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The Distribution of Food Energy for Major Commercial Fisheries in the Trophic Chain of the Georges Bank Ecosystem

by

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Abstract

In the present paper food resources used for formation of major commercial fish stocks of Georges Bank and adjacent waters are delineated based on the food composition data for pelagic, near-bottom and groundfish species, and on the assumption that the consumed fish is proportional to the weight of the fish, and the principal feeding pattern is constant for a given ecological group of fish. Over a half (56%) of the total fish stock in the region in question is formed due to planktonic food resources, approximately 25% due to nektonic organisms - the fish and cephalopods, and only 14% due to benthos mainly represented by the bottom crustaceans as fish food. 5% of the total fish stock feed on the other and non-identified organisms.

Introduction

A concept of regulation of an ecosystem as a whole based on intraspecific interrelationships was adopted quite recently (Edwards, 1976; Gulland, 1977, 1978), although the complexity of this problem arose as early as in the sixties (Borutsky, 1960). The methods for assessment of multispecific stocks developed in the recent years are resting upon a hypothesis that the increase of one stock is compensated for by the losses of the other (Hobson, Lenarz, 1977; Daan, 1979).

Generally speaking, the stocks of major groundfish and pelagic species inhabiting the waters of the eastern US coast drastically reduced during 1960-1970 (Edwards, 1970; Clarck,

Brown, 1977, 1978; Grosslein et al., 1978). Although the change of the abundance of the majority of fish species can undoubtedly be related to heavy exploitation, there are some exceptions, according to the above authors, showing that the increased abundance of, for instance, white hake lately resulted from reduced numbers of the other groundfish, the increased abundance of mackerel coincided with a failure in herring abundance, and the increased abundance of the squids can be regarded as a response to a decrease of pelagic and near-bottom fish stocks.

The accumulation of the planktonic food is not a decisive factor for replacement of pelagic species by the groundfish ones, but the redistribution of the energy flux passing through the ecosystem makes it realistic (Andersen, Ursin, 1978; Jones, Richards, 1976). So, Jones and Richards (1976), using the model of the total energy flux, demonstrated that the increased requirements of the groundfish in food, as a result of their increased abundance, can be satisfied at the expense of the food energy released from the reduction of biomass of the pelagic fish species.

Materials and Methods

The data of long-term feeding studies for major massive fish species of Georges Bank and adjacent waters obtained primarily during the joint USSR-USA trawling surveys in 1968 through 1974 were used in this paper. Food composition for different groups of the fish and the role of various food organisms in formation of their biomass are discussed (Vinogradov, 1983) (table 1). The calculations are based on the assumption that the formation of the biomass of one or another species is proportional to utilization of one or another group of food organisms, and they do not involve rates of assimilation or digestion of food. Another assumption is that the major pattern of feeding of the given ecological group of fish is constant.

The author assumes that, although rough, these calculations still allow to determine as a first approximation the major

food resources used for formation of the fish stocks on Georges Bank and in the adjacent waters, and to follow variations in the utilization of these resources due to non-regulated fishery.

Results

Our studies showed (table 1) that over a half (56%) of the fish stock in the region in question is formed due to planktonic food resources, approximately 25% due to nektonic organisms - the fish and cephalopods, and only 14% due to benthos, mainly represented by the bottom crustaceans. 5% of the total fish stock feed on the other (algae, detritus) and non-identified organisms.

The bulk of the fish biomass is formed at the expense of the food resources in the pelagial - plankton and nekton (mainly small fish feeding on plankton, and to a lesser degree the squids, also consuming the crustaceans and fish) (Vinogradov, Noskov, 1979). Only the seventh part of food for the fish is composed of the benthic organisms - mostly of the bottom crustaceans.

Over 80% of the biomass of the pelagic fish is formed due to utilization of the planktonic crustaceans, mainly euphausiids (41%) and copepods (26%); the 3/4 parts of the biomass of the near-bottom fish is formed due to consumption of the nekton-the fish and cephalopods, and almost 60% of the groundfish biomass is formed at the expense of the benthic food resources.

The variations in the biomass of the most massive pelagic (herring, mackerel) and near-bottom (hake, spiny dogfish, red hake) fish indicate that the depletion of the hake, red hake and herring biomass (fig. 1) resulted from the development and inadequate management of the fishery in the period from 1963-65 to 1968-69. The biomass of spiny dogfish, a non-commercial species, maintained at the same level, and a sevenfold increase of the mackerel biomass was observed (table 2). Further development of fishing for the pelagic fish species (herring, mackerel) by 1972-74 caused a still greater decrease of the herring bio-

mass, which by that time comprised only 10% of the estimate observed in the early sixties. The biomass of mackerel also reduced (by 2.3 compared with 1968-69) , but still it was 3 times as large as in 1963-65. The decrease of the spiny dogfish biomass by 1972-74 can be attributed to a reduction of its major food organisms - the massive pelagic fishes, namely, herring and mackerel (Edwards, Bowman, 1978; Grosslein et al., 1978). At the same time the biomass of hake increased from 414 thous. t in 1968-69 to 523 thous. t in 1972-74. Thus hake became second to mackerel in terms of biomass (table 2).

The variations of the biomass of massive fish species resulted in certain changes of their roles as consumers of food resources. The main consumers of the plankton, in particular planktonic crustaceans (euphausiids, copepods), instead of herring, became mackerel and shortfin squids (Vinogradov, Noskov, 1979); the importance of hake as a consumer of the fish and squids increased by 1972-74, and the consumption of these food resources by the spiny dogfish decreased. Due to a sharp decrease first of the herring, and then of mackerel biomass, the consumption of the planktonic crustaceans fell more than twice; reduction in numbers of the spiny dogfish also resulted in a limited utilization of the fish and squids.

Since there exists a close relationship between the formation of stocks of major pelagic fishes and the planktonic food resources at early as well as later development stages, their biomass is evidently more sensitive to changes of the primary and secondary production. In this respect,the fish with mixed feeding, which pass from the plankton at early ages to the nektonic (hake) or benthic (red hake) organisms with the growth, are in more advantageous situation.

A reduction in numbers of the plankton-eaters promotes a better food supply for younger age groups of hake and partly red hake. A decrease of the biomass of such a predator as spiny dogfish, the feeding spectrum of which partly coincides with that of the hake, and which at the same time feeds even on the adult hake and red hake results in a better food supply for

older age groups of hake and red hake. This also holds for the benthos-eaters (haddock, big and little skates, yellowtail flounder).

Thus, the trophic conditions that established on Georges Bank are quite favourable for a rapid recovery of the hake and red hake provided that the rational fishing for those fish species is observed.

Conclusions

56% of the fish stocks on Georges Bank and in the adjacent waters are formed due to the planktonic food resources, 25% due to nektonic organisms - the fish and cephalopods, and only 14% due to the benthos, mainly represented by the bottom cephalopods. 5% of the total fish stock feed on the other (algae, detritus) and non-identified organisms.

Over 80% of the pelagic fish production is formed due to consumption of the planktonic crustaceans, primarily the euphausiids (41%) and copepods (26%), the 3/4 parts of the near-bottom fish biomass is produced at the expense of the nekton - the fish and cephalopods, and almost 60% of the groundfish production is formed due to benthic food resources.

A decrease of abundance of massive plankton-eaters (herring, mackerel), benthos-eaters (haddock, skates, yellowtail flounder) and predators (spiny dogfish) results in reduced consumption of plankton and nekton resources and increased food supply for hake and red hake. Favourable trophic conditions promote a rapid recovery of their stocks under regulated fishery.

References

ANDERSEN K.P., URSIN E.A., 1978. A multispecies analysis of the effects of variations of effort upon stock composition of eleven North Sea fish species. Rapp.P.-V.Reun.Cons.perm.int. Explor. Mer., 172, pp. 1-26.

BORUTSKY E.V., 1960. On the food base. Trans. of the Severtzev Inst. of Morph. of Animals, iss. 13, p. 5-61.

CLARCK S.H. and BROWN B.E., 1977. Changes in biomass of finfishes and squids from the Gulf of Maine to Cape Hatteras, 1963-1974, as determined from research vessel survey data. U.S. Fish. Bull., 75(1), pp. 1-21.

CLARCK S.H. and BROWN B.E., 1978. Trends in biomass of finfish and squids in ICNAF Subarea 5 and Statistical area 6, 1964-1977, as determined from research vessel survey data. Northeast Fish.Ctr., Woods Hole Lab., Woods Hole, USA. (MS to be published in Investigacion Pesquera).

DAAN N., 1979. A review of replacement of depleted stocks by other species and the mechanism underlying the such replacement - ICES. Symps. on biol. basis of pelagic fish stock management. No 24, pp. 1-29.

EDWARDS R.L., 1976. Middle Atlantic fisheries: Recent changes in populations and outlook. Amer.Soc.Limnol.Oceanogr. Spec. Symp., Vol. 2, pp. 302-311.

EDWARDS R.L., BOWMAN R.E., 1978. An estimate of the food consumed by Continental Shelf fishes in the region between New Jersey and Nova Scotia. Symposium on predator-prey systems in fish communities. July 1978. Atlanta, pp. 1-58.

GROSSLEIN M.D., LANGTON R.W., SISSENVINE M.P., 1978. Fluctuation in pelagic fish stocks of the Northwest Atlantic Georges Bank Region in relation to species interactions. ICES Symposium on the biological basis of the pelagic fish stock management. Aberdeen, Paper No. 25, pp. 1-52.

GULLAND J.A., 1977. Goals and objectives of fishery management. U.N., FAO Fish.Tech.Paper, No. 166, pp. 1-14.

GULLAND J.A., 1978. Fishery management: new strategies for new conditions. Trans.Amer.Fish.Soc., 107,pp.1-11.

HOBSON E.S., LENARZ W.H., 1977. Report of a Colloquim on the multispecies fisheries problem. June 1976. Marine Fisheries Review, 39(39), pp. 8-13.

JONES R., RICHARDS J., 1976. Some observations on the interrelationships between the major fish species in the North Sea. ICES C.M. 1976/F: pp. 1-35.

VINOGRADOV V.I., NOSKOV A.S., 1979. Feeding of short-finned squid Illex illecebrosus and long-finned squid, Loligo pealei, off Nova Scotia and New England, 1974-1975. ICNAF Sel.Pap. No. 5, pp. 31-36.

VINOGRADOV V.I., 1983. Food relationships between silver and red hake and other fish species on Georges Bank and in adjacent waters. NAFO SCR Doc. 83/IX/80, Ser. No. 746, pp. 1-21.

Table 1 The role of different groups of food organisms in formation of the fish biomass of Georges Bank and adjacent waters in 1972-74 (mean annual value)

Group of fish / Groups of food organisms	Pelagic		Near-bottom		Groundfish		All fish	
	thous. t	%	thous. t	%	thous. t	%	thous. t	%
Copepods	620.0	26.2	-	-	-	-	620.0	14.3
Euphausiids	968.4	40.9	128.9	10.9	8.6	1.1	1105.9	25.6
Other planktonic crustaceans	335.7	14.2	1.4	0.1	0.4	+	337.5	7.8
Sagitta	149.0	6.3	-	-	-	-	149.0	3.4
Larval fish	28.6	1.2	-	-	-	-	28.6	0.7
Other plankton	160.9	6.8	-	-	-	-	160.9	3.7
Total plankton	2262.6	95.6	130.3	11.0	9.0	1.1	2401.9	55.5
Polychaeta	-	-	4.5	0.4	85.6	11.1	90.1	2.1
Shrimps	-	-	28.0	2.4	14.5	1.9	42.5	1.0
Amphipoda	30.0	1.3	12.2	1.0	93.2	12.0	135.4	3.1
Other bottom crustaceans	-	-	75.2	6.4	123.6	16.0	198.8	4.6
Molluscs	-	-	14.2	1.2	5.8	0.7	20.0	0.5
Echinodermata	-	-	6.5	0.5	109.9	14.2	116.4	2.7
Other benthos	-	-	-	-	7.9	1.0	7.9	0.2
Total benthos	30.0	1.3	140.6	11.9	440.5	56.9	611.1	14.2
Cephalopods	-	-	123.6	10.5	32.3	4.2	156.0	3.6
Fish	73.5	3.1	785.7	66.5	73.2	9.5	932.3	21.6
Total nekton	73.5	3.1	909.3	77.0	105.5	13.7	1088.3	25.2
Other and non-identified organisms	-	-	1.4	0.1	217.9	28.3	219.3	5.1
Grand total	2366.1	100.0	1181.6	100.0	772.9	100.0	4320.6	100.0

Table 2 Consumption of planktonic, benthic and nektonic food resources by major commercial fishes at different time periods in Georges Bank and adjacent waters region (fish biomass is given according to Edwards, Bowman, 1978)

Period		1963 - 1965					
Groups of food organisms	1	Biomass formed due to consumption of groups of food organisms, thous.t	including, %				
			herring	mackerel	hake	spiny dogfish	red hake
Planktonic crustaceans	2	3796	84	10	5	1	+
Other planktonic organisms	3	458	86	14	-	-	-
Benthic and nekto-benthic organisms	4	177	-	2	3	-	95
Fish	5	1604	-	-	47	48	5
Squids	6	260	-	-	23	69	8
Other	7	23	-	-	-	-	100
Total fish biomass, thous. t	8	6318	3566	472	999	1002	279

1	1968 - 1969						1972 - 1974					
	Biomass formed due to consumption of groups of food organisms, thous.t	including, %					Biomass formed due to consumption of groups of food organisms, thous.t	including, %				
		herring	mackerel	hake	spiny dog-fish	red hake		Herring	Mackerel	Hake	Spiny dog-fish	Red hake
2	3878	26	71	2	1	+	1575	18	75	6	1	+
3	582	22	78	-	-	-	233	15	85	-	-	-
4	172	-	11	1	-	88	83	-	9	3	-	88
5	1158	-	-	27	69	4	696	-	-	56	41	3
6	222	-	-	11	83	6	103	-	-	31	63	6
7	15	-	-	-	-	100	7	-	-	-	-	100
8	6027	1137	3266	414	1024	186	2697	310	1418	523	362	84

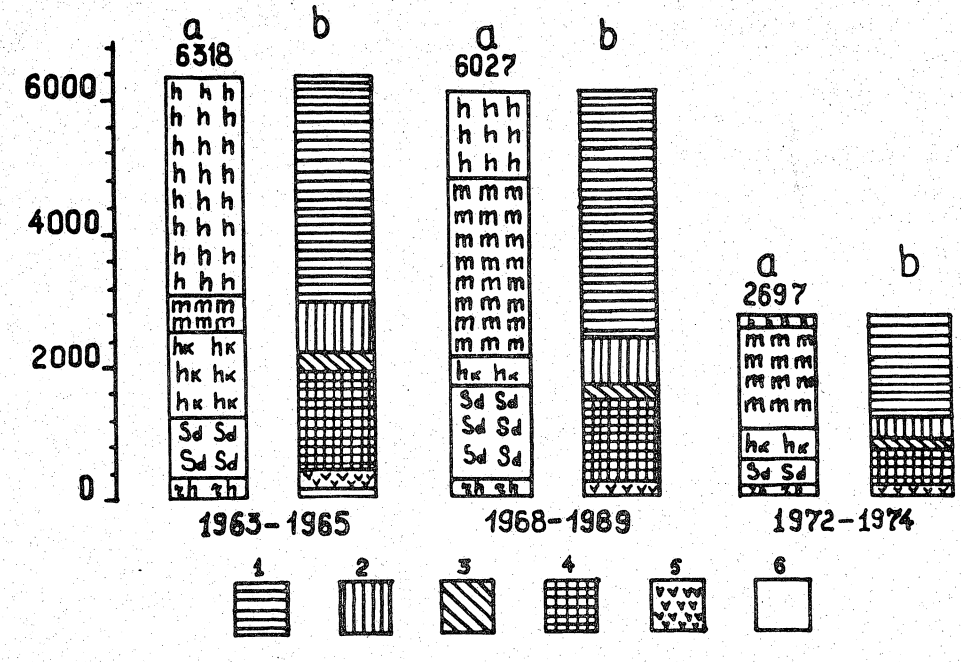

Fig. 1. Variation of the fish biomass (a) and of consumed fish (b) during the 1963-1974 period, thous. t.

Symbols: h - herring; m - mackerel; hk - hake; sd - spiny dogfish; rh - red hake; 1 - planktonic crustaceans; 2 - other plankton; 3 - benthos; 4 - fish; 5 - squids; 6 - the other (algae, detritus) and non-identified organisms.