Analysis of seasonality in trophic relationships of true seals (*Phocideae*) in the White Sea

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Abstract

The analysis of interspecific trophic relations of true seals in the White Sea on the basis of long-term study, done on feeding, is shown. Main finding is that the ringed and bearded seals have no competitive interrelations. Contrastingly, the harp seal had an impact on background seals, intensity of the competition was, however, insignificant due of harp seal seasonal stay in the White Sea. The ice-free seals, *i.e.* grey and harbor seals, did not show a trophic competition with ice-liking seals thanks to seasonality of stay in the White Sea and insignificant number. The trophic competition of these seals to other pinnipeds is possible at restoration of areas.

Key words: diet, qualitative feeding structure, trophic competition, seals activity

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Introduction

Studying of feeding of marine mammals that are at top of a trophic pyramid in marine ecosystems is motivated by their influence on marine bioresources. It is important especially for the species that have high numbers and a wide distribution. The trophological studies represent an important part of ecosystem approach applied to assess ecological capacity of Arctic seas.

Generally, the White Sea is estimated as a mesotrophic reservoir with sufficient stocks of fishes and invertebrates potentially available for marine mammals feeding. Since the White Sea represents almost closed reservoir, its uniqueness of could be characterized by the following features: a) alternation of two well-distinguished and different periods: i) the period of high rate

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of vital processes, and ii) the period of limitation (pause); b) existence of the long-term pause close to a half of year at thermophilic species; c) existence of sharp transitions from one period to another (Svetochev et Svetocheva 2012).

These features limit food availability for consumers within a year, and thus can be considered limiting factors for marine mammals of the White Sea. It is obviously important to estimate the trophic links which can arise among background inhabitants of the Arctic seas – the true seals, potential alterations related to climate change expected in the region.

The areas of cyclonic and anti-cyclonic circulations arising in the White Sea assist changes in plankton concentrations, and, consequently, pelagic fishes and crustacean occurrence (Palenichko 1957). These factors form favorable conditions for fattening of seals in summer-autumnal season when availability of food becomes higher. Effects of seasonal cycles on dynamics of thermal balance correspond to biological cycles of the marine mammals living in the White Sea. Therefore, annual courses of climate parameters could be corelated to annual seasonal structure some other important parameters of an ecosystem (hydrological, and hydrochemical parameters such as *e.g.* water transparency, concentration of dissolved gases and others) in the White as well as in the Barents Sea. For trophic studies, therefore, it is useful to consider the following seasons: winter (the I quarter) – January-March, spring (the II quarter) – April-June, summer (the III quarter) – July-September, fall (the IV quarter) – October-December (Shavikin et Iljin 2010).

Background ice-liking species of seals occur in the White Sea during the whole year. This is true for a ringed seal (*Pusa hispida*) and a bearded seal (*Erignathus barbatus*). Contrastingly, the harp seal (*Phoca groenlandica*) lives within the White Sea in large quantities from November to May. Harbour seal (*Phoca vitulina vitulina*) and limited number of grey seal (*Halichoerus grypus*) come into internal areas of the White sea only in the summer (Table 1).

Name	**Categories protection (Red Book RF and Lists IUCN)***	**M (average) kg**	**Number in the White Sea (if there is) /Total biomass, kg**	**Categories in the White Sea**
Harp seal	IUCN (LR/lc)	110	1 million** (1 million) **** /14 million 300000	Seasonal migrant
Ringed seal	IUCN (LR/lc)	60	24000** /1 million 440000	local
Bearded seal	IUCN (LR/lc)	160	6000** /960000	local
Gray seal	Red Book RF (3), IUCN (LR/lc)	100	1–50*** (4500) **** /5000	Seasonal migrant
Harbour seal	Red Book RF (3), IUCN (LR/lc)	70	1–50*** (2500)**** /3500	Seasonal migrant

Table 1. The seals of the White Sea. *Note:* * Red Book RF [3]; Lists IUCN [2]; ** the number of evaluations [ICES2016 [1], Svetochev et Svetocheva 1995, Bondarev 2004]; ***the number of expert evaluations [Zabavnikov et al. 2007, Kovacs et al. 2009];**** number in the Barents Sea.

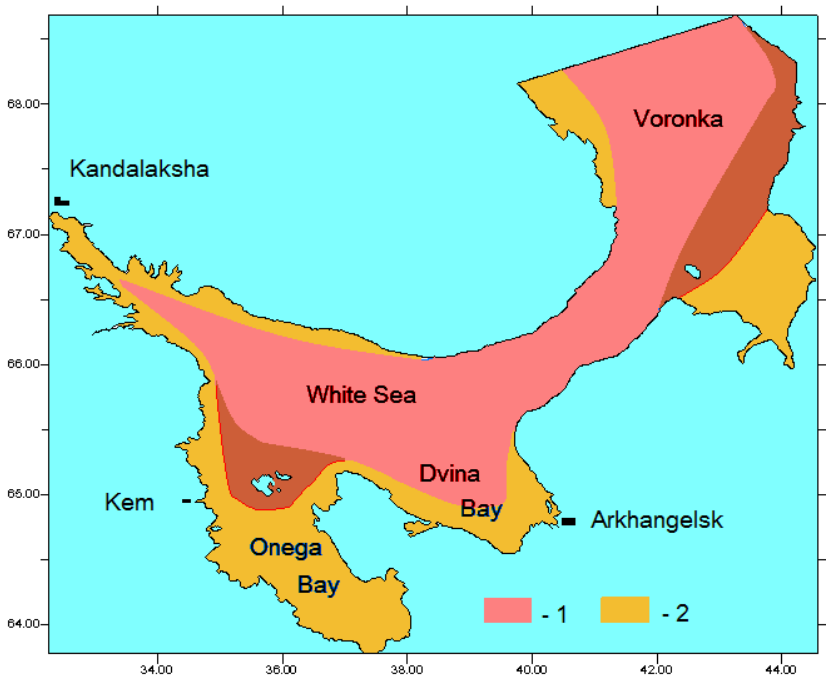

Fig. 1. Distribution of harp (1) and bearded (2) seals in the White Sea.

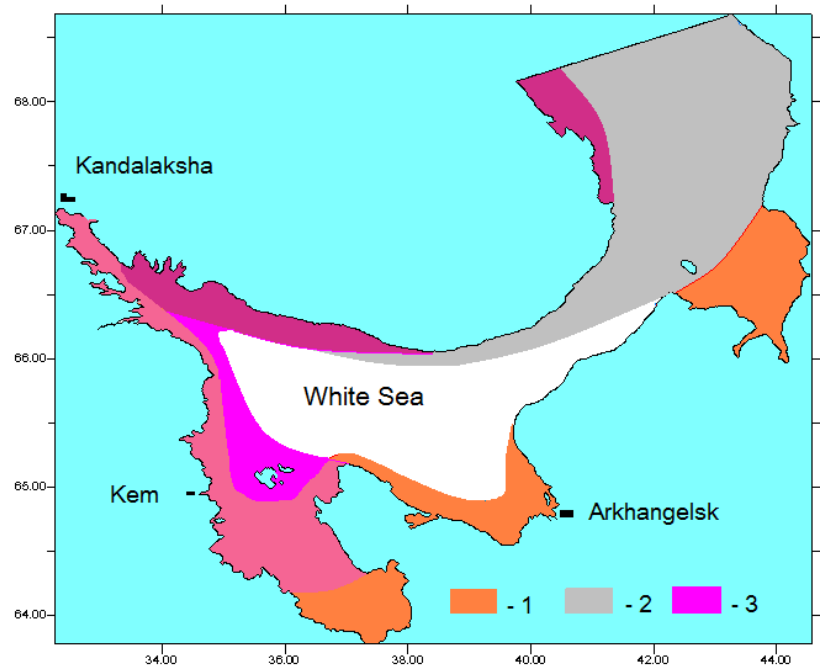

Fig. 2. Distribution of ringed (1), gray (2) and harbour (3) seals in the White Sea.

Typically, the harp seal is distributed in pelagic part of the sea on drifting ice. The species usually does not approach coast. In spring season, seals migrate to the Barents Sea on ice – *see* Fig. 1. The ringed and bearded seals live in the same coastal areas of the sea and round within the shelf. In winter, the ringed seal prefers land fast ice, and the bearded seal meets on land fast edge and on the drifting ice. The harbour and gray seals live near Kola peninsula coast. They drop in the White Sea after thawing of ice (Fig. 2).

During summer, harbour seal drop into inner bays (the Dwina and Onega Bays), whenever an expansion (or restoration) of sea ice-free area happens. The gray seal in the White Sea prefers the coast of the Kola peninsula and the Funnel (*see* Chapski (1976), Bichkov (1997), Potelov (1998). Thus, in the White Sea, two species of seals have the same habitat and inhabit it simultaneously within the course of the year. Another seal of mass lives in the open sea during a part of the year. Thermophilic (boreal) species are found in summer and tend to the restoration of the area.

Results and Discussion

Diet of the seals in the White Sea

Data about diet of the true seals in the White Sea recorded in the last 10–15 years were replenished with new additional data on qualitative and quantitative structure of fodders, features of seasonal feeding. Most of the information is related to ringed and harp seals. The qualitative structure of food of bearded seal was also replenished with new data. Data on feeding of harbour and gray seals in the White Sea, however, are not available so far.

The qualitative structure of ringed seal feeding is presented by 47 species and groups of animals, among which pelagic species number was 7, benthic-pelagic and benthic species reached 17 and 23, respectively. Among invertebrates, benthic and benthic-pelagic species prevailed. Among invertebrates with low occurrence frequency, there were *Nereis sp.* and *Anonyx nugax*, and shrimps of genera *Pandalus, Sabinea*. Some pelagics species might be found such as *e.g.* some shrimps and gipereids *Themisto*, having big specific weight in separate samples (Table 2, Fig. 3).

Among fishes, benthic and benthic-pelagic species are most widely presented. More frequent are fishes with small dimensions, having a leght of 9-12 cm long, like *e.g.* sandwort, navaga, capelin and goby. Polar and river flounder, smelts, liparis, *Pholis gunnelis*, *Zoarces viviparus*, and other fishes make insignificant relative share. Occurrence and number of stickleback have been studied insufficiently, however we suppose, that the 3-quill stickleback is dominating objects of seal fodder in the White Sea, and the 9-quill stickleback is usual in food as well (Svetocheva 2012).

Pelagic fishes are presented by herring and roll. The latter is of secondary importance in the White Sea though at winter seals consume mainly small vertebra herring. If they are not available, a navaga, a smelts, plaice and stickleback are consumed by seals Svetocheva et Svetochev (2010a). The ringed seal is labile in the diet and can feed on several dominating species simultaneously. Usually the seal consume those fodders, which finds in enough rates. In summer and in the fall, seal diet is more variable and includes fishes, crustacean and invertebrates.

The qualitative structure of diet of bearded seal in the White Sea is presented by crustacean, mollusca, worms and fish. All

they formed 25 species and several groups of the organisms living in different ecological zones (*see* Table 2, Fig. 3). Pelagic species are 4, benthic-pelagic reach 11, and benthic ones represent 10 species and groups.

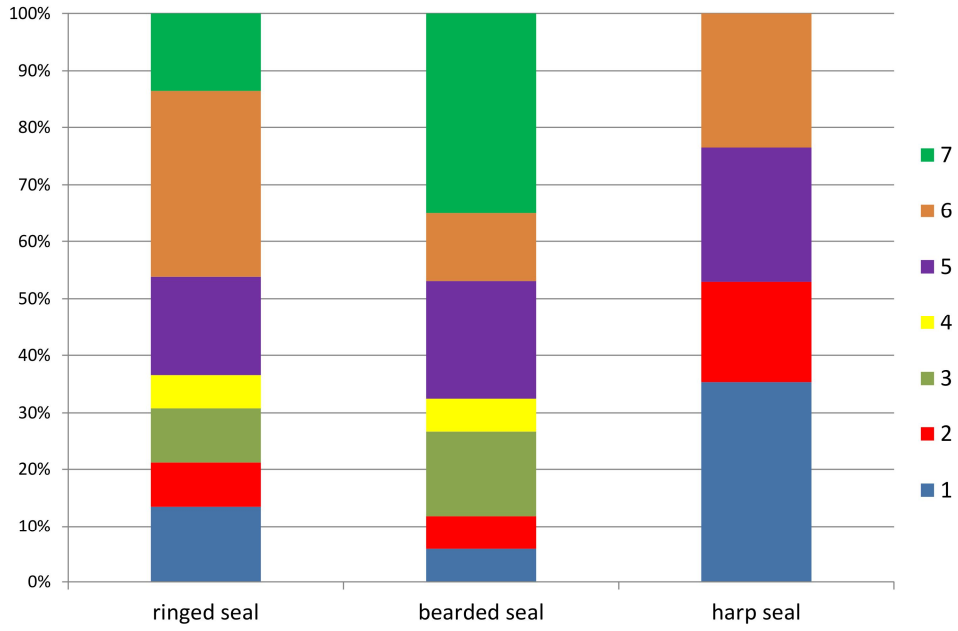

Fig. 3. Seals diet structure in the White Sea. A ratio of pelagic (1, 4), benthic-pelagic (2, 5) and benthic (3, 6) objects in the main groups of hydrobionts: crustacea (1, 2, 3), fishes (4, 5, 6), other invertebrates (7) (mollusca, polychaeta, hydroides, sea squirts, bryozoans, *etc.*), %.

Decapods, isopods, bivalve, smelts are considered dominating in feeding of bearded seal in the White Sea. The bearded seal hunts on salmon as well. In its diet, there are the loach, a whitefish, a bull-trout. During move of salmon, the bearded seal comes into the northern rivers (Potelov 1998, Lukin et Ognetov 2009). In the period of April-June (during destruction of ice fields), decapods (shrimps, a crab (*Hyas araneus*), goby, capelin, smelts, herring, navaga, flounder were found in food. However, domination of pelagic and benthic-pelagic shrimps (*Sclerocrangon, Crangon*) was typical. Among fishes, a benthic bull-calf-kerchak dominated. At the same time, pelagic amphipods (*Themisto libellula*), and also benthic-pelagic capelins and navaga are noted occasionally. In the summer, seals consume less actively since in the above-mentioned period. In their diet, however, endure a molt are included. At this time, all groups are presented in diet: fish, decapods, worms and molluscs. Most frequent are decapods. In the fall, the specific share of invertebrates increases, among crustacean, the pelagic shrimps and benthonic amfipoda (*Anonyx nugax)* prevail. Fish also makes a considerable share in food, like a bull-calf-kerchak, a navaga, a cod and a flounder (Svetochev et Svetocheva 2012, Svetocheva 2004, Svetocheva 2005, Svetocheva 2013).

Species	occurrence *				
	Bearded seal	Ringed seal	Harp seal	Gray seal	Harbour seal
hydroids	?	?			
crustaceans					
Crangon crangon	++	+	++		
Crangon septem spinosa		+	+		
Pandalus annulicornis		++	++		
Sclerocrangon borealis	++	+			
Sabinea septemcarinata	+	+			
Hyas araneus	++				
Eualus gaimardi		+			
Anonyx nugax	++	++	++		
Themisto libellula	+	++	++		
Themisto abissorum		+	+		
Gammarus sp.		+			
Gammarelles homari		+			
Mesidothea entomon	+	+			
Mysis oculata		+			
Tysanoessa inermis		+	++		
Decapoda (not determined)	++	+	+	+	+
Amphipoda (not determined)	++	+	+	+	+
other invertebrates					
Nereis virens	++	++			
Nereis pelagica	+	++			
Nereis sp.	+	+			
Metriolium senile	++				
Mya arenaria	++				
Buccinum sp.	+				
Cardium sp.	+				
bivalves (not determined)	+	+			
fish					
Coregonus lavaretus pidschian	+	?		+	+
salmon **	+	?		+	+
Clupea harengus pallasii	+	++		+	+
Ammodytes hexapterus marinus	++	++	++		
Pungitius pungitius		++			
Gasterosteus aculeatus		++			
Anarhichas lupus	+**	+**			
Pholis gunnelis		+			
Lumpenus fabricii		+			
Lumpenus sp.		+			
Lycodes sp.		+	+		
Zoarces viviparous		+			
Myoxocephalus scorpius	++	++	+		+
Myoxocephalus quadricornis labradoricus		+			
Gymnacanthus tricuspis		+	+		
Triglops murrayi	+	+			
Liparis liparis		++	+		
Liparis gibbus		+			
Liparis tunicatus		+			

Species	occurrence *				
	Bearded seal	Ringed seal	Harp seal	Gray seal	Harbour seal
Platichthys flesus bogdanovi	++	++			+
Liopsetta glacialis	+	++			
Platessa platessa		+			+
Limanda limanda		++			
Gadus morhua maris-albi	+	+		+	+
Eleginus navaga	++	++	+		
Boreogadus saida		+			
Mallotus villosus villosus	+	++	++	+	+
Osmerus eperlanus dentex n. Dvinensis	++	+	+		
echinoderms	?	?			
bryozoans	+	?			
sea squirts	+	+			

Table 2. Qualitative feeding structure of seals in the White Sea (based on data compiled from Chapski (1976), Potelov (1998), Svetocheva (2005), Potelov (1971), Svetocheva et Svetochev (2010b), Nilssen et al. (1995). *Note*: * ++ – common; + – uncommon; ** taken from the network; ? – may be found in food.

Winter feeding of bearded seal in the White Sea has not been studied yet. It is supposed, that fish has major importance at this time (navaga, and perhaps, herring). In general, priorities in seal diet change intra- and interseasonally. Fish has the greatest value in the fall, crustacean dominate during whole ice-free period, other invertebrates make an insignificant share. Mollusca weren't noted at all at summertime, perhaps, because of a small amount of samples (2 samples) in the summer. It is obvious that, unlike the Barents Sea, the share of fish fodders of bearded seal increases in the White Sea, and the share of mollusca – decreases.

Harp seal feeding in the White Sea is studied for the spring period since samples could be received only during catches. Data about winter feeding are not available. In general, it is considered the harp seal diet form mainly pelagic fishes and crustaceans. During spring, consumption of food by seals is low. The important for harp seal feeding in the White and Barents seas are pelagic species (11 species), then benthic-pelagic (15), and and benthic ones (16) making together only 42 species and groups) - Potelov (1998), Nilssen et al. (1995). The author´s observation made in the White Sea in the spring (April-May) for seals aged of 1 and more years on their food and selectivity was not too conclusive, however, fish and crustacean were the equivalent components (*see* Table. 2, Fig. 3). Seals are fed with amphipods, evfauziida, shrimps, bull-calves, smelts, capelin, sandwort and navaga. In this period, harp seals search for food throughout a water column from near-surface areas to the bottom. Among fishes, the predominating species are the capelin and a sandwort - Svetochev et Svetocheva (2008), Svetochev et Svetocheva (2009) and Svetochev (2010).

Food of a gray seal in the White Sea has not yet been studied, but is known, that the seals consume pelagic fish, including large ones, like herring, capelin, cod in the Barents Sea (Chapski 1976). Because seals in the White Sea meet within the Funnel, the Throat and Kandalaksha Bay (in the waters, near the Kola peninsula) occasionally, it is possible to assume that the gray seal can consume young cods, capelin, herring and salmon species of fish here (*see*

Table. 2). Feeding of harbour seal in the White Sea has not been studied. At the North Sea coast, cod, bull-calves, herring, flounder, seldom salmon and some other fishes were found in seal stomachs (*see* Table. 2) - (Chapski 1976).

Trophic competitive of seals in the White Sea

Feeding and trophic relations could be estimated, using the following indicators: selective ability, diet competition, plasticity, activity and diet potential. Research of qualitative diet structure of seals showed, that species consume hydrobionts according to the way of their life and behaviour. The ringed seal and the bearded seal are fed mainly in the intertidal zone (in a broad sense), the harp seal – in pelagial, and gray and harbour seals probably have a certain selectivity, preferring pelagic objects of a littoral complex. Ice-liking seals have high plasticity of feeding, freely changing the objects dominating in diet, depending on their availability. In particular, the ringed seal replaces a herring with the capelin, a sandwort, stickleback and polychaeta, the bearded seal easily replaces smelts by decapods and cod, and for harp seal diet selectivity in the White Sea is noted only for beaters (aged more of 1 year). The ringed seal and bearded seal are fed during the whole year, the periods of the compelled hunger are connected with abiotic and hydroweather conditions. The harp seal lives in the White Sea only during a part of year. In the spring season empty digestive tracts in samples can be found in 90% individuals. Gray and harbour seals come into the sea in the summer, perhaps, following a cod. Wide ranges of seal food allow to assume that the fodder capacity of the sea isn't too great. Besides, other possibilities of food supply for seals in the White Sea, are not studied since biomass and efficiency of a sandwort are still unknown. It is, therefore, rather difficult to express the trophic indicators stated above quantitatively, except for the trophic competition which is more convenient for estimating through numerical characteristics.

At unknown feeding base as the index showing the extent of the diet competition (EDC) of species the modified settlement indicator of C. V. Martino and M. S. Karapetkova (*see* Chuchukalo 2006) which is used for an assessment of the trophic interspecific competition of fishes:

$$EDC=a1/a2*d*dd1*dd2/100 \qquad Eqn.1$$

To estimate marine mammals daily diet, we used the average weight of fodder objects consumed per day, but not the size of a daily diet percentage of the body weight therefore this indicator can be expressed as follows:

$$EDC=(a1*dd2)/(a2*dd1)*d/100 \qquad Eqn.2$$

where EDC – extent of the diet competition; a1, a2 – seals biomass in the White Sea (kg); dd1, dd2 –daily diets (kg); d – coefficient of diet similarity (Shorygin coefficient, *see* Chuchukalo (2006) or the sum of the smallest percent of the general for two species of fodder objects (%).

Calculation of the general biomass for each seal was done using average body weight and the numerical structure received by direct accounts or an expert assessment (*see* Table. 1). Results of calculations for an assessment of the trophic competition among seals in the White Sea are showed in Table. 3.

	Ringed seal	Bearded seal	Harp seal	Gray seal	Harbour seal
Ringed seal		4.2	**36.9**	0.006	0.004
Bearded seal	9.4		**63.2**	0.018	0.011
Harp seal	0.4	0.3		0.001	0.001
Gray seal	**466.6**	**645.1**	**8236.8**		5.9
Harbour seal	**703.5**	**855.8**	**11521.7**	12	

Table 3. Trophic competition of seals in the White Sea.

At ringed and bearded seals having similar ranges of diet, the competition was practically absent (less than 10 conditional units). The indicator of influence of ringed seal on bearded seal was higher, than the return indicator. It is possible to explain by higher number of White Sea of ringed seal individuals. Both seals species widely use benthic and benthic-pelagic hydrobionts, the share of mollusca in bearded seal diet is insignificant. However, the fishes and crustacean dominating in diet coincided only partially. If consider qualitative diet structure of seals in certain areas of the sea is considered, then they do not coincide. These features allow both seals species to coexist successfully on condition of preservation of number balance.

Seasonal distribution of ringed seal and bearded seal in different regions of the White Sea can not be mixed and is uniform in space. Our observations confirmed ringed seals bearded seal usually small in number in places of summer congestions (Svetochev et Svetocheva (1995), Svetocheva et Svetochev (2010b), Svetocheva et Svetochev (2011)). It is obvious there have to be certain locuses where bearded seals also regularly form congestions (for example, for rest), and such places can be found practically in all regions of the White Sea.

The ringed seal has no impact on the harp seal. However the feedback is very essential. It is obvious the high number of the harp seal and use of the mass species of pelagic and benthic-pelagic objects, same with ringed seal, has paramount value here. It is interesting the quantitative index of harp seal influence on bearded seal appeared higher, than on ringed seal. It is likely connected with a big difference in number of these seals. However, intensity of harp seal feeding in the White Sea is low. Thus, during the nursing period (summer-fall), a seal goes out to the Barents Sea. Therefore, fodder conditions for the seals who are constantly living in the White Sea do not change negatively.

Boreal or ice-free seals – gray and harbour seals do not compete with other seals. The return indicators of influence on them the ice-free seals were very high, however at insufficient information on qualitative diet structure of EDC points only to a full overshoot of boreal seals diet ranges by ice-liking species.

Dwelling of seals in almost closed White Sea with its final food supply causes a constant numerical ratio of populations and forcedness of seasonal migrations for separate species. Distribution of seals during different seasons of year has specific

features. They are: (1) different areas at constant inhabitants (of ringed and bearded seals) and the migrating harp seal, and also (2) distinction in distribution of ringed seal and bearded seal on places at coincidence of areas. All ice-liking seals use a large number of various hydrobionts in diet. Under such conditions, the competitive relations among seals is reduced. Therefore existence (or absence) of the competition and its intensity depend on a degree of similarity of qualitative structure of food and the sizes of populations of seals.

The assessment of the interspecific trophic competition among true seals showed existence of some intensity in the relations of harp seal with ringed and bearded seals. It is explained by the high number of the White Sea population of harp seal. However, seasonality of stay of this seal in the White Sea reduces intensity degree. Between ringed and bearded seals, the trophic competition is absent. Gray and harbour seals do not affect intensity in the relations with ice-liking seals only thanks to the insignificant number of individuals and seasonality of stay in the White Sea. However, high values of the indicator point suggest the possible competitive relations of ice-free seals with othes pinnipedians of their areas in the White Sea.

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