Fish Communities of the Upper Epipelagic Layer of the Bering Sea during the Period of Anadromous and Catadromous Migrations of Pacific Salmon

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In accordance with the BASIS program, expeditionary research on the upper epipelagic layers (0–50 m) of the western Bering Sea was carried out by scientists aboard the RV *TINRO* in autumn 2002–2003 and summer 2003. The methods of our investigations are reported by Temnykh et al. (2002). Here, we use trawl catch data from the *TINRO* surveys to describe the species composition of upper epipelagic fish communities during the period of salmon migrations in the western Bering Sea. In addition, we analyze the results of joint trawl fishing operations by Russian, Japanese, and U.S. vessels in autumn 2002, and discuss a number of methodological problems revealed by our findings.

In autumn, the number of fish species composing upper epipelagic communities was the same in 2002 and 2003 (48 species; 23–28 families; Table 1). However, the qualitative composition of species in these years was slightly different. The coefficient of Serensen-Chekanovsky, which is often used for comparing the qualitative composition of fauna (Kafanov and Kudryashov 2000), was 0.79. In summer 2003, the composition of upper epipelagic communities consisted of 52 species of fish and other nekton. This composition was only slightly different than in autumn 2002–2003. The Serensen-Chekanovsky coefficients were 0.70 for comparisons of summer and autumn surveys in 2003, and 0.78 for comparisons of summer 2003 and autumn 2002 surveys. Several species of fish caught only in summer 2003 were not listed in Table 1, that is: Salmonidae: *Salvelinus malma*; Hemitripteridae: *Hemitripterus villosus*; Psychrolutidae: *Malacocottus* sp.; Stichaeidae: *Stichaeidae* spp.; Icosteidae: *Icosteus aenigmaticus*; *and* Anarhichadidae: *Anarhichas orientalis.*

Table 1. A list of fish species captured during the BASIS survey by the RV *TINRO* in autumn 2002 and 2003. The year in parentheses indicates species was caught only in that year; species without indication of year were caught in both 2002 and 2003.

Family	Genus and species	Family	*Genus and species*
Petromyzonidae	*Lampetra tridentatus*; *Lampetra camtschatica*	Gasterosteidae	*Gasterosteus aculeatus*
Lamnidae	*Lamna ditropis* (2003)	Sebastidae	*Sebastes* sp.
Squalidae	*Squalus acanthias* (2003); *Somniosus pacificus* (2002)	Anoplopomatidae	*Anoplopoma fimbria*
Clupeidae	*Clupea pallasii*	Hexagrammidae	*Pleurogrammus monopterygius*
Engraulidae	*Engraulis japonicus*	Cottidae	*Gymnacanthus detrisus* (2003), *Hemilepidotus jordani* (2003), *H. sp.* (2002), *Melletes papilio, Myoxocephalus verrucosus, M. polyacanthocephalus, M.* sp. (2002), *Triglops pingelii* (2002), *T.* sp. (2002)
Salmonidae	*Oncorhynchus gorbuscha, O. keta, O. kisutch, O. nerka, O. tshawytscha*	Hemitripteridae	*Blepsias bilobus, Nautichthys pribilovius* (2003)
Osmeridae	*Mallotus villosus, Osmerus mordax dentex*	Agonidae	*Aspidophoroides bartoni* (2002), *Podothecus veternus, Pallasina aix* (2002)
Microstomiidae	*Leuroglossus Schmidt, Lipolagus ochotensis*	Cyclopteridae	*Aptocyclus ventricosus, Eumicrotremus orbis, E. birulai (2002)*
Notosudidae	*Scopelosaurus harryi*	Liparidae	*Liparis gibbus, Liparis* spp.
Anotopteridae	*Anotopterus nikparini* (2003)	Stichaeidae	*Leptoclinus maculates, Lumpenus sagitta* (2003)
Alepisauridae	*Alepisaurus ferox* (2002)	Zaproridae	*Zaprora silenus*
Paralepididae	*Lestidium ringens* (2003)	Ammodytidae	*Ammodytes hexapterus*
Myctophidae	*Diaphus theta, Stenobrachius leucopsarus, Tarletonbeania crenularis*	Anarhichadidae	*Anarchichtis ocellatus* (2003)
Gadidae	*Theragra chalcogramma, Boreogadus saida, Eleginus gracilis*	Pleuronectidae	*Hippoglossoides robustus, Reinhardtius hippoglossoides, Pleuronectidae gen.* sp. (2002), *Limanda sakhalinensis* (2002)
Scomberesocidae	*Cololabis saira* (2003)		

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Considering only the abundance of all species in the RV *TINRO* catches, our results confirm that the base of upper epipelagic fish communities was composed of about 10 species in autumn 2002-2003 and summer 2003 (Table 2). In autumn 2002, *Stenobrachius leucopsarus* (39.7%), *Theragra chalcogramma* (17.9%), *Oncorhynchus keta* (12.9%), *Pleurogrammus monopterygius* (10.9%), *O. nerka* (7.0%), and *Mallotus villosus* (6.6%) were the dominant species. In autumn 2003, there were no substantial migrations of mezopelagic fish in the upper epipelagic layers, which are usually associated with the characteristics of water dynamics (Radchenko and Ivanov 1997). At the same time, a large transport of pollock fingerlings (694.4 t) from the eastern Bering Sea to Anadirskiy Bay was observed. This is why, in comparison with autumn 2002, the base structure (94%) of dominant species in autumn 2003 had changed to *T. chalcogramma* (49.8%), *O. keta* (18.3%), *M. villosus* (13.7%), *O. nerka* (6.5%), *Leuroglossus schmidti* (3.8%), and *O. tshawytscha* (1.9%). The abundance of Pacific salmon was very high, and their total biomass was 563.1 t (21.8% of total for all species) in autumn 2002 and 399.1 tons (28.1% of total) in autumn 2003. The biomass of Pacific salmon was mainly composed of immature fish, which were concentrated in deep-water regions. In summer 2003, the biomass of Pacific salmon was large (842.3 t; 77.5% of total for all species). The large biomass of salmon was associated with high intensity inflow of Pacific water into the western Bering Sea in summer 2003, and was also observed from eastern to western parts of the region. During this period, the extremely high biomass of Pacific salmon was composed of both immature and maturing fish. Among Pacific salmon, *O. keta*, *O. nerka*, and *O. gorbuscha* were the dominant species, and *O. tshawytscha* also made up a considerable part of the catch. In summer 2003, the base structure (92.2% of dominant species) was composed of *O. keta* (63.0%), *P. monopterygius* (11%), *O. nerka* (7.8%), *O. tshawytscha* (4.7%), mezopelagic fishes (3.6%, approximately in equal share, *L. schmidti* and *S. leucopsarus*), and *T. chalcogramma* (2.8%).

According to Temnykh (2004), there has been a considerable increase (2–3 times) in the biomass of Pacific salmon in the western Bering Sea compared to the level of biomass in the 1980s and first half of the 1990s, and this is connected with an increase in the abundance of chum and sockeye salmon. Our investigations proved that in many respects Pacific salmon determined the structure of fish communities of the upper epipelagic layer in the western Bering Sea during autumn 2002 and summer-autumn 2003. The main result of our research was that in the upper epipelagic layer in the western Bering Sea there was a high total abundance of Pacific salmon within a low level of fish productivity, due to the decrease of pollock and Pacific herring resources.

In autumn 2002, for the first time we received data on comparative trawl catching ability during joint epipelagic surveys by Russian, U.S., and Japanese vessels (Tables 3 and 4). A comparative analysis of data on the structure of the catches, according to the results of consistent trawling, revealed a number of problems with the methods used to obtain primary data. We think that the methods used to conduct epipelagic surveys on U.S. and Japanese vessels decrease the scientific and applied value of the data for use in biocenosis investigations. The abundance of nekton, especially mezopelagic species, was greatly underestimated because U.S. and Japanese vessels trawled only during the day time. The trawl used by the *Northwest Explorer* had a small vertical spread that allowed fishing only in the upper 30-m epipelagic layer, which is not deep enough for salmon surveys. The distance between stations during Japanese research vessel surveys was too large (60-nm latitude and almost 100-nm longitude), which allows abundance to be estimated only for widely-spread and major species in the area**.**

Table 2. Composition, biomass (x 10^3 t) and ratio (%) of fishes (species and group) in the upper epipelagic layer (0–50 m) of the Russian part of the Bering Sea in autumn (August 31–October 10) 2002 and summer (July 15–August 24) and autumn (September 14–October 25) 2003.

	Autumn 2002		Summer 2003		Autumn 2003	
Species and group	Biomass (x 10^3 t)	%	Biomass (x 10^3 t)	%	Biomass (x 10^3 t)	%
Oncorhynchus keta	334.3	12.9	684.5	63	260.1	18.3
O. nerka	180.5	7	84.2	7.8	92.4	6.5
O. gorbuscha	26.1	1	18.8	1.7	15.6	1.1
O. tshawytscha	20	0.8	51.2	4.7	26.7	1.9
O. kisutch	2.2	0.1	3.6	0.3	4.3	0.3
Theragra chalcogramma	464.4	17.9	29.9	2.8	709.9	49.8
Pleurogrammus monopterygius	281.5	10.9	119.6	11.0	14.3	1.0
Mesopelagic fishes	1050.9	40.6	38.9	3.6	71.4	5.0
Mallotus villosus	171.4	6.6	2.7	0.2	195.2	13.7
Clupea pallasii	23.6	0.9	10.2	0.9	10.6	0.7
Lamna ditropis	4.9	0.2	6	0.6	5.7	0.4
Other fishes	27.3	1.1	36.3	3.4	17.9	1.3
Total fishes	2587.1	100	1085.9	100	1424.1	100
Number of trawl operations	78		71		71	

Ratios of the approximate abundance of salmon and juvenile Atka mackerel in catches by U.S., Japanese, and Russian vessels are given in Table 5. At first examination, these ratios could be considered as calibration factors that standardize the amounts of catches on different vessels. These coefficients could be used to correct estimates of the abundance of major species of nekton, when combining the results from all surveys in Bering Sea. However, the total number of operations for calibrating the trawls used by each ship was small, and that is why we consider the total value of the abundance of each species to be an approximate estimate. We need multi-dimensional experiments and a greater number of joint trawl operations to obtain more exact results in the future. In fact, it is very important to define the abundance ratios of all salmon species at different epipelagic depths. A multi-dimensional experiment with catches at different depth levels during a 24-hr period for many days at one station, perhaps, will permit us to obtain data on the vertical distribution of salmon and associated species of nekton.

Table 3. Research period and number of joint trawl operations used to compare trawl catches by three vessels in the Bering Sea, September 2002.

Vessels involved in synchronous research	Research period	Number of joint trawl operations
Northwest Explorer & *Kaiyo maru*	September 12–14	5
TINRO & *Northwest Explorer*	September 16–17	6
TINRO, *Northwest Explorer*, & *Kaiyo maru*	September 15	1

Table 4. Ratios of the main parameters of trawling (% by value fit with parameter of RV *TINRO*) for three trawl vessels used for BASIS cruises in September 2002.

Parameter of trawling	*Northwest Explorer*	*Kaiyo maru*	*TINRO*
Towing speed (knots)	89.5	116.8	100.0
Warps length, m	141.7	92.7	100.0
Vertical trawl mouth opening, m	45.9	135.6	100.0
Horizontal trawl mouth opening, m	143.1	158.9	100.0
Volume trawled during towing, km^3	58.4	251.1	100.0
Square trawled during towing, km^2	128.5	186.0	100.0

Table 5. Ratios of the abundance of salmon (*Oncorhynchus* spp.) and Atka mackerel (*Pleurogrammus monopterigius*) in catches by U.S. (*Northwest Explorer*), Japanese (*Kaiyo maru*), and Russian (*TINRO*) vessels (catches of RV *TINRO* adjusted to 100%). Inds. = number of individuals.

	Abundance							
	O. keta		*O. nerka*		*O. tshawytscha*		*Pleurogrammus monopterigius*	
Vessel	Inds./km^2	%	Inds./km^2	%	Inds./km^2	%	Inds./km^2	%
NW Explorer	774.0	65	62.0	187	12.0	37	12186	17
Kaiyo maru	1294.0	108	6.0	18	-	-	147333	208
TINRO	1194.0	100	33.0	100	32.0	100	70709	100
NW Explorer	875.0	76	33.0	92	16.5	63	4321	19
TINRO	1145.0	100	36.0	100	26.0	100	22762	100
NW Explorer	337.0	60	11.8	102	13.7	48	2241	15
Kaiyo maru	564.0	100	11.5	100	28.5	100	20609	100

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