decreases) (table 1). For cod preying on sprat the size electivity becomes apparent at length exceeding 50 cm (C_V= 10.95%) and increases for fishes above 70 cm (C_V= 6.05%).

In relation to sand eel the size electivity becomes apparent for cod above 70 cm and for haddock above 35 cm in length (tables 2,4).

In other words, on attaining the sizes mentioned above the cod, whiting and haddock utilize medium-sized and large fishes as prevailing food items. As to large predators no energy losses spent for search and capture of small sprat and sand eel are probably compensated by the energy available from their consumption.

In the case of saithe such picture is shaded because fishes are grouped according to the length into rather large classes combining fishes with different structure of energy balance.

The results of examination of size electivity indices of predatory gadoids feeding may appear to be useful for assessing of abundance of small fish species available for consumption.

However, for using of data on feeding in the multispecies stock assessment models (e.g., multispecies virtual population analysis, MVPA), a quantification of the preference and availability of a certain age group of one or another species as a prey for one or another age group of predator should be presented. Sparre (1980) showed that the preference and availability of food ("suitability" according to the terminology adopted by ICES) may be empirically evaluated from the data on stomach contents and abundance of interacting populations of fishes involved in the multispecies cohort analysis.

The matrices of relative stomach contents distributed in accordance with the age of the predator itself and its preys are used as initial information for calculation of suitability coefficients. For simplification of producing of these matrices, the

total weight of food consumed by a predator of a certain age group is assumed to be equal to 1, and food items not involved in the multispecies cohort analysis are attributed to the category of "other food" and arbitrarily considered as a taxonomic unit with age equal to 1 year.

Since the material given in the present paper is a small portion of the total volume collected in the first quarter of 1981 during the ICES experiment, the authors are far from attempting to make any preliminary estimates. The authors have for an object to make an attempt to generalize the first experience of participation in the experiment and to discuss some aspects of methods for the material collection and processing. So, the matrices produced from the materials processed by the authors are rather of illustrative character although these matrices give a certain consideration about availability based on age-length relationship between predators and their preys.

The tables 5 and 6 show the food composition of cod and whiting as percentage of the total food weight; the predators are grouped according to the length groups recommended in the ICES methods (Anon., 1980). It is convenient to analyse the food composition according to these tables.

Major food for cod of 20-24 cm long taken from the western North Sea was represented by benthic organisms, such as decapods (hermit crabs, shrimps, crabs), polychaetes and isopods. The cod 25-49 cm in length fed mainly on the fish, such as sprat, cod, sand eel and whiting. However, decapods (Crangonidae, Pandalidae, Paguridae) still constituted a great proportion (31.6%) in feeding of cod 25-29 cm long. Large cod 50-100 cm in length fed principally on the fish, such as sprat, herring, whiting and haddock and to a lesser extent on Norway pout and cod. The high feeding intensity of cod was recorded. Total mean index of stomach fullness reached 185‰.

The whiting 15-19 cm in length from the western North Sea preyed mainly on decapods (Crangonidae, Pandalidae, etc.- 44.1%). The fish and polychaetes were equally represented in the stomachs of whiting of this size group. Euphausiids and mysids accounted for a great proportion (19.3%). The fish, mainly sand eel, is a

prevailing food for whiting of 20-24 cm in length. As is evident from table 6, with increasing length of whiting the proportion of fishes in the stomach contents increases with concomitant decrease in proportion of decapods, euphausiids and polychaetes. The food medium-sized and large whiting 25-45 cm in length was mainly represented by the fish, such as eel, sprat and Norway pout.

In the tables 7 and 8 the data on individual analysis of stomachs and age determination of the fish from otoliths are converted into the matrices of the relative stomach contents in accordance with the methods stated above.

As is evident from the tables 7-8 the relative significance of some fish species in the feeding of predators of different age is in disagreement with their percentage value given in tables 5-6 where the predators are combined into length classes corresponding arbitrarily to the same age groups. It is quite obvious that the use of the group method, when the fish age is reconstructured according to the length-age keys, entails great errors. In this connection, the group method of collecting and analysing of stomachs utilized by the ICES along with individual methods is considered, in our opinion, to be inadmissible for using of data on fish feeding in MVPA. Despite the labour-consuming nature of the individual method, it should be considered as the most suitable one for such problems.

Although the produced matrices are mainly of illustrative character, nevertheless preliminary analysis of even the incomplete matrices permits to conclude that just as size composition of consumed fishes for the period between 1975 and 1977 the age distribution of fishes consumed by cod and whiting indicates the absence of sprat older than 3 years and Norway pout older than 1 year in their feeding whereas cod and whiting consume sand eel of nearly all the age groups. The data on age distribution of herring consumed by cod and cannibalism of age 3 cod eating yearlings are of great interest.

Conclusions

A comparison between length composition of fishes consumed by predatory gadoids and peculiarities of their distribution

and relative abundance permits to conclude that sprat above 14 cm in length (older than 3-4 years) is not recorded in the stomach contents of whiting and cod, and may be less available food for these predators. The absence of blue whiting above 17 cm in length and small number of medium-sized and large Norway pout observed in the saithe stomachs are not associated with selectivity of its feeding.

With predator growth, the length range of organisms consumed by cod, whiting and haddock increased in the beginning and then narrowed. The size electivity becomes apparent for whiting of above 30 cm in length, for cod above 50-70 cm and haddock above 35 cm in length.

The matrices of relative stomach contents of cod and whiting produced in accordance with age of predator and its preys are in close agreement with long-term observations on length relationships between them. These matrices extended and supplemented with the materials which were collected and analysed by means of the individual method may be used to calculate the food suitability coefficients in multispecies VPA by Sparre's method (1980).

References

1. Anon.1980. Report of the Ad Hoc Working Group on Multispecies Assessment Model Testing. ICES C.M./G:2, 18 p.

2. Daan N., 1973. A quantitative analysis of the food intake of North Sea cod Gadus morhua. Netherlands Journal of Sea Research, N 6(4):479-517.

3. Methodic manual for studying of feeding and food relations between fishes in the environment. 1974. M.,"Nauka", p.1-254.

4. Plokhinsky N.A., 1970. The biometry. 2nd ed. M.: Izd-vo Mosk. gos. un-ta, p.1-367.

5. Sparre P., 1980. A goal Function of Fisheries ICES C.M./G:40, 81 p.

6. Ursin E., 1973. On the prey size preferences of cod and dab. Meddr.Danm.Fisk-og.Havunders (N.S.), N 7:85-98.

7. Werner E., 1979. Niche Partitioning by Food size in Fish Communities.-Prey Systems in Fish Communities and their role in Fisheries Management. Atlanta:311-322.

Table 1 Relationship between length of whiting and length of sprat consumed (ICES Divs IVb and IVc), 1975-1976

Indices	Length of whiting, cm					
	below 21	21-25	26-30	31-35	36-40	above 40
	Sprat					
L_{min} - L_{max}, cm	2-12	2-12	2-13	10-13	10-74	11-13
L_{mean}, cm	2,23	2.14	5,9	11.5	11.9	11.9
σ	0.67	1.07	4.51	0.90	1,11	0.67
C_v, %	30,04	50,00	76,44	7,83	9,33	5.63

Table 2 Relationship between length of cod and length of fishes consumed (ICES Div. IVb), 1975-1976

Indices	Length of cod, cm							
	below 31	31-50	51-70	above 71	below 31	31-50	51-70	above 71
	Sprat				Sand eel			
L_{min} - L_{max}, cm	8-9	8-14	9-14	11-13	5-9	5-13	7-21	10-17
L_{mean}, cm	8,5	10.6	11,6	11,9	6,7	10.0	12.1	12.6
σ	0.52	1.61	1,27	0.72	1.10	2.35	3,85	2.42
C_v, %	6.12	15.9	10,95	6.05	16.42	23.50	31,82	19.21

Table 3 Relationship between length of saithe and length of fishes consumed (ICES Div. IVa), 1975-1976

Indices	Length of saithe, cm							
	31-50	51-100	31-50	51-100	31-50	51-100	31-50	51-100
	Norway pout		Blue whiting		Haddock		Sand eel	
L_{min}-L_{max}, cm	4-15	5-18	10-14	10-16	6-9	6-14	9-12	9-20
L_{mean}, cm	6.8	7.9	11,9	12.2	7.5	8.7	11,4	13,1
σ	1.59	2.76	1,11	1,33	1,05	1,59	0.86	0,90
C_v, %	23.38	34.94	9,32	10.9	14.0	18,28	7.54	7.44

Table 4 Relationship between length of haddock and length of haddock and length of fishes consumed (ICES Div. IVa), 1976-1977

Indices	Length of haddock, cm					
	below 31	31-35	36-70	below 31	31-35	36-70
	Norway pout			Sand eel		
L_{min} - L_{max}, cm	4-7	7-8	8-12	6-9	6-13	9-13
L_{mean}, cm	5,9	7,6	9,5	7,5	8,8	10,7
σ	0,95	0,52	0,97	1,17	1,71	0,96
C_v, %	16.10	6,84	10,21	15,60	19,43	18,97

Table 5 Food composition (% by weight) of cod, 1st quarter 1981

Food organisms	Length of cod, cm					
	20-24	25-29	30-39	40-49	50-69	70-100
Cod		32.4				I,0
Whiting		8,5	6,4		0,6	3I,8
Haddock					6,0	I0,8
Herring					I7,6	29,7
Sprat		I8,4	24,8		4I,3	I5,7
Sand eel			24,2			
Norway pout			4,3		2,I	0,6
Other fish	6,6	4,2	24,6	78,3	I6,0	4,2
Total fish	6,6	63,5	84,3	78,3	83,6	93,8
Decapoda	80,I	3I,6	I3,4	2I,7	8,0	3,7
Amphipoda		0,2				0,I
Isopoda	6,4	0,9				
Euphausiacea		0,2				
Polychaeta	3,3	3,I	2,0		0,9	0,5
Gastropoda / Bivalvia			0,2		7,5	I,9
Others	3,6	0,5	0,I			
No.of stomachs, spec.	I9	55	59	6	22	30
% of empty stomachs	I5,8	I0,9	6,8	-	4,5	6,7
Total index of stomach Fullness, ‰	63,I	89,5	184,8	73,6	9I,0	II0,0

Table 6 Food composition (% by weight) of whiting, 1st quarter 1981

Food organisms	Length of whiting, cm				
	15-19	20-24	25-30	31-40	40 above
Sprat			25.9		
Norway pout				15.6	
Sand eel		35.1	47.2	28.4	100.0
Other fish	19.3	11.2	2.4	50.6	
Toral fish	19.3	46.3	75.5	94.6	
Decapoda: Pandalus borealis Crangon crangon	27.4	9.9	4.4	0.9	
Other decapoda	16.7	-	4.8	1.7	
Cephalopoda				0.4	
Amphipoda		3.1	0.5		
Euphausiacea	9.3	31.0	13.2	0.4	
Misidacea	10.0				
Polychaeta	17.3	7.4	1.6	2.0	
No. of stomachs, spec.	48	55	51	50	2
% of empty stomachs	56.3	27.3	19.6	26.0	-
Total mean index of stomach fullness, ‰	7.0	32.2	2.3	81.1	89.3

Table 7 Relative stomach contents of cod, 1st quarter 1981

Prey species	Prey age, years	Age of predator-cod, years					
		1	2	3	4	5	6	7
Sprat	1	0.45	0.17	0.01	0.00	0.00	0.00
	2	0.00	0.01	0.14	0.01	0.00	0.00
	3	0.00	0.00	0.00	0.34	0.00	0.00
Whiting	1	0.00	0.02	0.02	0.00	0.00	0.00
	2	0.03	0.01	0.04	0.00	0.00	0.00
	3	0.06	0.00	0.00	0.42	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.99
Herring	1	0.00	0.12	0.06	0.00	0.00	0.00
	2	0.00	0.00	0.12	0.16	0.00	0.00
	3	0.00	0.00	0.12	0.00	0.00	0.00
	5	0.00	0.01	0.00	0.00	0.99	0.00

Table 7. (cont'd)

Prey species	Prey age, years	Age of predator-cod, years					
		I	2	3	4	5	6	7
Haddock	2	0,00	0,05	0,01	0,00	0,00	0,00
	3	0,00	0,00	0,12	0,00	0,00	0,00
Sand eel	I	0,01	0,00	0,00	0,00	0,00	0,00
	2	0,04	0,00	0,00	0,00	0,00	0,00
	3	0,05	0,00	0,00	0,00	0,00	0,00
	4	0,02	0,00	0,00	0,00	0,00	0,00
Cod	I	0,00	0,08	0,00	0,00	0,00	0,001
Norway pout	I	0,00	0,02	0,01	0,00	0,00	0,00
P.platessa	I	0,00	0,02	0,02	0,00	0,00	0,00
Other food	I	0,34	0,49	0,28	0,07	0,01	0,01
Total		1,00	1,00	1,00	1,00	1,00	1,00

Table 8 Relative stomach contents of whiting, 1st quarter 1981

Prey species	Prey age, years	Age of predator-whiting, years					
		3	4	5	6	7	8
Sand eel	2	0,70	0,00	0,00	0,00	0,00	0,00
	3	0,00	0,38	0,00	0,00	0,00	1,00
	4	0,00	0,43	0,00	0,00	0,00	0,00
Sprat	I	0,26	0,09	0,00	0,00	0,00	0,00
Norway pout	I	0,00	0,14	0,97	0,81	0,00	0,00
Other food*	I	0,04	0,01	0,03	0,19	1,00	0,00
Total		1,00	1,00	1,00	1,00	1,00	1,00

* Food items, except fish and commercial invertebrates, are regarded as one taxonomic unit with age 1.