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On Two Types of Diurnal Vertical Migrations of Sea Fishes

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A B S T R A C T

A number of observations carried out on a diurnal station in the Newfoundland area reveals periodical changes in cod catches taken by a bottom trawl. At night catches increased and un the day - time they decreased. The periodicity of catches observed is related with feeding of cod on bottom organisms.

Sinking to the bottom in the day-time and scattering in water layers at night are very typical for cod and haddock behaviour. Just therefore catches of these fish species taken by a bottom trawl are larger in the day-time than at night, as a rule. The biological importance of cod and haddock diurnal vertical migrations is supplying with food. These fish move in water layers together with their travelling prey. In their turn, capelin, herring, Euphasiidae etc., the main food objects of cod and haddock, repeat diurnal vertical migrations of zooplankton, for instance of Calanoida. While surfacing at night Calanoida get in the feeding area where phytoplankton occur. But as small plankton Crustacea sink in the day-time they avoid plankton-eaters that search their prey mainly with their eyes. Getting into semi-lit deep layers by day, zooplankton find themselves in relatively safe conditions.

Changes in illumination are an orienting factor for all water animals performing diurnal vertical migrations (Konstantinov 1958, 1964a); in the process of evolution there developed an adaptive reaction to illumination. Such a reaction enables the water animals to get into the feeding or safe layers in proper time. Similarly, almost indefinable differences in the chemical composition of river water enable the diadromous salmon to find a way in "their" stream and insignificant fluctuations of sea water temperature predetermine areas to which capelin will migrate to spawn (Konstantinov 1964b, 1965, 1967; Prokhorov 1965).

However it is known that sometimes cod and haddock perform diurnal vertical migrations of another, quite opposite, type: at night they migrate to depths and in the day-time they surface. In such cases catches taken by a bottom trawl at night are greater than those obtained in the day-time (Kopytov 1955; Jones 1956). For the first time both types of cod diurnal vertical migrations are essentially described by Brunel (1963, 1965).

The authors of the given paper carried out regular expeditions to reveal reasons making cod conduct sometimes diurnal vertical migrations of the first type and sometimes of another one.

In 1964-1968 there were made diurnal stations in North-West Atlantic on board the research vessels ("Sevastopol","Novorossiisk", "Rossiya"). A number of trawlings of equal duration was carried out on each station along the constant course (near the buoy). All the cod caught were measured and stomachs of 10 small fishes (less than 50 cm in length) taken from each catch were fixed in formalin solution, those of 10 average-sized specimens (51-70 cm) and of 10 large fishes (more than 70 cm). Later the content of stomachs fixed was analysed in the laboratory on shore.

A comparison of all results showed that diurnal vertical migrations of the second type (at night to the ground, in the day-time in water layers) are performed by cod while feeding on bottom animals. Data obtained by us on one of diurnal stations (on March 3-5, 1967, near the buoy in 48°35'N and 50°32'5"W) are given below.

Fig.1 shows that catches taken by a bottom trawl at night were larger than those taken in the day-time. Consequently, at night cod stayed closely to the ground. To characterize a value of main food objects for cod we applied an index often used by the Soviet ichthyologists: it is a partial index of stomach fullness. The weight of any food object found in the stomach of a fish analysed is divided into the weight of this fish; a result of dividing - a partial index of stomach fullness - is expressed in parts per ten thousands (‱). Using this index one can compare the food value of any object in different fishes or in various samples (sets) even when fishes studied are different by their weight. For the first time a partial index of stomach fullness was introduced into practice by L.A.Zenkevich and V.A.Brotskaya (1931).

In stomachs of cod caught by us on a diurnal station there were found both the bottom and actively swimming animals. To find out what animals affect the behaviour of feeding cod to a greater extent, it is necessary to take into account not only a partial index of stomach fullness but also frequency of occurrence (i.e. the ratio of a number of stomachs containing a certain food object to the whole number of stomachs in a sample). As it is evident from Table 1, actively swimming animals (for instance, capelin) were found in a smaller number of stomachs compared to bottom animals. When studying the feeding of fish the Soviet ichthyologists (Komarova 1939; Zatsepin 1939) used long ago one more index - significance index; this index also includes a partial index of stomach fullness and frequency of occurrence being their geometric mean (in other words, when "a" is an index of stomach fullness, "b" is frequency of occurrence, then $\sqrt{ab}$ is significance index).

Comparing significance indices for bottom and actively swimming animals one can be convinced that cod caught on a diurnal station were mainly feeding on bottom animals (Table 1).

The fact that cod feeding on such animals remain near the bottom at night is easily explained. Cod is a night and crepuscular predator; as aquarium observations showed (Tarverdieva 1962; Woodhead 1965), at night cod move and feed more actively than in the day-time. That is why when feeding on animals moving to water layers cod swim to the surface together with these animals at night (changes in intensity of illumination serve as an orienting factor). In other words, feeding on actively swimming animals cod conduct diurnal vertical migrations of the first type. On the contrary, when feeding mainly on bottom animals cod remain near the ground at night and scatter in water layers in the day-time, i.e. they carry out diurnal vertical migrations of the second type.

It is essential to note that bottom animals play a smaller role in a diet of the Barents Sea cod than in that of the North-West Atlantic cod (Turuk 1968). In connection with such a difference in feeding of the Barents Sea cod conduct more often diurnal vertical migrations of the first type and the cod in North-West Atlantic mainly perform those of the second type. These features of cod behaviour are very essential for their fishery by a bottom trawl.

Many fish species, as redfish, herring, argentine, luminous anchovy etc., feed only in water layers and never take food from the bottom. Diurnal vertical migrations of the first type (moving upwards at night and sinking to depths in the day-time) are common to all these fishes. For instance, bottom trawl catches of redfish are always greater in the day-time (Konstantinov and Scherbino 1958; Templeman 1959).

So, the biological importance of diurnal vertical migrations for fish is supplying with food; periodical changes in illumination serve as an orienting factor. The other environmental conditions (temperature, salinity etc.) are not motive force for diurnal vertical migrations though in some cases they can be limited, for instance, when a sharply pronounced thermocline is observed. As Tables 2 and 3 show, on the diurnal station represented by us the temperature and salinity both near the bottom and in water layers were either almost unchanged or fluctuated without any certain periodicity.

Table 1

Food composition of cod caught on a diurnal station

No. of trawling	Time of trawling (hours, minutes)	Date of trawling	Pelagic animals (Mallotus, Themisto)			Bottom animals (Polychaeta, Isopoda, Cumacea, Amphipoda, Decapoda, Mollusca, Ophiurae)		
			Partial index of stomach fullness, in $^{o}/ooo$	Frequency of occurrence in stomachs, in %	Significance index	Partial index of stomach fullness, in $^{o}/ooo$	Frequency of occurrence in stomachs, in %	Significance index
I0I	$2I^{I0}$ - 22^{I0}	March 3	874,I	I3,3	I07,8	63I,6	90,0	238,4
I02	00^{I0} - $0I^{I0}$	March 4	873,9	33,3	I70,5	539,I	96,6	228,2
I03	04^{55} - 05^{55}	"	332I,2	60,0	446,3	728,6	83,2	246,2
I04	$I0^{I0}$ - II^{I0}	"	239,9	43,3	I0I,9	629,2	96,6	246,5
I05	$I4^{00}$ - $I5^{00}$	"	85I,9	30,0	I59,9	436,5	86,6	I94,6
I06	$I7^{35}$ - $I8^{35}$	"	446,4	I0,0	66,8	968,I	I00,0	3II,I
I07	$2I^{I0}$ - 22^{I0}	"	720,I	43,3	I76,6	339,4	86,6	I7I,4
I08	00^{25} - $0I^{25}$	March 5	73,5	20,0	38,3	668,3	93,2	249,6
I09	03^{35} - 04^{35}	"	489,5	26,6	II4,I	775,3	90,0	264,I
II0	07^{05} - 08^{05}	"	4,6	30,0	II,7	700,0	I00,0	264,6

Table 2

Water temperature on a diurnal station, in °C

Depth, in m	23hr. 40 min. March 3	04 hr. 25 min. March 4	09 hr. 37 min. March 4	13 hr. 30 min. March 4	16 hr. 49 min. March 4	20 hr. 40 min. March 4	00 hr. 10 min. March 5	3 hr. 10 min. March 5	6 hr. 20 min. March 5
0	-I,67	-I,66	-I,67	-I,60	-I,60	-I,64	-I,66	-I,66	-I,66
20	-I,64	-I,66	-I,68	-I,64	-I,65	-I,64	-I,65	-I,65	-I,66
50	-I,70	-I,66	-I,64	-I,59	-I,64	-I,6I	-I,64	-I,66	-I,69
75	-I,64	-I,64	-I,57	-I,58	-I,6I	-I,60	-I,6I	-I,62	-I,65
I00	-I,5I	-I,55	-I,58	-I,55	-I,56	-I,56	-I,57	-I,60	-I,64
I50	-I,44	-I,55	-0,84	-0,55	-I,64	-I,02	-0,68	-I,36	-I,44
200	0,3I	0,I6	-0,I2	-0,0I	-0,24	-0,2I	-0,20	-0,3I	-0,40

Table 3

Water salinity on a diurnal station, in $^{o}/oo$

Depth, in m	23 hr. 40 min. March 3	04 hr. 25 min. March 4	09 hr. 37 min. March 4	13 hr. 30 min. March 4	16 hr. 49 min. March4	20 hr. 40 min. March 4	0 hr. 10 min. March 5	3 hr. 10 min. March 5	6 hr. 20 min March 5
0	32,72	32,72	32,70	32,72	32,73	32,73	32,73	32,7I	32,74
20	32,73	32,7I	32,7I	32,90	32,73	32,73	32,73	32,7I	32,73
50	32,79	32,69	-	32,79	32,76	32,78	32,75	32,73	32,75
I00	32,89	32,86	32,83	32,85	32,82	32,84	32,83	32,80	32,76
200	33,38	33,35	33,25	33,32	33,24	-	33,26	-	33,2I

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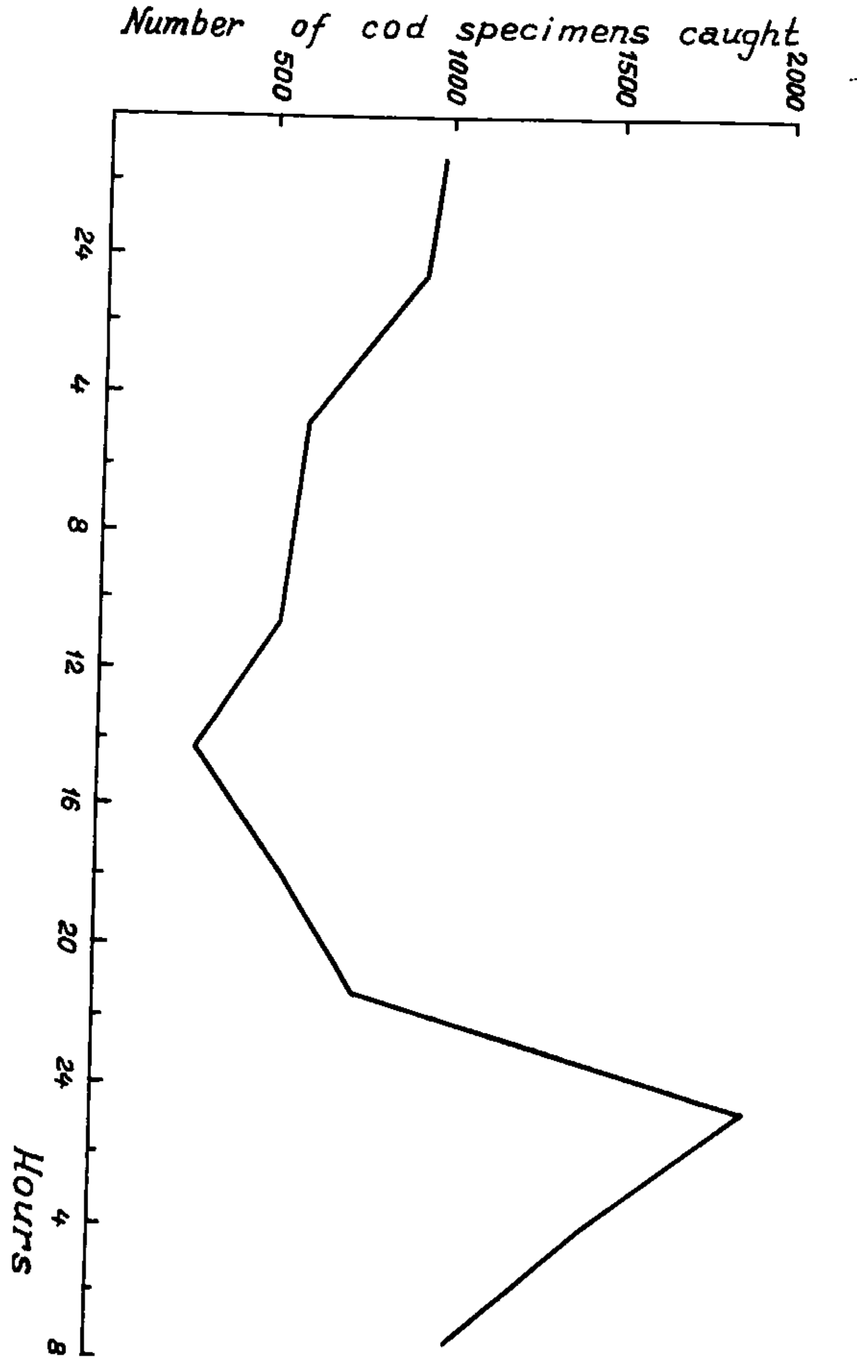

Fig. 1

Fig. 1. Cod catches per 1 hour trawling taken by a bottom trawl on a diurnal station.