



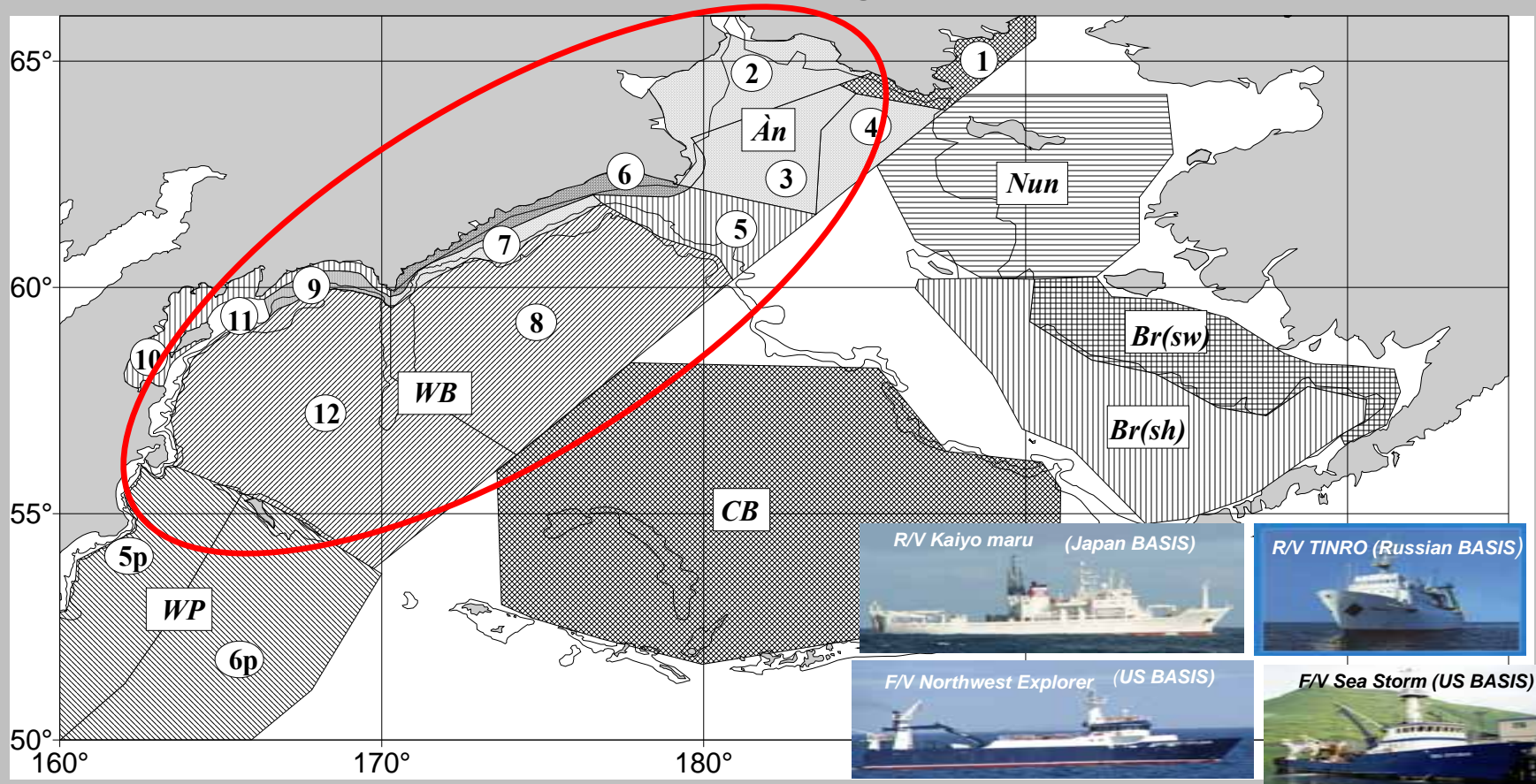
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2008

The Pacific salmon role in trophic structure of the upper epipelagic layer in the western Bering Sea during summer-autumn 2002–2006





Map of biostatistical regions of data executed in 6 surveys by TINRO-Centre on the R/V *TINRO*, *Sea Storm* and *Kaiyo maru* research vessels under the international research program BASIS (Bering-Aleutian Salmon International Survey) in the epipelagic layer of the western Bering Sea in 2002–2007.



In the Bering Sea: 1 - Bering Strait, 2 - northwestern Anadyr Bay, 3 - southeastern Anadyr Bay, 4 - eastern Anadyr Bay, 5 - Navarin region, 6 - Koryak shelf, 7 - Koryak slope, 8 - western Aleutian Basin, 9 - Olutorskiy slope, 10 - shelf of Karaginskiy and Olutorskiy bays, 11 - Karaginskiy slope, 12 - Commander Basin, 5p - Kamchatka Trench, 6p - oceanic waters off Kamchatka and Commander Islands, An - Anadyr Bay, WB - western Bering Sea basins, WP - oceanic waters near Commander Islands, CB - central deep Bering Sea, Nun - Nunivak region, Br(sw) - shallow area of Bristol Bay (< 50 m), Br(sh) - shelf zone of the Bristol Bay (> 50 m) (from Shuntov et al. 1986; Shuntov et al. 1988a, b; Volkov et al. 2004).

By results of 6 surveys by TINRO-Centre in the upper epipelagic layer of the western Bering Sea only for summer and autumn 2002–2006 are:

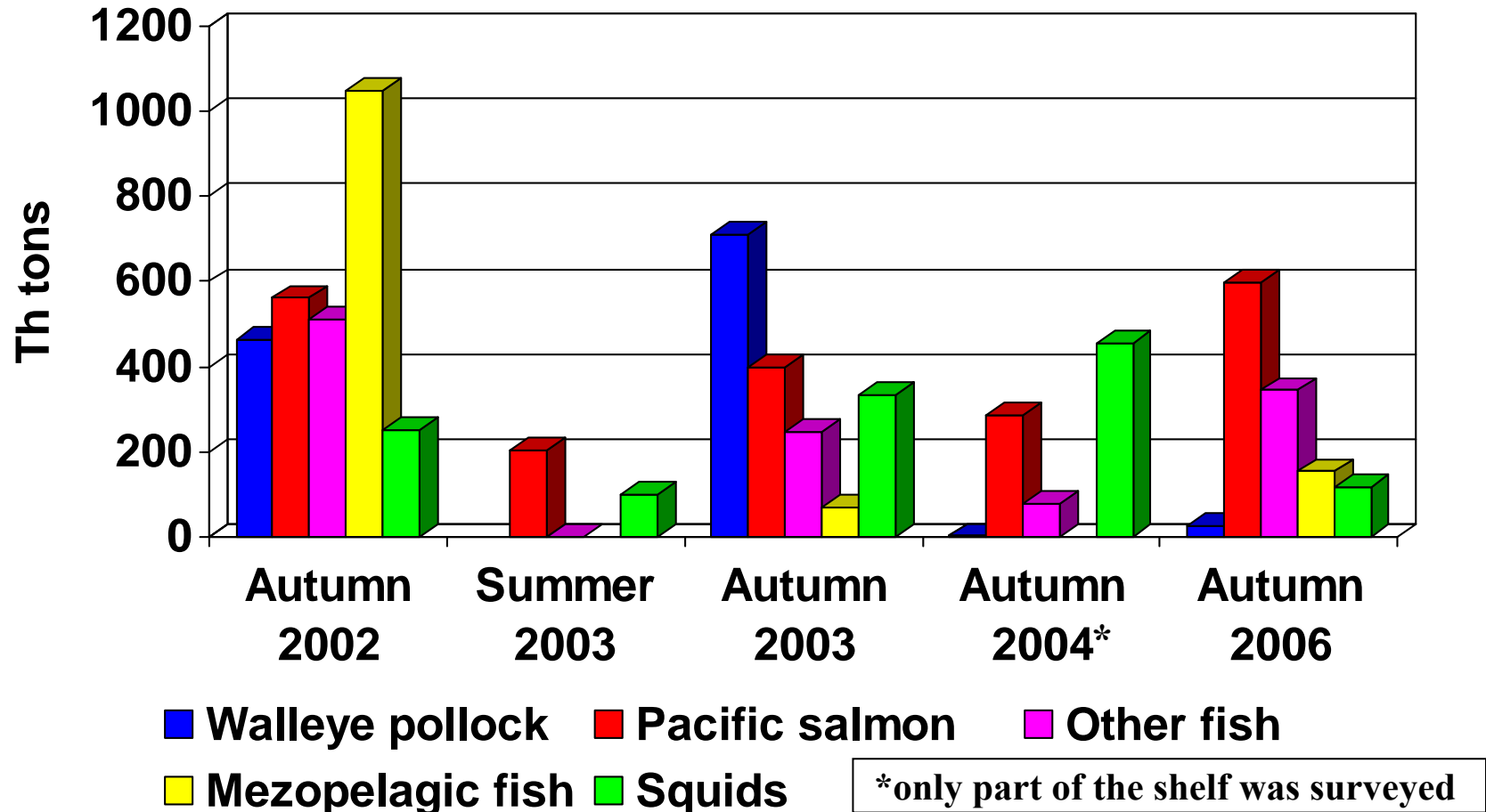
- ➡ The total quantitative estimates of nekton and plankton biomass has been obtained.**
- ➡ The information of salmon and nekton feeding and food supply for salmon (macroplankton and small nekton) has been collected.**
- ➡ The food relationships of nekton has been determined.**
- ➡ The consumption values of forage resources by salmon and other nekton species has been estimated.**
- ➡ The consumption values of forage resources has been accounted for 1986–1987, 1990 and 2002–2006 periods. The comparison of salmon role in ecosystem of the western Bering Sea in 1980 and 2000 has been made.**

1. Did the high level of Pacific salmon abundance affected trophic interactions in the western Bering Sea epipelagic communities?



2. Is carrying capacity of the upper epipelagic zone sufficient to sustain salmon in terms of food supply in the western Bering Sea ?

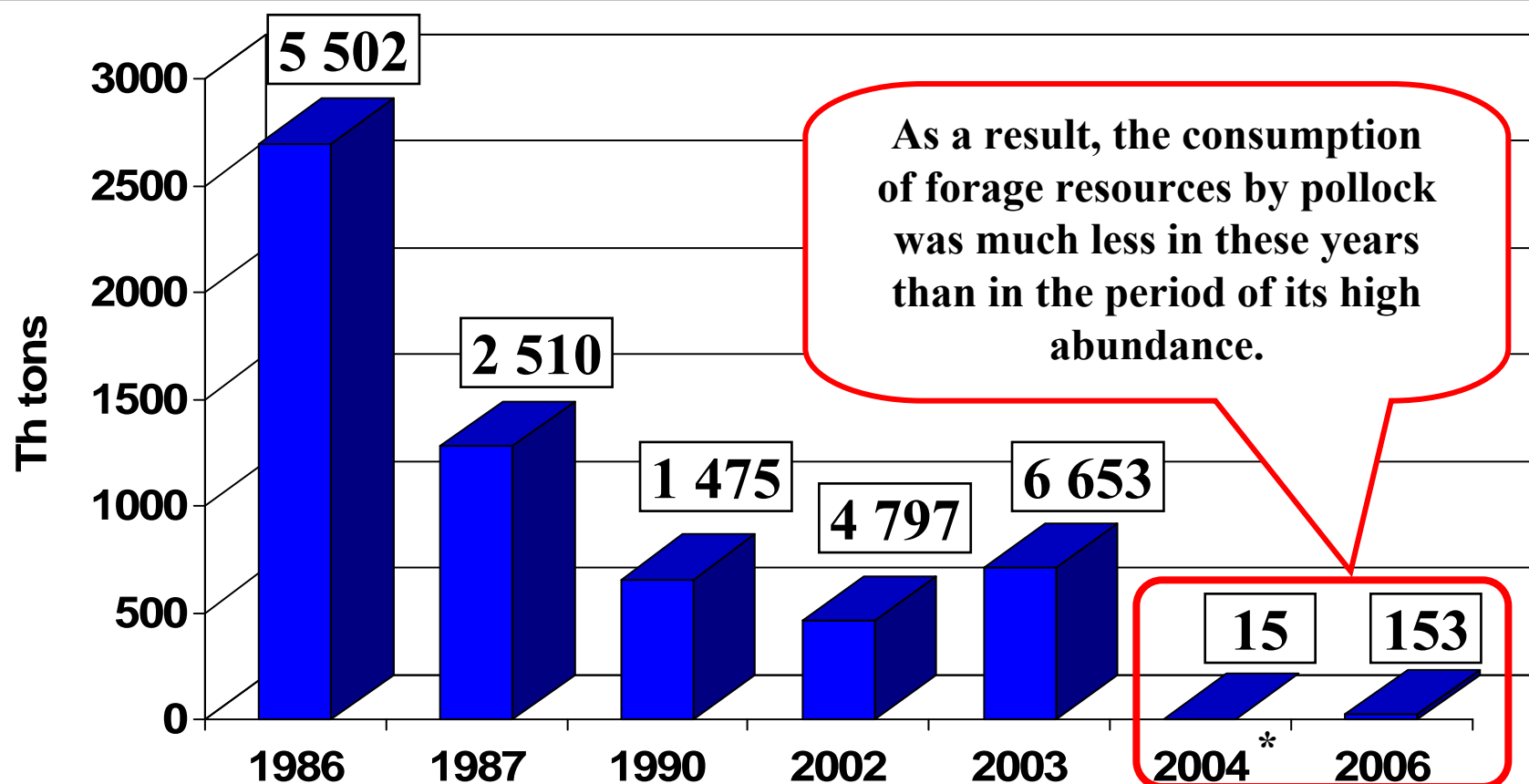
The nekton biomass (thousand tons) in the upper epipelagic layer in the western Bering Sea during summer 2003 and autumn 2002–2006 (from Shuntov et al. 1993; Shuntov & Sviridov 2005; Glebov et al 2006)



The epipelagic nekton community of western Bering Sea in summer-autumn period is formed by Walleye pollock, Pacific salmon, squids and also mezopelagic fish, capelin, atka mackerel and Pacific herring in the period of their high biomass. The biomass, physiological conditions, distribution, migrations these nekton groups and species determine the main trophic relationships in the epipelagic communities.

The walleye pollock' biomass and consumption (thousand tons) of forage resources by pollock in the upper epipelagic layer in the western Bering Sea during autumn 1986–1987, 1990 and 2002–2006

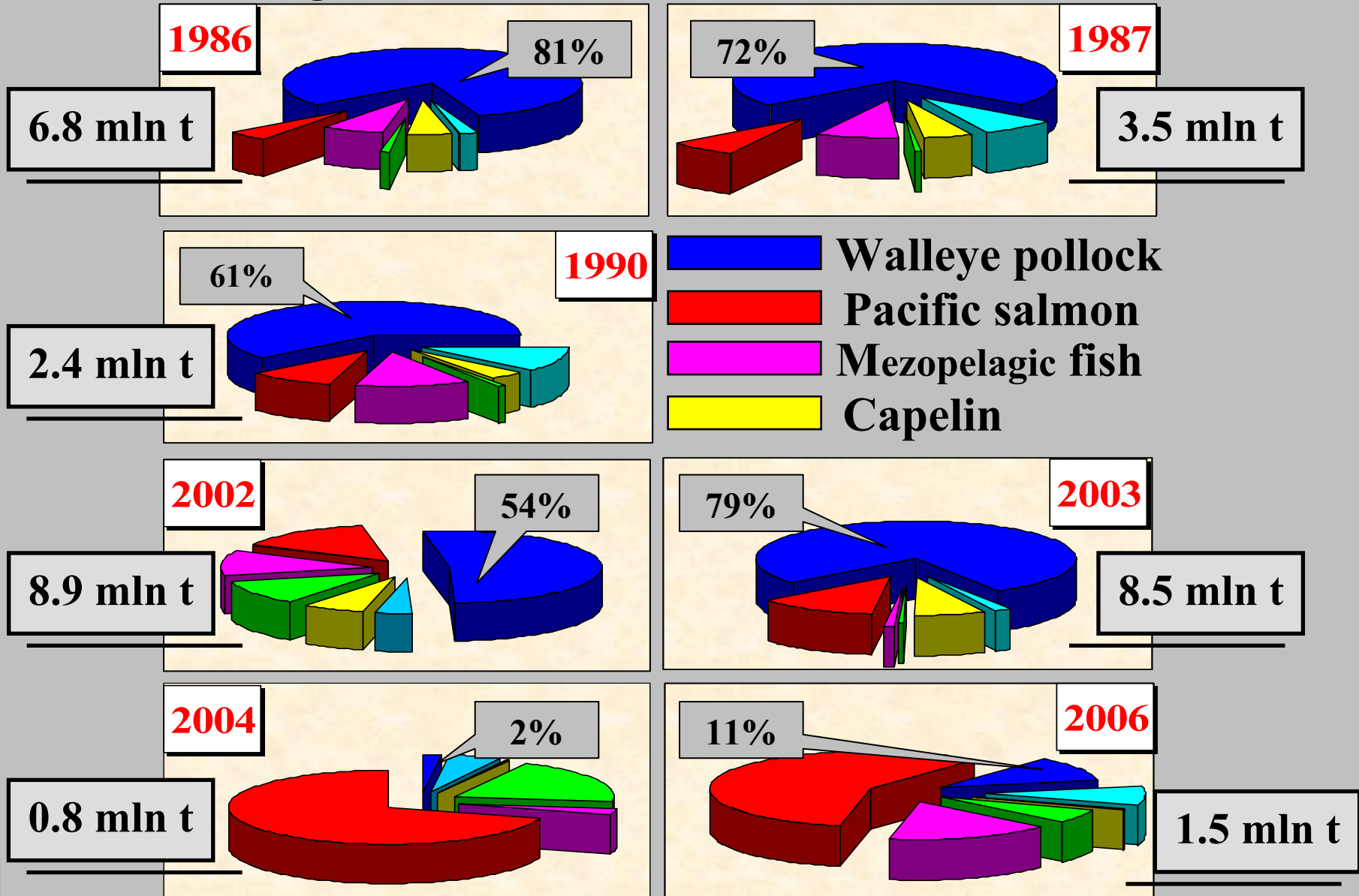
(from Shuntov et al. 1993; Shuntov & Sviridov 2005; Glebov et al 2006)



The pollock distribution in the western Bering Sea is very variable and depends on its stock and dynamical environmental conditions.

The juvenile pollock migrations in the northwestern part of Sea in 2004 and 2006 reduced considerably (Nikolaev & Stepanenko 2006).

The total consumption (million tons) of forage resources **by fish** in the upper epipelagic layer in the western Bering Sea during autumn 1986–1987, 1990 and 2002–2006



Consumption forage resources (thousand tons) **by**
Pacific salmon in western Bering Sea.

Autumn 1986

302 th t;

4%

Autumn 1987

235 th t;

7%

Autumn 1990

234 th t;

8%

Autumn 2002

1344 th t;

15%

Autumn 2003

1036 th t;

12%

Summer 2003

2354 th t;

65%

Autumn 2004

567 th t;

69%

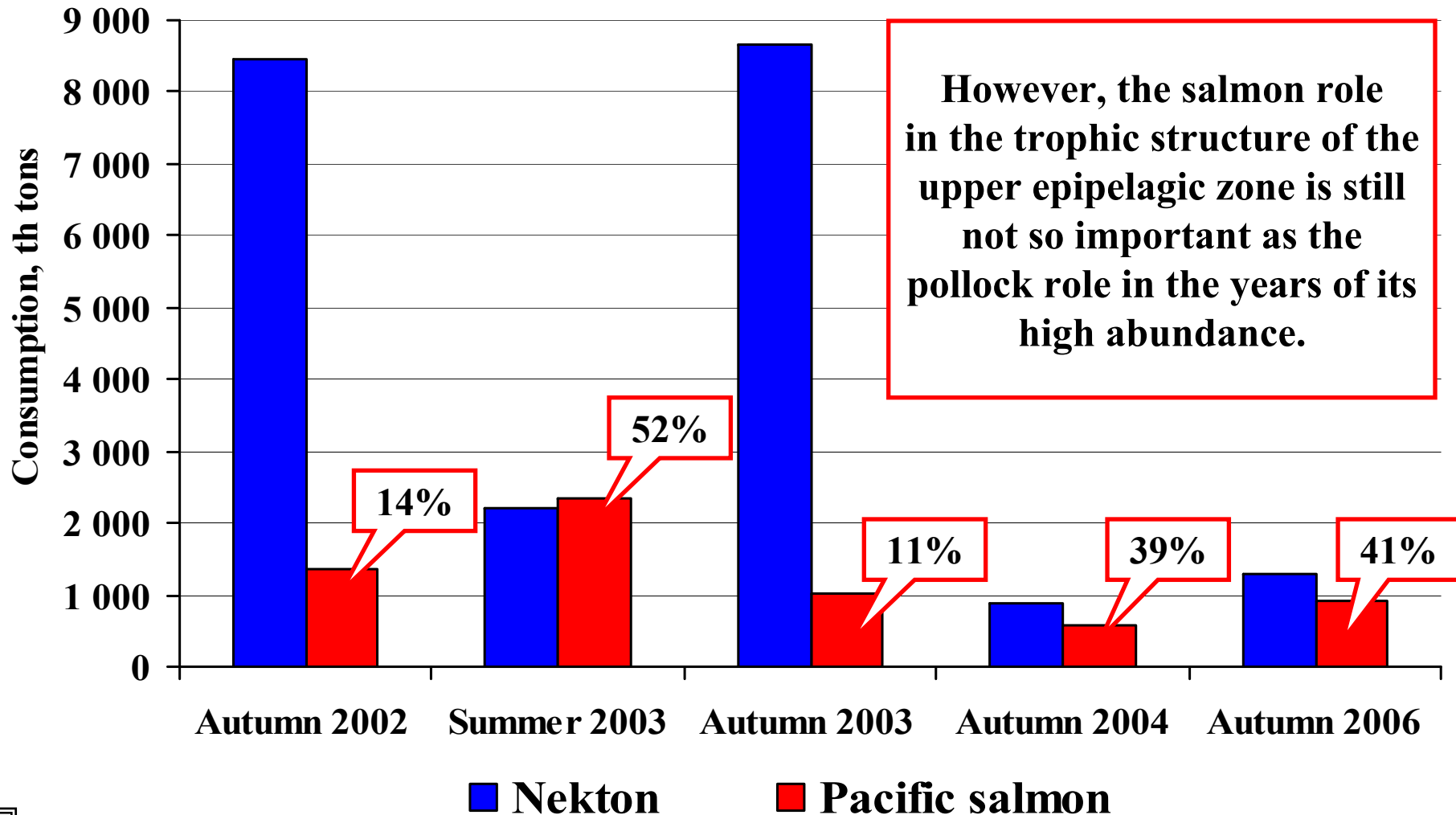
Autumn 2006

842 th t;

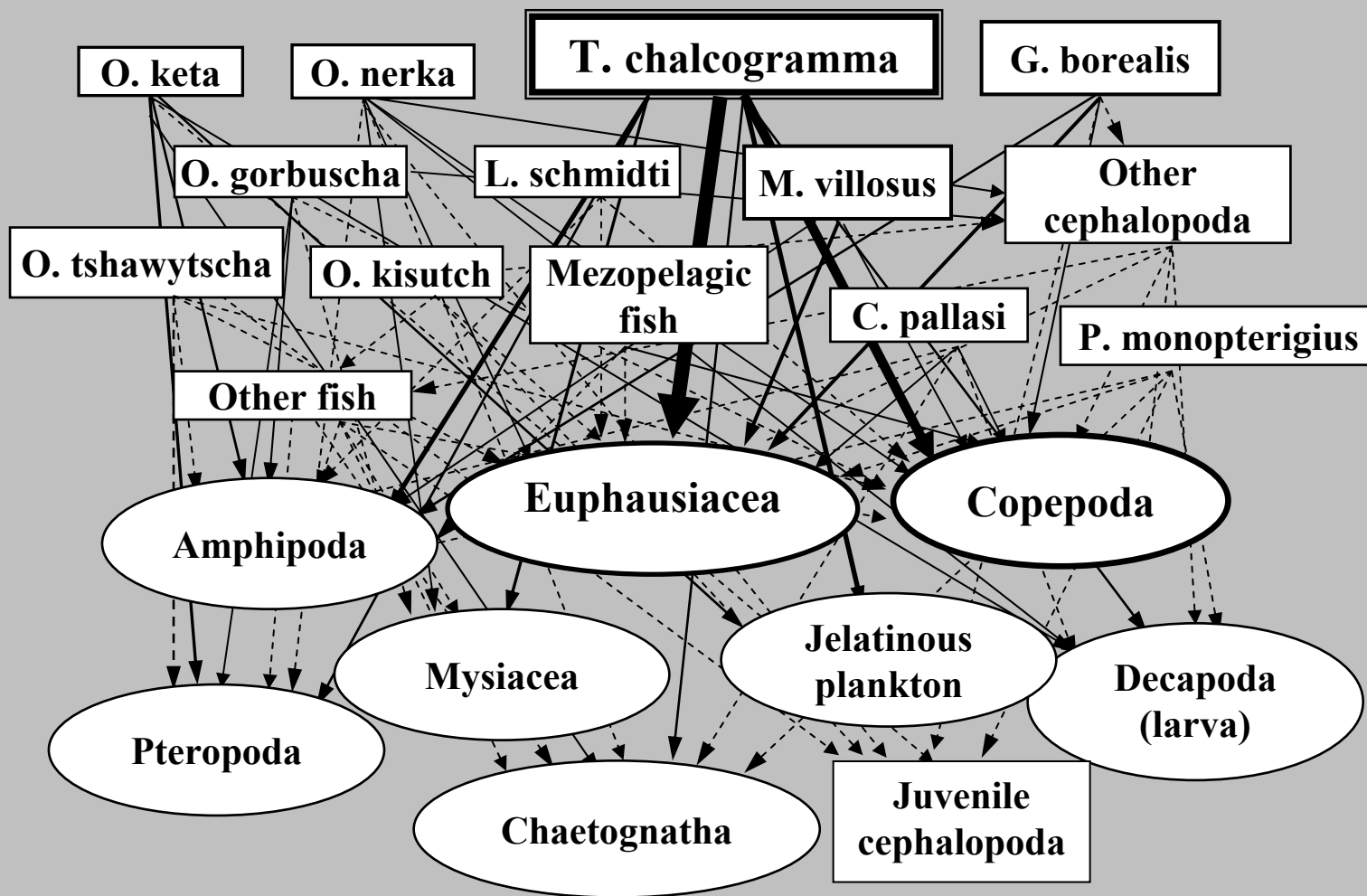
47%

The share (%) of Pacific salmon
in total consumption of forage
resources **by fish** has **increased**
in \approx 12–15 times

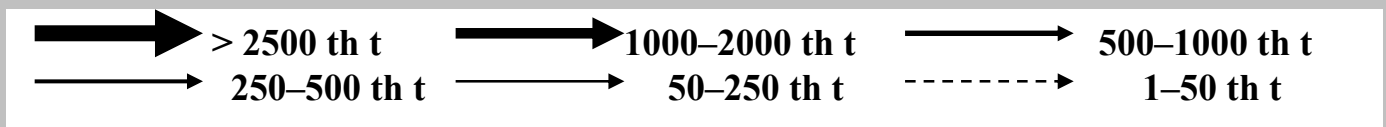
The total consumption (thousand tons) of forage resources **by nekton** and **Pacific salmon** in the upper epipelagic layer in the western Bering Sea during summer 2003 and autumn 2002–2006



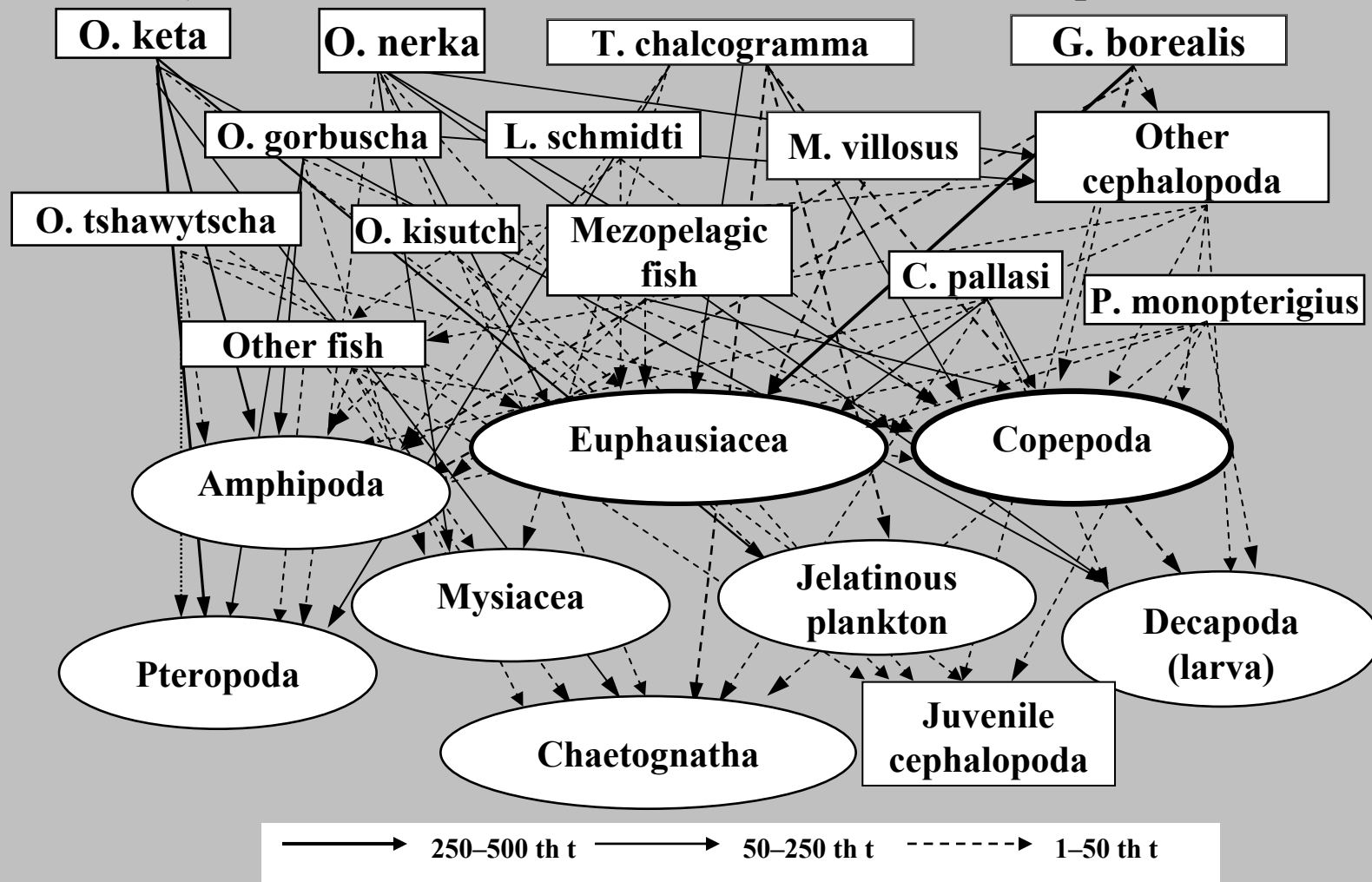
The scheme of the basic trophic relationships between most abundant nekton species and main zooplankton groups in the upper epipelagic zone of the western Bering Sea in autumn 2003. (Thickness of arrows — volumes of season consumption, thousand tons).



In autumn 2003 the predominant pathway of energy flow was pathway from two zooplankton groups: euphausiids and copepods towards walleye pollock.

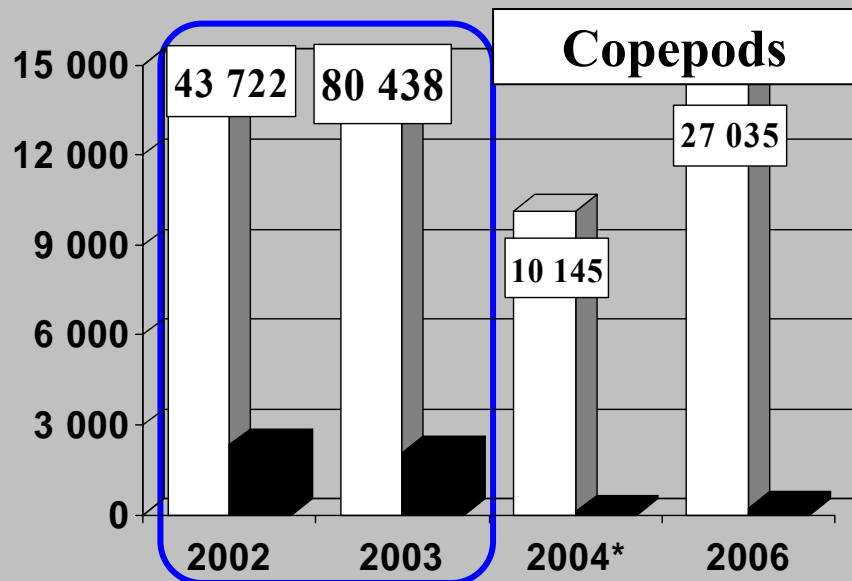


The scheme of the basic trophic relationships between most abundant nekton species and main zooplankton groups in the upper epipelagic zone of the western Bering Sea in autumn 2006. (Thickness of arrows — volumes of season consumption, thousand tons).

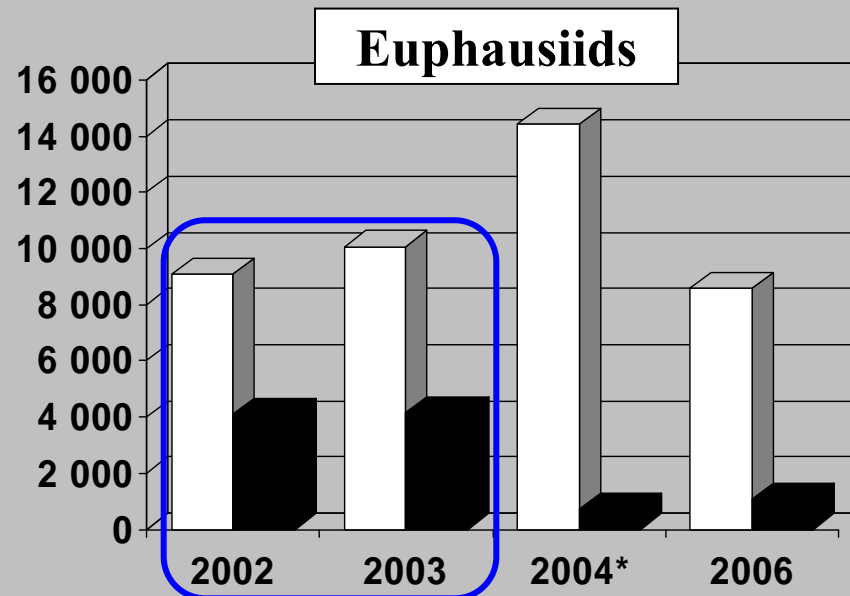


The changes in food web have occurred in autumn 2006. The consumption of the all zooplankton groups by nekton reduced, the trophic relationships between nekton and zooplankton and the pathways of energy flows have changed.

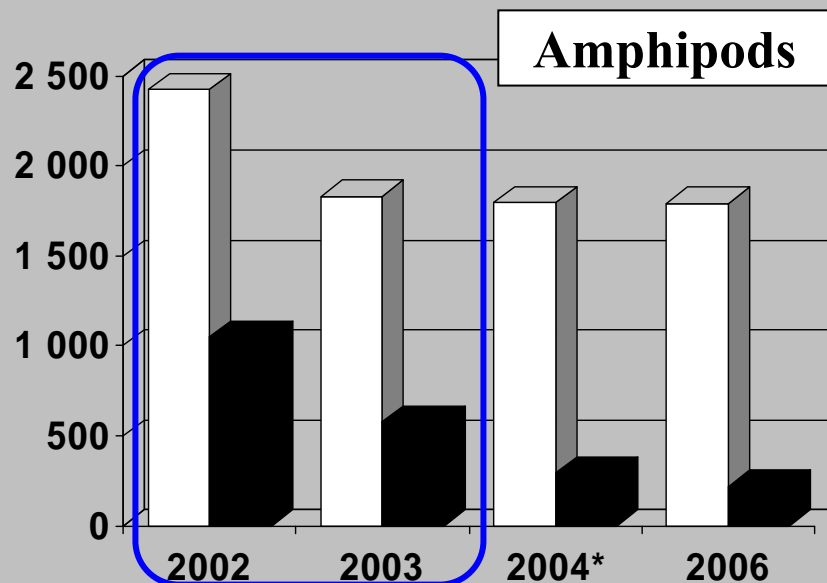
Thousands tons



Thousands tons



Thousands tons

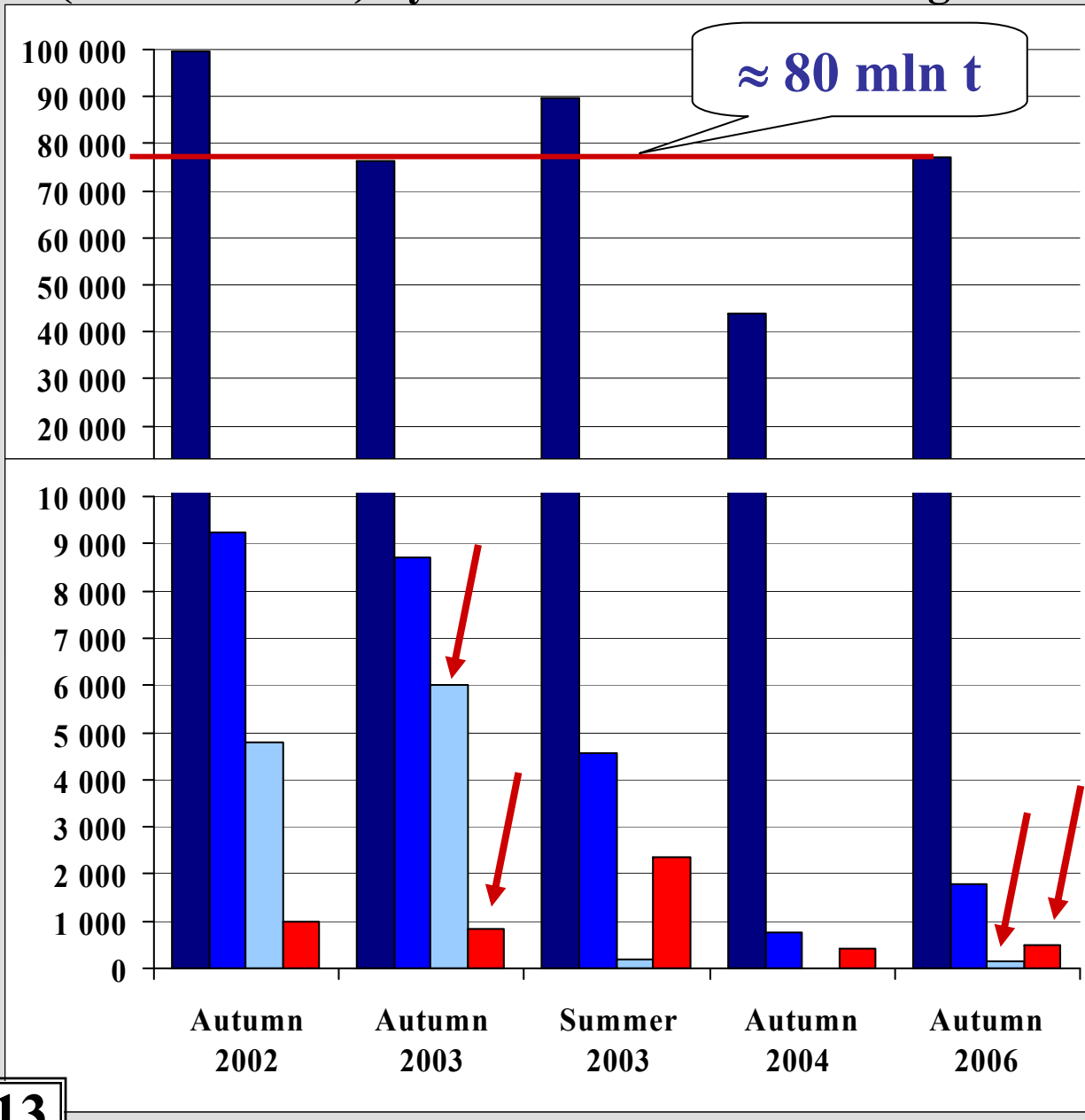


□ Biomass of plankton group
■ Consumption by nekton

In general, the consumption of **euphausiids** by nekton has decreased from 4.1 to 1 mln t, **copepods** – from 2.3 to 0.2 and **amphipods** – from 1.1 to 0.3 mln t.

The energy flows from zooplankton toward higher trophic levels of the upper epipelagic communities have decreased considerably.

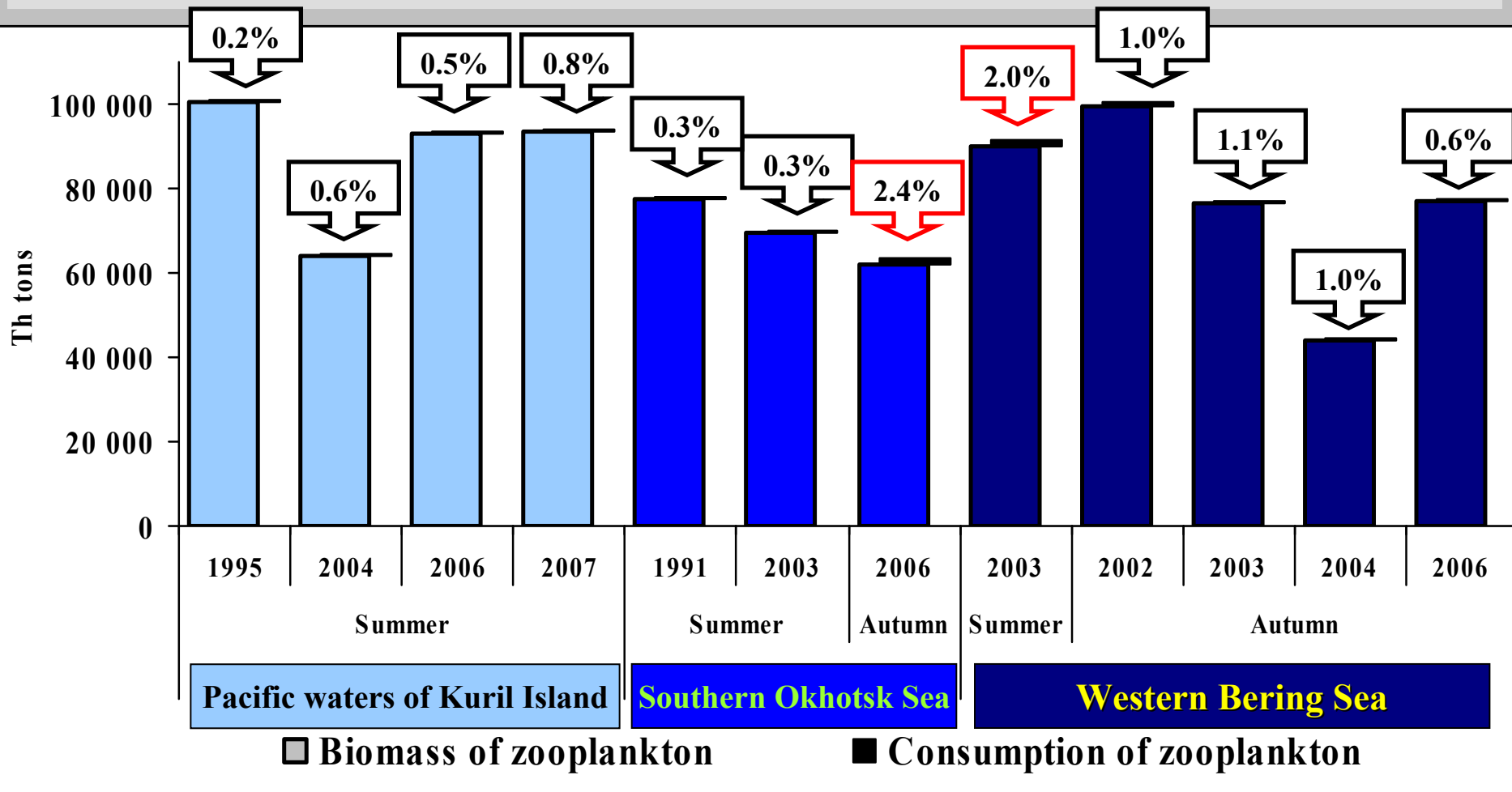
The biomass of zooplankton and its consumption (thousand tons) by nekton in western Bering Sea



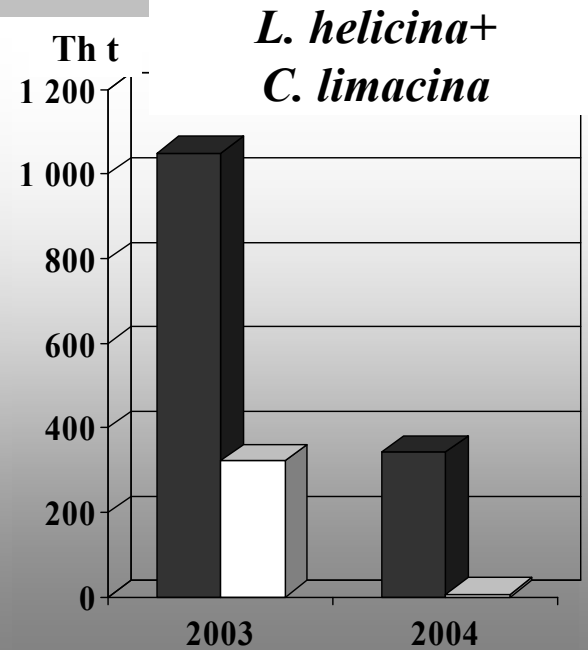
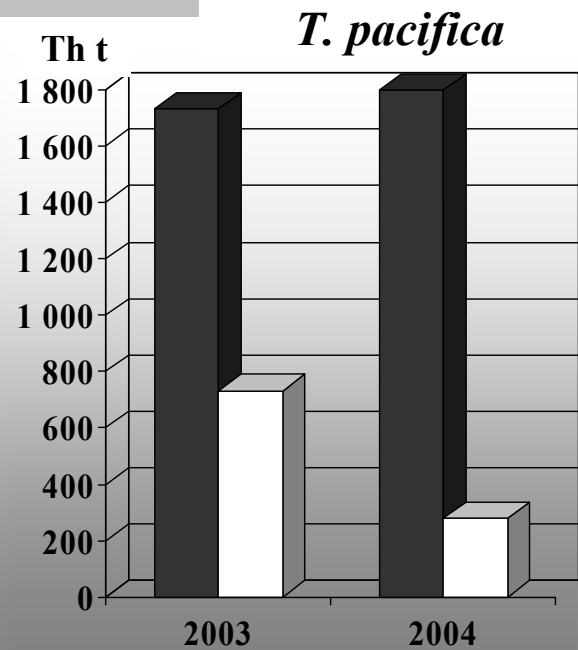
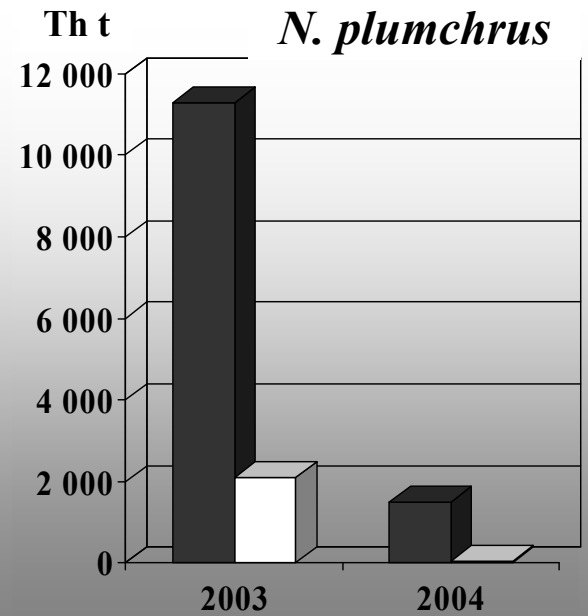
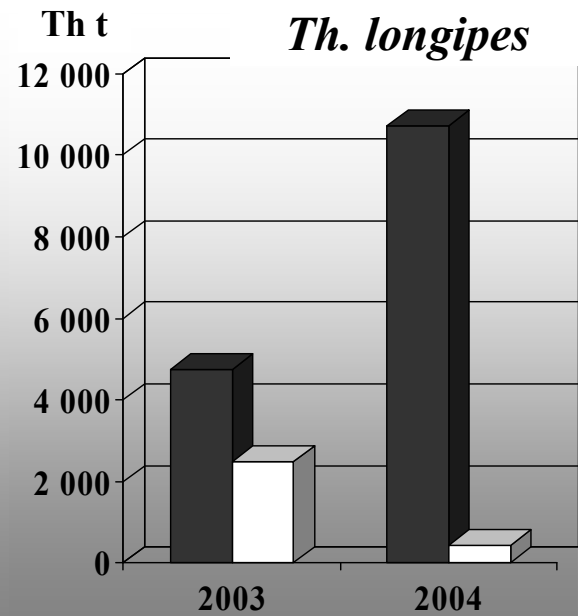
➤ Despite of abundance increasing, the Pacific salmon consume much less of the forage resources compared to many major nekton species.

Only during summer zooplankton is largely affected by grazing of Pacific salmon.

The biomass of zooplankton and its consumption (thousand tons) by **Pacific salmon** in the epipelagic zone of the Okhotsk and Bering Seas and Pacific waters of Kuril Islands



In the all investigated regions the salmon contribution in consumption zooplankton is low: 0.2-2.4% of total zooplankton biomass (without production) in dependence on region and year.



However not all zooplankton species are equally consumed by nekton, as only few species are consumed most actively. In epipelagic zone of the western Bering Sea the abundance of these species preferred by nekton is sufficient.

For example, total biomass of 5 species which are the most important food items of nekton (*Th. longipes*, *N. plumchrus*, *T. pacifica*, *C. limacina*, and *L. helicina*) was estimated as 15-19 million tons, which exceeds consumption of these species several times.

If we take into account zooplankton production, the difference between zooplankton biomass and zooplankton consumption by nekton will be even higher.

 **Biomass**
 **Consumption**

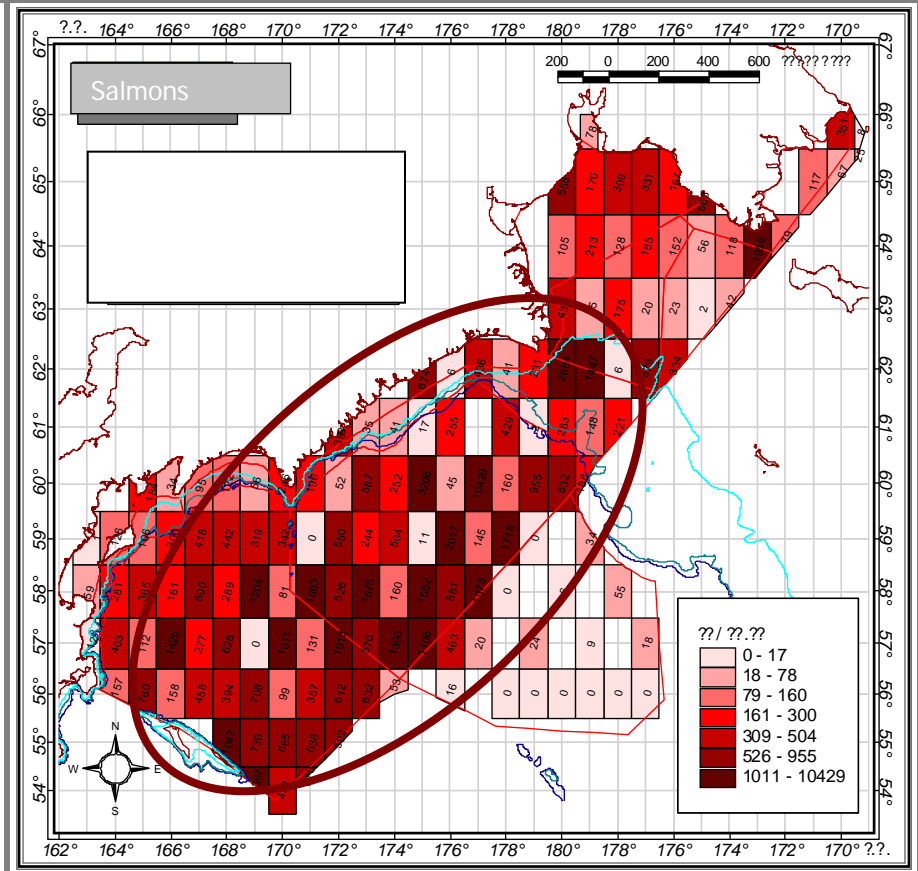
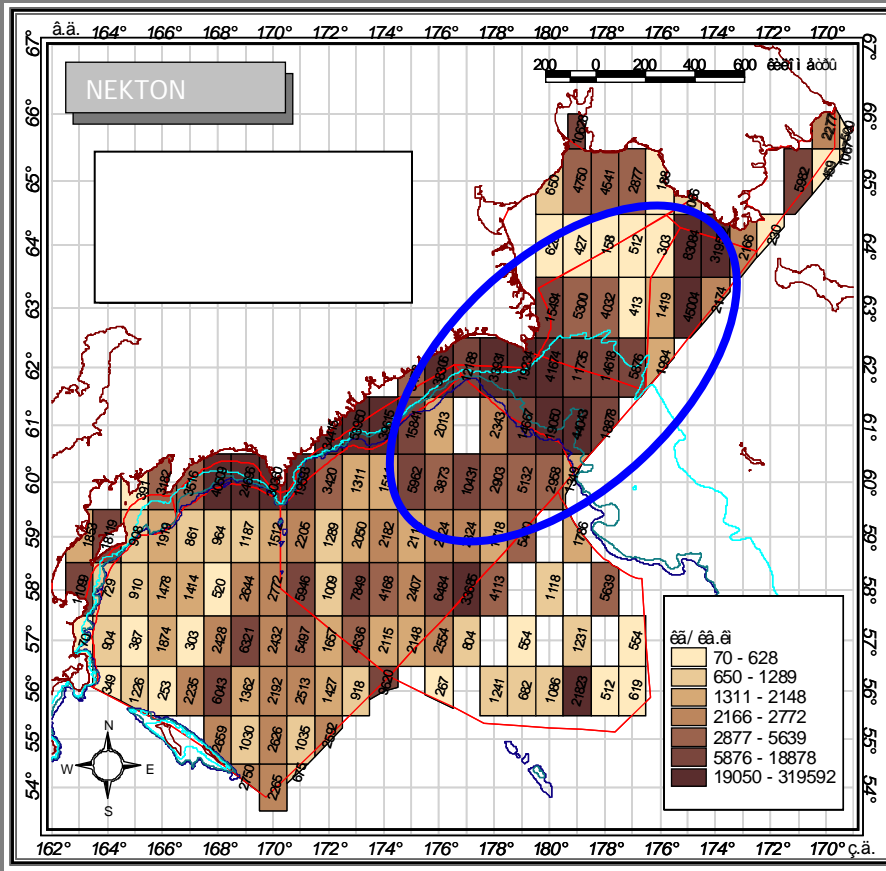
Daily food ratios of chum and sockeye salmon in the western Bering Sea in 1980-2000-ies.

Years	1986	1987	1992	2002	2003	2004
Size group, cm	Chum					
10-20	7.0	n/d	n/d	7.5	7.0	7.9
30-40	3.2	3.8	n/d	4.6	3.9	2.1
40-50	n/d	n/d	n/d	3.8	3.9	2.4
50-60	n/d	n/d	n/d	4.5	3.8	3.2
	Sockeye					
20-30	n/d	n/d	4.1	4.7	6.0	6.0
30-40	n/d	n/d	3.2	2.8	4.8	3.2
40-50	n/d	n/d	5.4	1.8	3.6	2.8
50-60	n/d	n/d	4.0	1.8	3.8	1.0

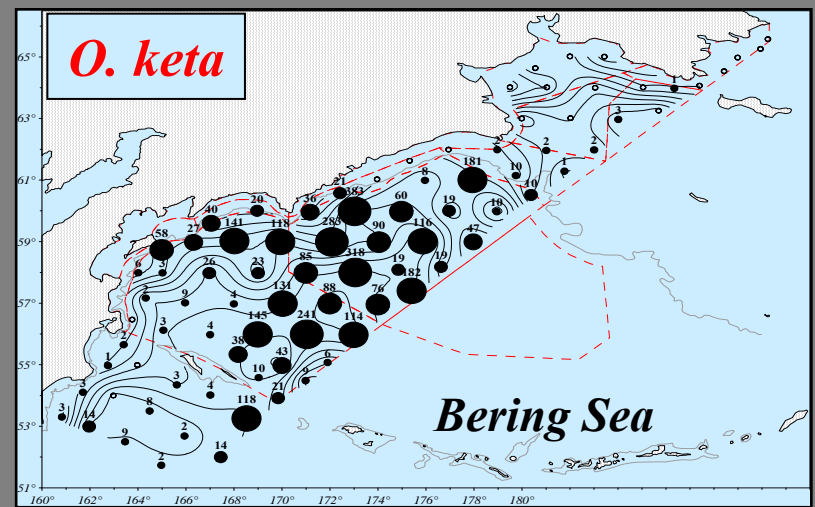
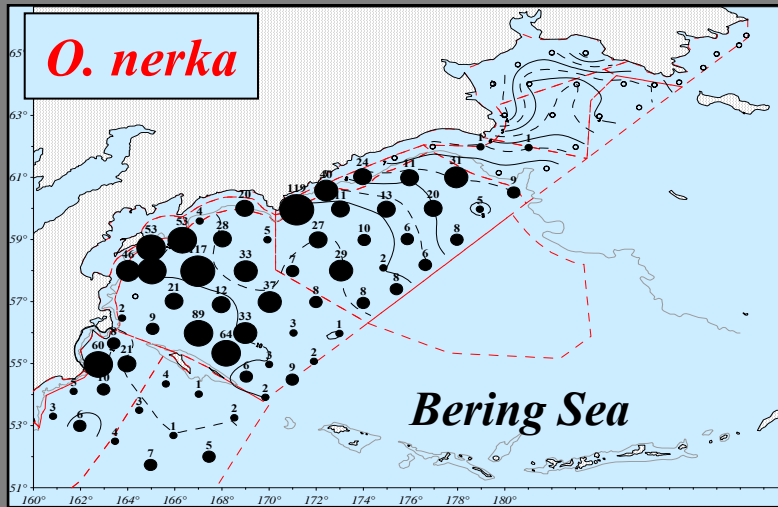
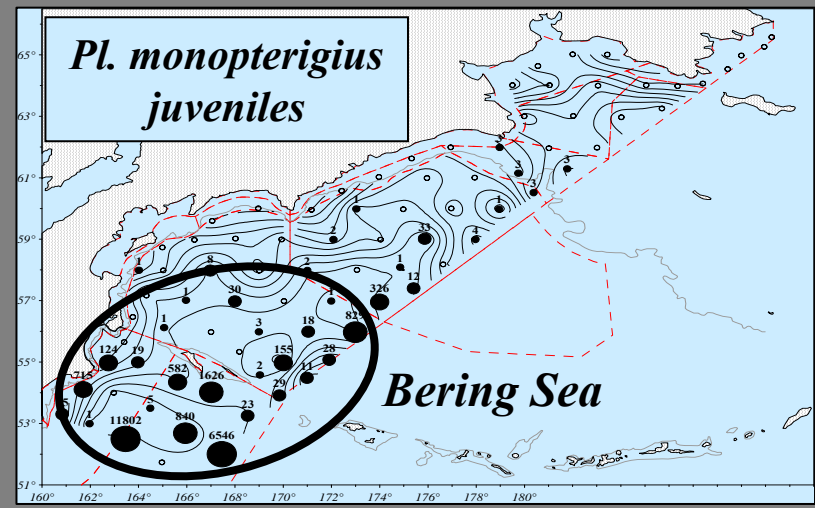
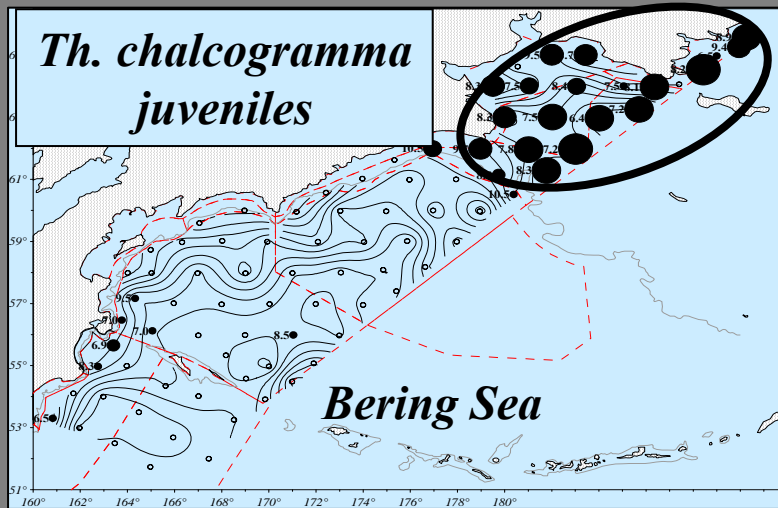
The satisfactory food supply for salmon in the western Bering Sea is proved by stable and high values of their daily rations, and by permanent preference in their feeding for hyperiids, pteropods, and euphausiids.

Nekton (left) and Pacific salmon (right) biomass in the epipelagic layer of the western Bering Sea during summer period of 1980-2004 (Shuntov, Temnykh 2006)

Other important factors of satisfactory foraging environment for Pacific salmon are the spatial dissociation of the major consumers and different migration timing.

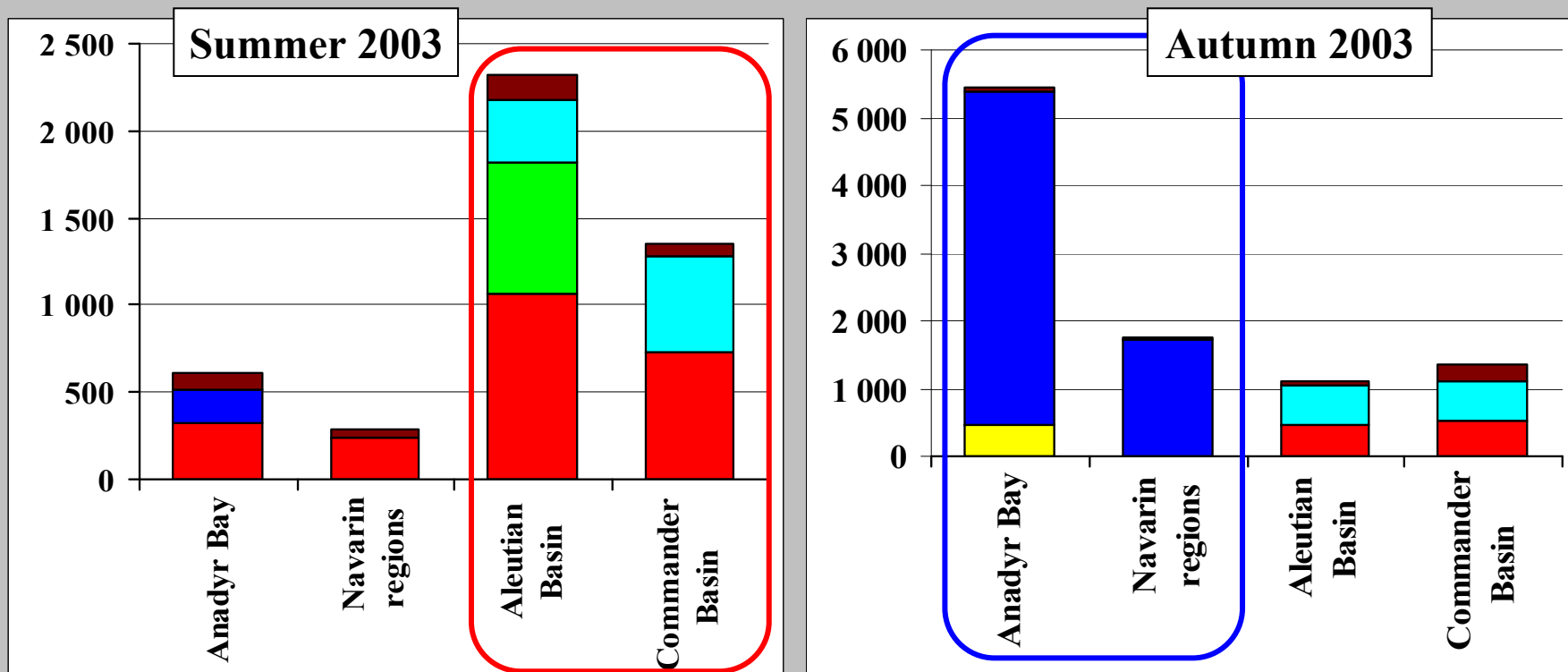


Distribution of walleye pollock, atka mackerel, chum and sockeye in the western Bering Sea in autumn 2002-2004

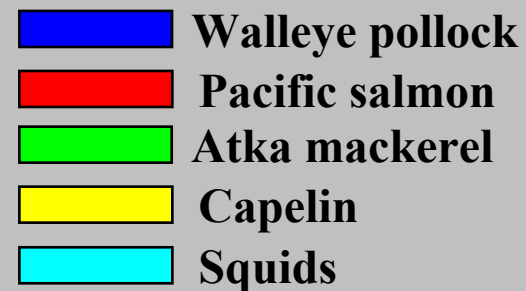


Pacific salmon, juveniles atka mackerel, and squids are fed mainly in the deep-water areas of the western Bering Sea. But the main feeding grounds of pollock, capelin and herring are located in shallow waters in the Anadyr Bay and Cape Navarin.

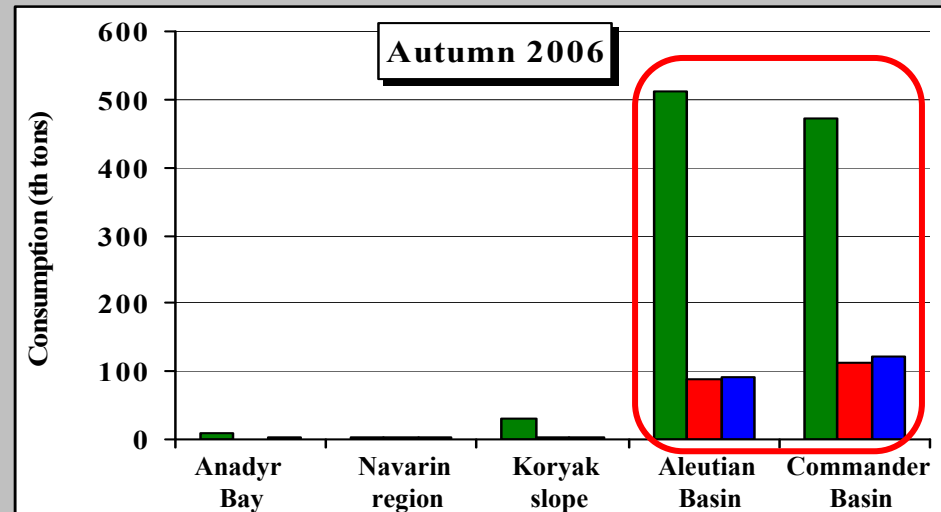
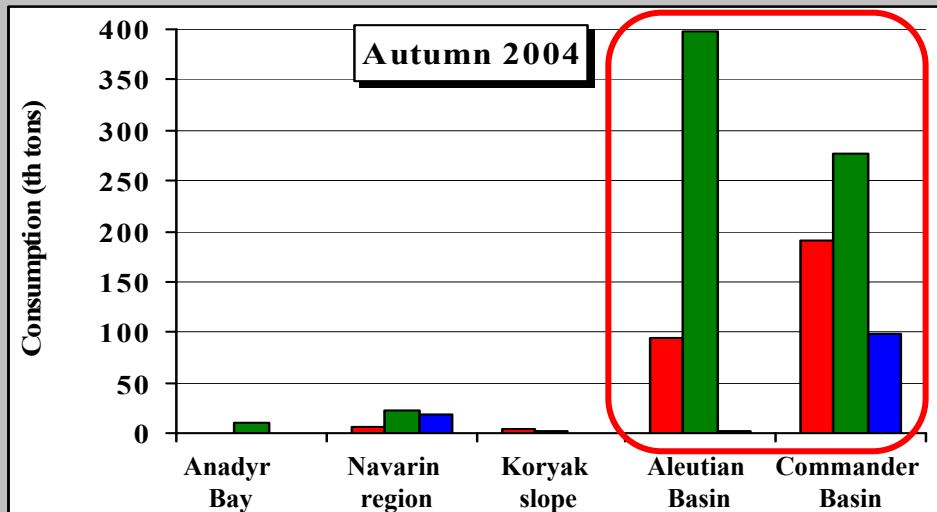
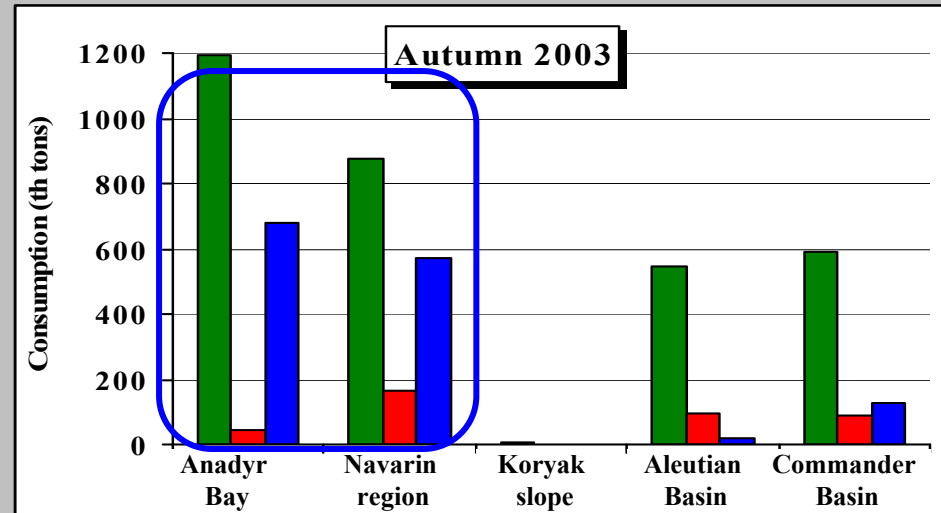
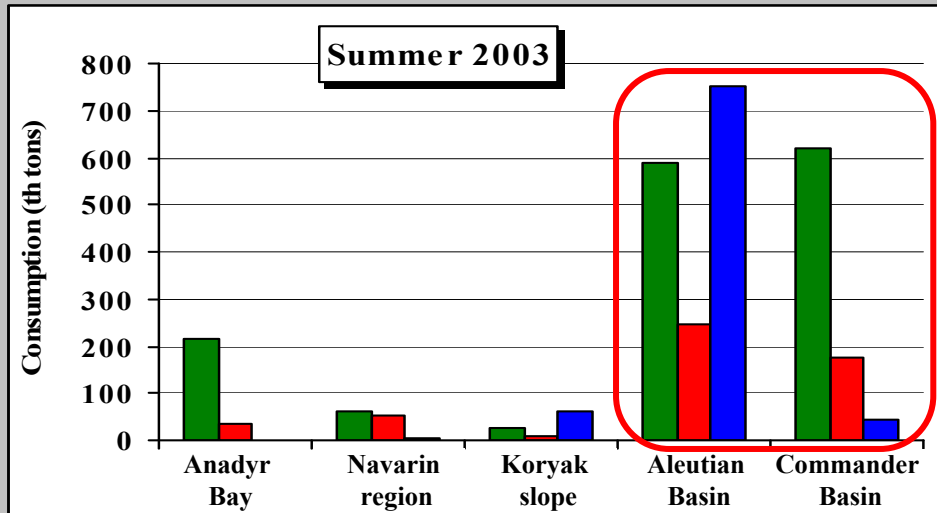
The consumption (thousand tons) of zooplankton forage groups by nekton in the upper epipelagic layer in the different areas of western Bering Sea during summer and autumn 2003



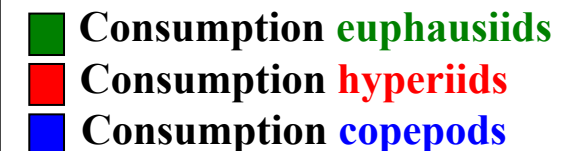
Therefore the forage resources of deep-water areas were affected by pacific salmon, atka mackerel, and squids during summer-autumn period. The consumption of zooplankton by pollock, and capelin was very high in shallows waters in autumn (especially in period when pollock was abundant).



The consumption (thousand tons) of zooplankton forage groups by nekton in the upper epipelagic layer in the different areas of western Bering Sea during summer 2003 and autumn 2003–2006



In 2004 and 2006 (when walleye pollock abundance in upper epipelagic zone was low) the consumption of forage resources was highest in deep-water areas compared to shallow areas.



Some competition for food between Pacific salmon and more abundant nekton species is possible in cases of the feeding grounds overlapping and clashes of migrations dates, but it is mitigated by plasticity and electivity of salmon feeding, as well as by excess forage reserves.

The all salmon species have a high feeding plasticity and are able to change their feeding habits (replacing one object of a feed by another). Thus in salmon diets zooplankton species can be replaced on small size of nekton species in dependence on the state of forage resources. This ability is good illustrated by different feeding habits of salmon in the western and eastern parts of Bering Sea.

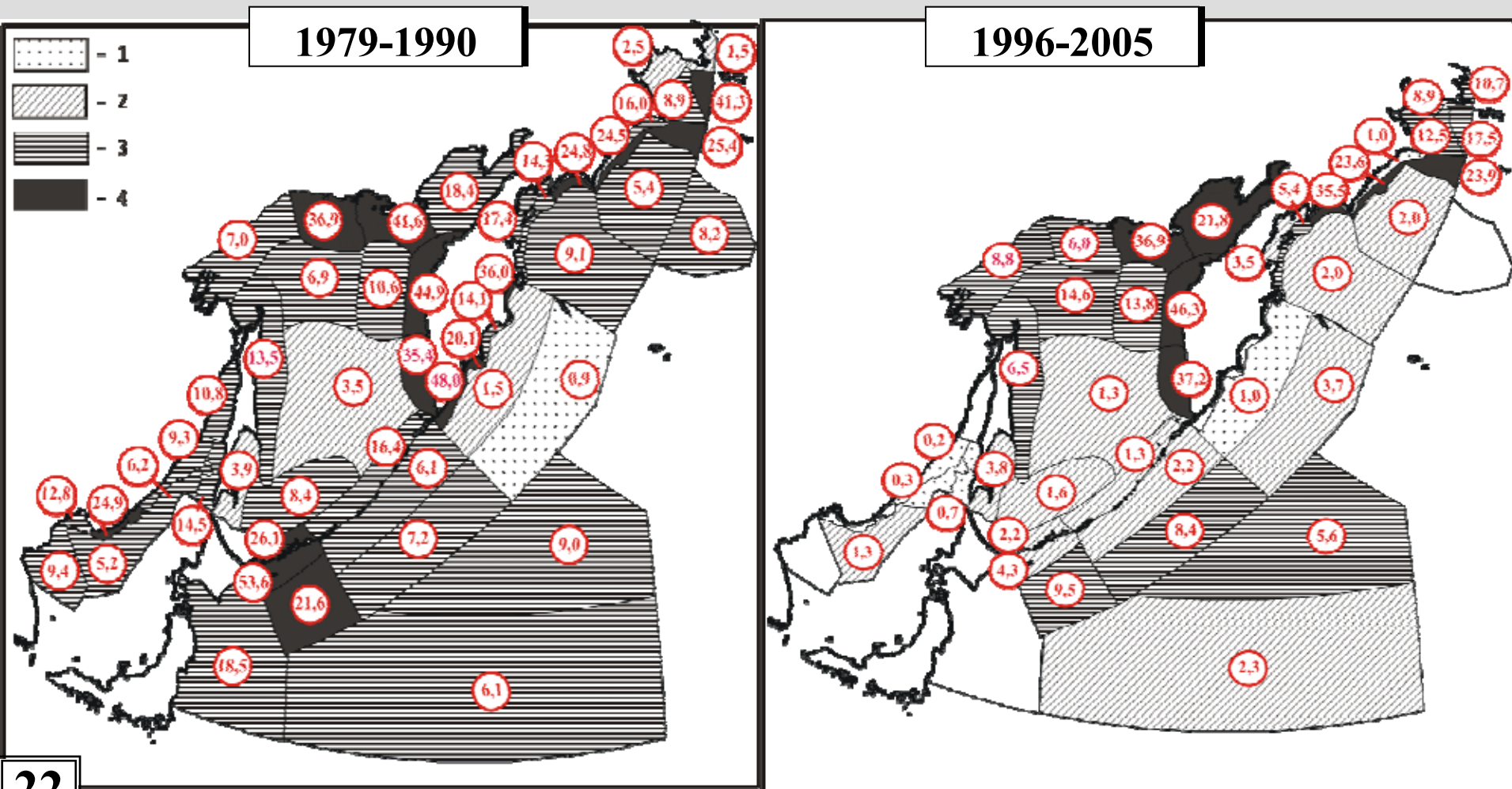
In the upper epipelagic zone of the western Bering Sea the **biomass of small size of nekton species is estimated as **1.5 mln tons** in present time. For comparison the **huperiids biomass** (the main food items for salmon) is estimated **1.8-2.5 mln tons**.**

The basic stocks of small size of nekton are concentrated mainly in shallow areas and in this areas the small size nekton can be additional fodder resources for fishes.

The nekton biomass ($t\ km^2$) in the different regions of Far Eastern Seas and North Pacific in 1979–1990 and 1996–2005 гг.

(from Shuntov et al, in press)

1 — < 1 ; 2 — 1.1–5.0; 3 — 5.5–20.0; 4 — $> 20\ t\ km^2$;



Based on the above we can conclude that:

- **Any fluctuations in biomass of the major consumers lead to changes in the pelagic communities' trophic structure. However, even multiple variations in the highly-fluctuated species' biomass, such as walleye pollock, result only in trophic relationships' changes and energy flows' directions.**
- **The Pacific salmon contribution to the forage resources consumption is insignificant, and recent rise of their abundance is unlikely to cause serious shifts in trophic structure of the Far-Eastern Seas upper epipelagic zone.**
- **Pelagic layer carrying capacity (in relation to forage supply sufficiency) depends from complex of multiple factors: amount of forage resources and major consumers' abundance, spatial dissociation and different migration timing.**

According to our data, carrying capacity of the upper epipelagic layer of the Far-Eastern Seas and pacific waters Eastern Kamshatka and Kuril Islands in relation to Pacific salmon is significant.

However, this conclusion is based on the data obtained in the Far-Eastern Seas in summer and autumn only. Such calculations cannot be done for open waters of the North Pacific in winter and spring seasons because of absence of representational data that is an important gap in the knowledge on carrying capacity for salmon.

Issues that should be addressed in future research in the NORTH PACIFIC in winter and spring:

- ?
- The quantitative composition of nekton and plankton epipelagic communities
- The food relationships between zooplankton and nekton (especially pacific salmon) species
- The competition between the pacific salmon of different populations

Thank you for attention



**WE ARE FINE IN SUMMER-
AUTUMN,
BUT IN WINTER AND
SPRING????????????????????????????????**