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Database and GIS Technologies in Studying Nekton of the Northwest Pacific: The First Results and Perspectives

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Abstract

A lot of trawl cards are kept in TINRO-Center archives, which contain the data of scientific-research and fishery-research cruises to the Eastern Indian Ocean, almost entire Pacific Ocean and adjacent seas within the period of 1950-2003. This priceless material needs generalization that implies its transformation into the format that could be analyzed using statistical and cartographic computer programs. Therefore in the Laboratory of Applied Biocenology created the database containing information of 242 thoroughly selected trips of 1980-2003 in 40,920 cards. Newly organized information was used in a lot of recent reports and scientific papers.

After the database had been organized, the next natural step in improvement of informational provision of fishery investigations was creation of GIS of quantitative hydrobionts distribution in the far-eastern seas on its basis. Currently, the first module, which describes Okhotsk Sea nekton, is ready. When preparing it, the data of 68 cruises were used, in the course of which within the period from February 27, 1980 to January 19, 2003 6151 trawl stations was performed. About 5000 maps, put in GIS, themselves give the opportunity to estimate spatial and temporal dynamics of any biological resource of the Okhotsk Sea nekton. Besides, GIS permits to make various calculations on its data, including accounts of one- and multi-species fluctuations of spatial distribution of sea animals – seasonal and interannual.

As an example of analytical ability of GIS, long-term (lasting several tens of years) fluctuations of abundance of some fish species are considered. In particular, is shown, that "Walleye pollock - Pacific herring" and "Pacific sardine – Japanese anchovy" are pairs of alternative species, the opposing fluctuations of which abundance occur in antiphase. On the contrary, Chum salmon and Pink salmon are not alternative species, but complimentary ones. Conditions, favorable for one species, are also favorable for another one. At that, increase or decrease of chum and pink salmon abundance happens synchronously (inphase fluctuations). Therefore, competition, affecting abundance and especially suppression of one species by another, is not observed. Thus, there are no reasons to worry about overpopulation and the fate of the pacific salmon, at least, in the Okhotsk Sea. This conclusion is well conformed to the results of investigation of ecological carrying capacity of the sea, conducted by the Laboratory of Applied Biocenology of TINRO-Center.

These primary examples demonstrate only a small part of analytical opportunities of database and GIS. It will undoubtedly become an unprecedented basis for investigation of species abundance and composition, diversity and other integral characteristics of nekton, as well as a reliable basis for further monitoring of the conditions of pelagic ecosystem and some species populations: from mass commercial ones up to indicators, endemic, rare and endangered ones. In 2004 it is planned to supplement GIS with data on the Japan Sea nekton, and later – on the Bering Sea and open waters of the Pacific Ocean. After that it is supposed to create similar informational systems on benthos and nektobenthos, and in future also on plankton.

About 300 thousand trawl cards are kept in TINRO-Center archives (Fig. 1), which contain the data of more than 1500 cruises to the Eastern Indian Ocean, almost entire Pacific Ocean and adjacent seas within the period of 1950-2003. This invaluable material requires generalization and comprehension, which is impossible without its compression into a form, accessible for analysis, by means of prior statistical and cartographical computer treatment.

From 1981 this information has been partially computerized using uniform ASUOR system forms, developed by VNIRO for the Russian EC computers, and from 1995 a more advanced software – "Ichthyolog" for personal computers using a dBase for DOS by TINRO employee N.Kravchenko. Database is continuously growing due to addition of new and retrospective materials (Bocharov, Ozerin, 1995; Ozerin et al., 1995), and now this format in the Regional Data Center (RDC) of the Institute contains information about 557 trips from 91,500 cards.

From 1996 in the Laboratory for Applied Biocenology I started to work with RDC files using Microsoft Access, a well-known program for dealing with database. Gradually a system including hundreds of queries realizing new algorithms of trawl survey data processing was created on its basis. After that an interface for input, editing and checking of raw data was elaborated, which allowed us to extend considerably the number of users of this new software. Finally the structure itself of relational tables was changed, and we turned to the new system completely independent of (but compatible with) "Ichthyolog" program. Parallel to elaboration of the database form it was filled up and information, both imported from RDC and newly inputted, was substantially edited. In the result the Laboratory received its own database, containing information of 242 thoroughly selected trips of 1980-2003 in 40,920 cards, which was original by content and scope. A standard structure of the database (Fig. 2) is easily supplemented with additional data modules on mass-measurements, biological analyses, and stomach contents of fish. Information from hydrological and plankton stations can be also added. Fragments of this database and various versions of its software were used as a basis for dozens of reports and scientific papers, written during the recent years. But for the first time it was mentioned in press only in 2002 (Dulepova, Volvenko, 2002).

The next natural step in improvement of informational provision of fishery investigations was creation of GIS of quantitative hydrobionts distribution in the far-eastern seas on its basis. Currently, the first module, which describes Okhotsk Sea nekton, is ready. When preparing it, the data of 68 scientific-research and fishery-research cruises were used, in the course of which within the period from February 27, 1980 to January 19, 2003 at least one valuable pelagic trawling haul in the Sea of Okhotsk was performed. The following hauls were not considered as valuable: 1) accidental, 2) technical or adjustment, 3) purely commercial, 4) lasting for more than 3.5 hours or less than 10 min (if in the latter case a net was taken out without a catch), and 5) made in epipelagic water layers (the depth of towing is down to 200 m) with a speed not less than 3 knots. After quality control the number of sampling was equal to 6151 trawl stations. For each trawl station number and weight of every animal species per unit of sampled area in ind./km^2 and kg/km^2 were calculated using "area" method (Volvenko, 2000) and taking into account variability of trawl geometry, varied coefficients of catchability and volume allowances, and correction compensating stepwise trawling. These data in ArcView GIS 3.2 software are averaged by 257 one-degree trapeziums with their centers corresponding to intersection points of meridians and parallels (Fig. 3).

Thus, raster method of data representation was realized in GIS. It does not give information about location of sampling points and hides details of precise attitude position of the limits of distribution and quantitative development of this or that phenomenon. At the same time, quantization gives a generalized picture (a bird's eye view, a plane or a space view): it allows us to ignore minor valueless topographic fluctuations and smoothes some artifacts of primary acquisition. It ensures comparability of values, describing standard averaging polygons for investigation of space distribution of different phenomena and/or the same phenomenon but in different time intervals facilitating by that spatial-temporal analysis of water area. It is also of no small importance that quantum cells easily connected with database and that many logical and mathematical functions are easily performed on the raster-type data structure (DeMers, 1999).

Adopted in this GIS one-degree raster resolution by latitude and longitude gives a regular grid of polygons in a form of one-degree trapezoid with easily identified locations and borders. Their areas turned out to be the smallest among suitable for representation of mean long-term values of hydrobionts density. Bigger polygons – "standard areas of biostatistical information averaging" – are introduced by the other characteristic and for the other purposes (see Volvenko, 2003b), and it is not expedient to introduce smaller ones because of the lack of input data. Besides, a 1-degree area is considered to be the smallest area for biotic zoning in the regional scale. One-degree discretization of basic data proved to be perfect at ichthyofaunistic zoning of the Sea of Japan (Kafanov et al., 2000, 2001; Kafanov, Volvenko, 2001).

Maps constructed using the whole set of trawling stations, show average annual pattern of nekton distribution in the Okhotsk Sea in the entire water column within the period of 1980-2003 regardless of a season. In order to reveal spatial and temporal distributional patterns of marine organisms, three principles of grouping and selection of data were introduced: 1) by the water strata of trawling they are subdivided into epipelagic, upper epipelagic and mesopelagic, 2) by seasons – into summer, autumn, winter and spring, 3) by years – into three long-term periods: 1980-1990, 1991-1995 and 1996-2003. According to such classification spatial-temporal distribution of any species density, extraspecific, or intraspecific size-age animal groups density are fully characterized by a series of 64 charts (32 for number and 32 for weight). Almost 1000 of the most significant and interesting of them will be soon published under the title "Atlas of quantitative distribution of nekton species in the Sea of Okhotsk" (2003 in press).

About 5000 maps, put in GIS, themselves give the opportunity to estimate spatial and temporal dynamics of any biological resource of the Okhotsk Sea nekton (see for example: Volvenko, 2003a). Besides, GIS permits to make various calculations on its data, including calculation of one- and multi-species fluctuations of spatial distribution of hydrobionts – seasonal and long-term interannual. Here lies the difference between computer-based cartography (programs for making maps from graphic primitives) and GIS with its analytical abilities (DeMers, 1999). I shall illustrate it with some examples.

Long-term (lasting several tens of years) fluctuations of abundance of some fish species are natural and generated mainly by changes of climatic and oceanologic conditions, which are similar by duration. At that, different needs of different species in certain abiotic conditions are manifested in antiphase course of their abundance oscillations (Davydov, 1986; Shuntov, 1986). Thus, for example, from the early 1990s large-scale migrations of Pacific sardine *Sardinops melanostictus* to the Russian waters stopped, and walleye pollock *Theragra chalcogramma* abundance considerably reduced, though the abundance of more psychrophilic alternative nekton species – Pacific herring *Clupea pallasii*, Japanese anchovy *Engraulis japonicus* and others – increased (Shuntov, 1999).

The mentioned species are naturally grouped in pairs as follows: pollock-herring are permanent abundant elements of the Okhotsk Sea nekton, and sardine-anchovy are subtropical migrants which at times come in from adjacent more southern waters of Japan in considerable amounts. After calculation of biomass difference of alternative species one can observe progressive changes of zones of their predominance within the sea. In the 80s pollock dominated over herring almost everywhere, and in the end of the considered period three zones were formed approximately equal by area. Herring prevails in the northwestern part, and pollock – in the northeastern part (Fig. 4). At the same time a parallel process took place in the southeastern part: anchovy gradually and almost completely replaced sardine (Fig. 5).

The following Figure earnestly demonstrates alternativity of these species (Fig. 6). On the upper diagram data on variations of pollock share in nekton in 1996-2003 in comparison with the 80s are shown on one axis, and that of herring – on another axis. On the lower diagram one can see the same information about anchovy and sardine. Variation can be positive, i. e. increase, or negative, i. e. decrease of a species shares in nekton, or zero, i. e. preservation of *status quo*. This parameter can range from –100% to +100%. Location of dots mainly in the second and forth quarters[1] of both diagrams on Fig. 6 indicates the existence of a negative correlation, or antiphase (opposing) fluctuations in species abundance.

[1] If quarters are numbered as it is accepted in geometry, i. e. beginning from the upper right one and further along the circle counter-clockwise.

Recently, when abundance of Pacific salmon reached its historical maximum for the entire period of observations (see, for example: Beamish, Bouillon, 1993; Gritsenko et al., 2002; Klovach, 2003), some authors began to propose chum salmon *Oncorhynchus keta* and pink salmon *O. gorbuscha* as a pair of alternative species. The point is that these are the most abundant salmon species in Asia. Areas of their habitat and feeding are considerably overlapped in time and space, and their diet composition can be similar.

It is considered that carrying capacity of the entire North Pacific with respect to salmons is at its upper limit (Klovach, 1999; Volobuev, 1999, 2000; Volobuev, Volobuev, 2000; Gritsenko et al., 2000; Gritsenko, Klovach, 2002), that is why overpopulation here leads to competition between two species, poor feeding during the marine life period, and, as a result, to the increase of mortality, decrease of reproduction and reduction of population abundance (Klovach et al., 1996; Klovach, 1999, 2000, 2001, 2003; Gritsenko et al., 2000; Gritsenko, Klovach, 2002). Particularly for the Sea of Okhotsk, it is concluded that one species (chum) is depressed by another one (pink), and worsening of chum biological parameters in the years of high pink abundance is considered as an effect of Gauze's principle of competitive exclusion (Volobuev, Volobuev, 2000). It is supposed that the further growth of these species production in the Sea of Okhotsk will lead to negative consequences (Volobuev, 1999), even to the reduction of their genetic diversity and ability for adaptations (Volobuev, 2000).

When analyzing a pair chum-pink using the same methods as for the other species, it can be easily observed that beginning from the first half of the 1990s the zone of pink predominance has been greatly enlarged and occupies almost entire southern deepwater basin of the sea (Fig. 7). On the plot of variations of species shares correlation (Fig. 8), however, primary location of dots in odd quarters (first and third) indicates the existence of a positive correlation or inphase fluctuations of species abundance. This situation is completely opposite to that one observed for two other pairs (compare Figs. 6 and 8). Chum and pink are not alternative species, but complimentary ones. Conditions, favorable for one species, are also favorable for another one. At that, increase or decrease of chum and pink salmon abundance happens synchronously. Therefore, competition, affecting abundance and especially suppression of one species by another, is not observed.

Thus, there are no reasons to worry about the fate of the pacific salmon, at least, in the Sea of Okhotsk. This conclusion is well conformed to the results of investigation of ecological carrying capacity of the Okhotsk Sea, conducted by the Laboratory of Applied Biocenology of TINRO-Center. Recently it has been shown (Volvenko, Titiayeva, 1999; Volvenko, 2001) that fish communities of the northern part of the sea are poorly integrated systems with very weak negative interactions (like predation or competition) between a small number of mass-abundant species, forming the lion’s share of the total nekton biomass. Abundance of these species is controlled mainly by abiotic factors – climato-oceanological ones, but not by biotic factors – interspecific interactions. In conditions like that feeding competition among fishes is absent (or inconsiderable), feeding resources are underused[1], and there is a possibility of increasing ichthyomass up to much greater values than those observed within the period under study. Recently a similar conclusion was also made concerning the southern part of the Okhotsk Sea (Temnykh et al., 2003). Good feeding conditions in this area and the absence of big local populations of plankton-feeding nekton species (such as pollock, herring and capelin in the northern part) allow to speak about "underoccupation" of the open pelagic water layers of the Southern Sea of Okhotsk and about "underexploitation" of its plankton resources by this reason. Most likely this is the reason (and the effect of Soya warm current as well) of the presence of great number of salmons here in the late autumn and winter.

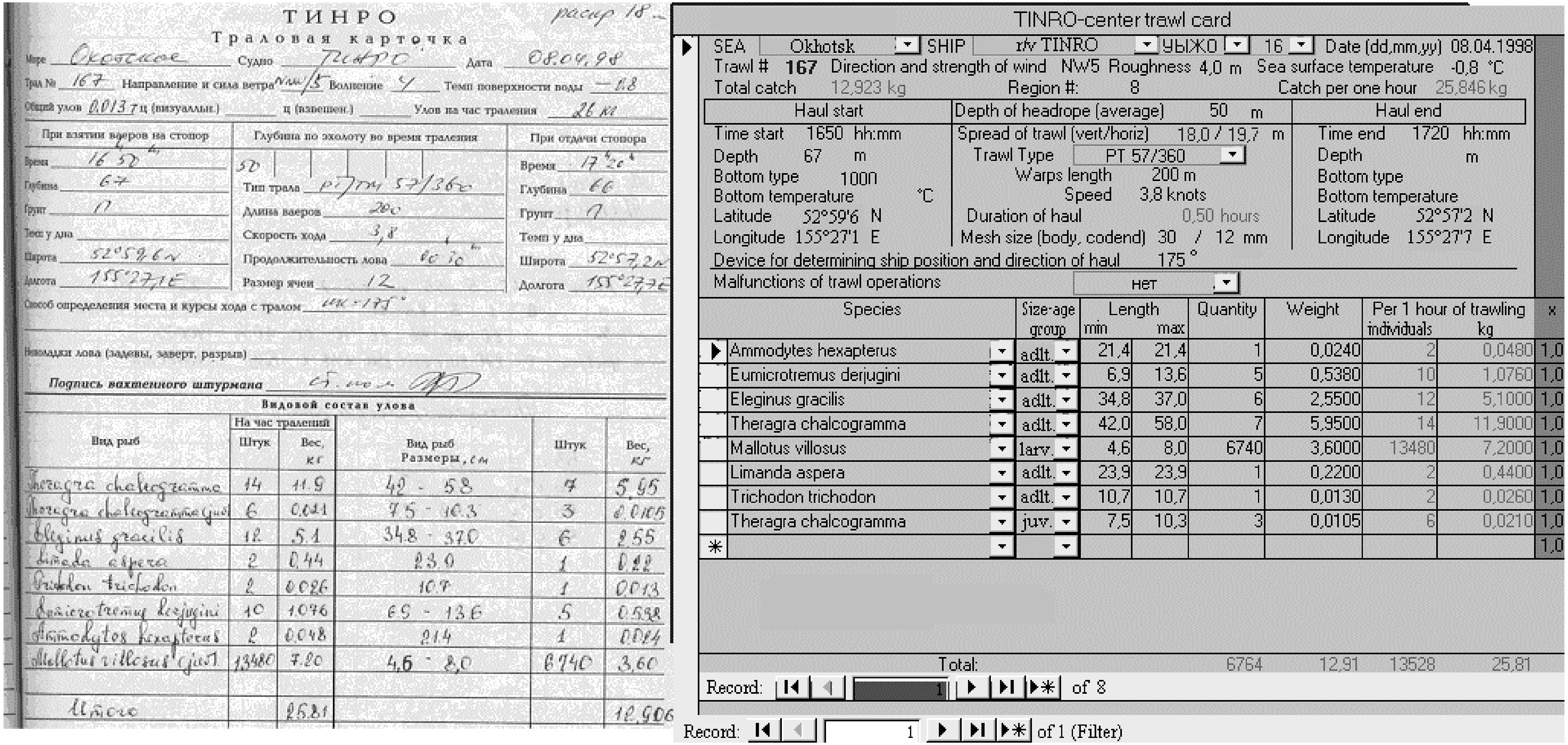
These primary examples demonstrate only a small part of analytical ability of GIS. It will undoubtedly become an unprecedented by minuteness and size basis for investigation of species abundance and composition, diversity and other integral characteristics of nekton, as well as a reliable basis for further monitoring of the conditions of pelagic ecosystem and some species populations: from mass commercial ones up to indicators, endemic, rare and endangered ones.

So, a considerable block of informational supply for investigation of biological resources of

[1] Abundance of zooplankton in the Okhotsk Sea is so high that about 26% of its production is not consumed in pelagic water layers, and changing into detritus, enlarges energy reserve of ecosystem (Shuntov, Dulepova, 1996).

the Russian Far-Eastern seas has been completed, but it is only the first one. In 2004 it is planned to supplement it with data on the Sea of Japan nekton, and later on – the Bering Sea and open waters of the Pacific Ocean (Fig. 9). After that it is supposed to create similar informational systems on benthos and nektobenthos, and in future also on plankton.

Our first experience of work on this project has shown that very considerable efforts should be spent on thorough analysis and selection of trawl cards, their input in computer database, scrupulous editing, numerous verifications and corrections. Algorithms of some methods of errors search and elimination have been published (see, for example, Volvenko, 1999) and realized in special software, others cannot be formalized as they need routine hand work or qualified mental work: careful revision of numbers and text fragments, knowledge of taxonomy and fauna, areas of animals dwelling, their maximal sizes, etc. The obtained intermediate and final results of statistical and cartographical treatment also need verification by experts in separate taxonomic groups and communities as a whole. That is why schedule time and the possibility itself of this project realization depend on the number of involved qualified specialists and, of cause, availability of considerable additional finance.



ТИНРО расп 18

Траловая карточка

Море Охотское Судно ТИНРО Дата 08.04.98

Трал № 167 Направление и сила ветра NW/5 Волнение 4 Темп поверхности воды –0,8

Общий улов 0,0137 ц (визуальн.) ц (взвешен.) Улов на час траления 26 кг

При взятии ваеров на стопор	Глубина по эхолоту во время траления	При отдачи стопора
Время 16 50	50	Время 17 20
Глубина 67	Тип трала РТ/ТМ 57/360	Глубина 66
Грунт П	Длина ваеров 200	Грунт П
Темп у дна	Скорость хода 3,8	Темп у дна
Широта 52°59,6N	Продолжительность лова 0с 30	Широта 52°57,2N
Долгота 155°27,1E	Размер ячеи 12	Долгота 155°27,7E

Способ определения места и курсы хода с тралом ИК-175°

Неполадки лова (задевы, заверт, разрыв)

Подпись вахтенного штурмана

Видовой состав улова

Вид рыб	На час траления: Штук	На час траления: Вес, кг	Вид рыб Размеры, см	Штук	Вес, кг
Theragra chalcogramma	14	11.9	42 - 58	7	5.95
Theragra chalcogramma juv	6	0.021	7.5 - 10.3	3	0.0105
Eleginus gracilis	12	5.1	34.8 - 37.0	6	2.55
Limanda aspera	2	0.44	23.9	1	0.22
Trichodon trichodon	2	0.026	10.7	1	0.013
Eumicrotremus derjugini	10	1.076	6.9 - 13.6	5	0.538
Ammodytes hexapterus	2	0.048	21.4	1	0.024
Mallotus villosus juv.	13480	7.20	4.6 - 8.0	6740	3.60
Итого		25.81			12.906

TINRO-center trawl card

SEA Okhotsk SHIP r/v TINRO ЫЖО 16 Date (dd,mm,yy) 08.04.1998

Trawl # 167 Direction and strength of wind NW5 Roughness 4,0 m Sea surface temperature -0,8 °C

Total catch 12,923 kg Region #: 8 Catch per one hour 25,846 kg

Haul start	Depth of headrope (average) 50 m	Haul end
Time start 1650 hh:mm	Spread of trawl (vert/horiz) 18,0 / 19,7 m	Time end 1720 hh:mm
Depth 67 m	Trawl Type PT 57/360	Depth m
Bottom type 100П	Warps length 200 m	Bottom type
Bottom temperature °C	Speed 3,8 knots	Bottom temperature
Latitude 52°59'6 N	Duration of haul 0,50 hours	Latitude 52°57'2 N
Longitude 155°27'1 E	Mesh size (body, codend) 30 / 12 mm	Longitude 155°27'7 E

Device for determining ship position and direction of haul 175°

Malfunctions of trawl operations нет

Species	Size-age group	Length min	Length max	Quantity	Weight	Per 1 hour of trawling individuals	Per 1 hour of trawling kg	x
Ammodytes hexapterus	adlt.	21,4	21,4	1	0,0240	2	0,0480	1,0
Eumicrotremus derjugini	adlt.	6,9	13,6	5	0,5380	10	1,0760	1,0
Eleginus gracilis	adlt.	34,8	37,0	6	2,5500	12	5,1000	1,0
Theragra chalcogramma	adlt.	42,0	58,0	7	5,9500	14	11,9000	1,0
Mallotus villosus	larv.	4,6	8,0	6740	3,6000	13480	7,2000	1,0
Limanda aspera	adlt.	23,9	23,9	1	0,2200	2	0,4400	1,0
Trichodon trichodon	adlt.	10,7	10,7	1	0,0130	2	0,0260	1,0
Theragra chalcogramma	juv.	7,5	10,3	3	0,0105	6	0,0210	1,0
*								1,0
Total:				6764	12,91	13528	25,81	

Record: 1 of 8

Record: 1 of 1 (Filter)

Fig. 1. Trawl card – a document, filled in by a navigator and a scientist for every trawling in scientific-research and fishery-research cruises. On the left there is a hand-written paper form. On the right there is its digital analogue, or one of possible forms of a trawl card presentation, in a computer database

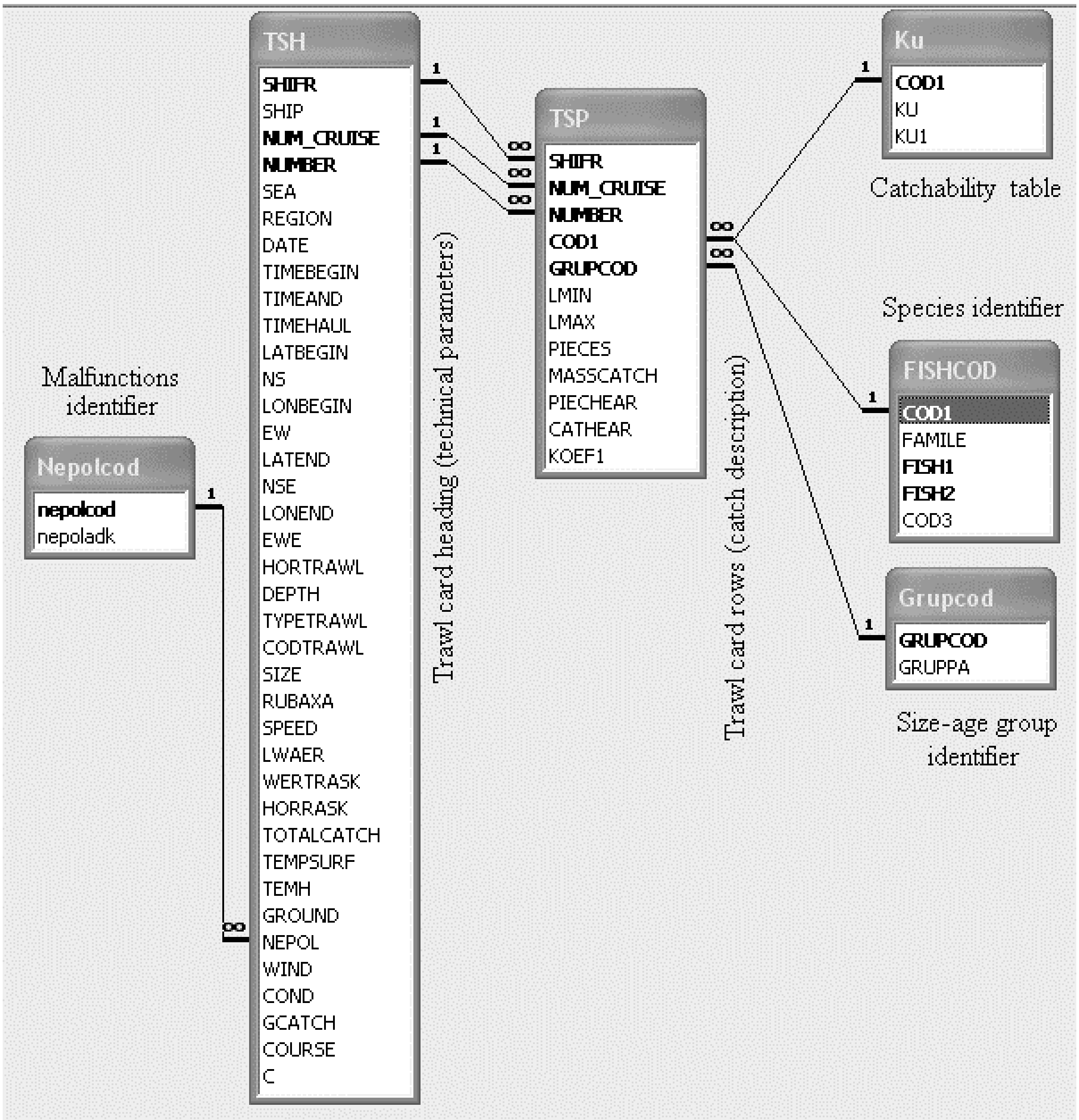


Fig. 2. Database structure. Key fields are given in bold font. Lines show relations between the tables

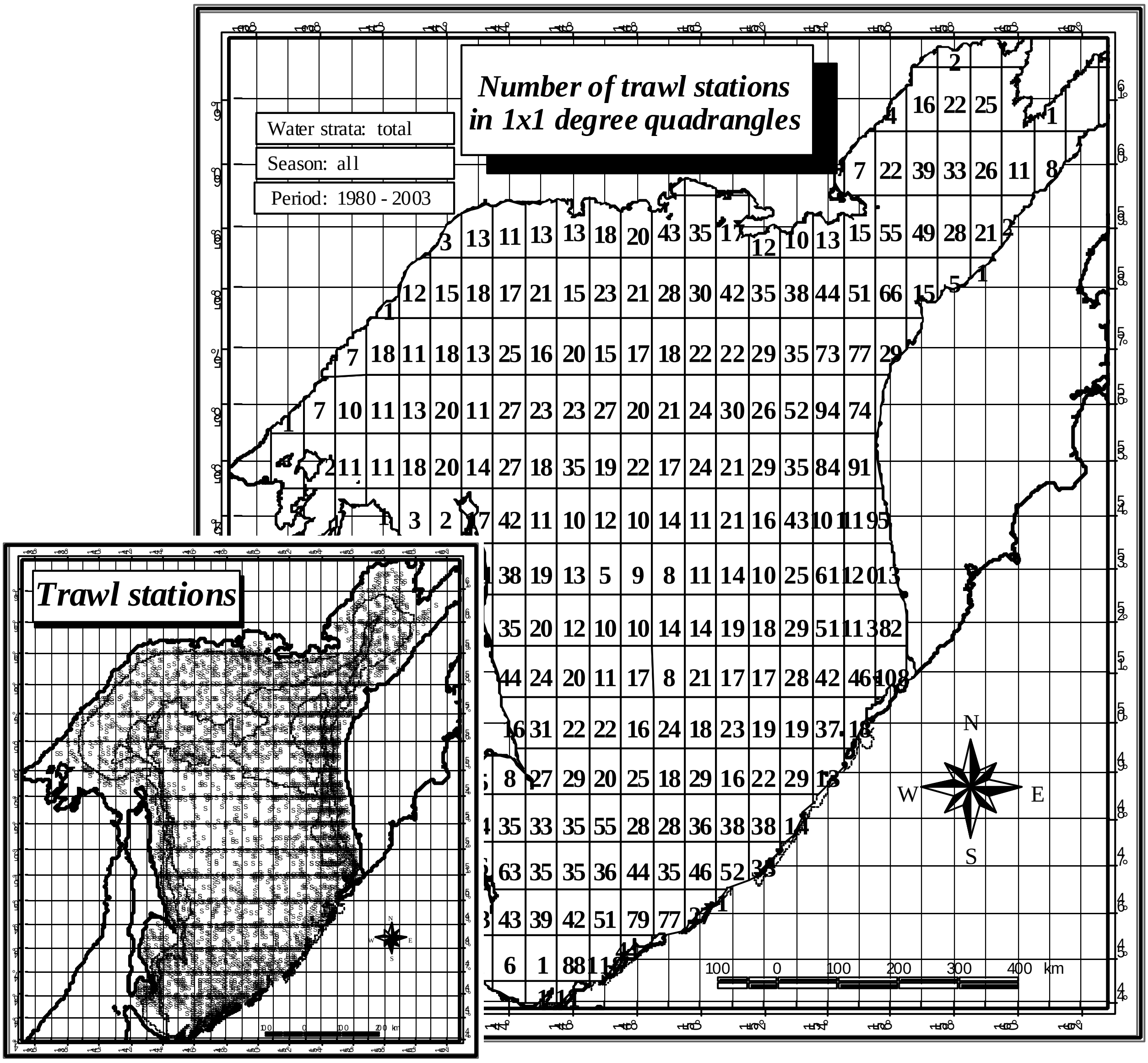


Fig. 3. A scheme of location of 6151 trawl stations and distribution of the number of stations between 257 of 1x1 degree quadrangles with centers in points of meridians and parallels intersection

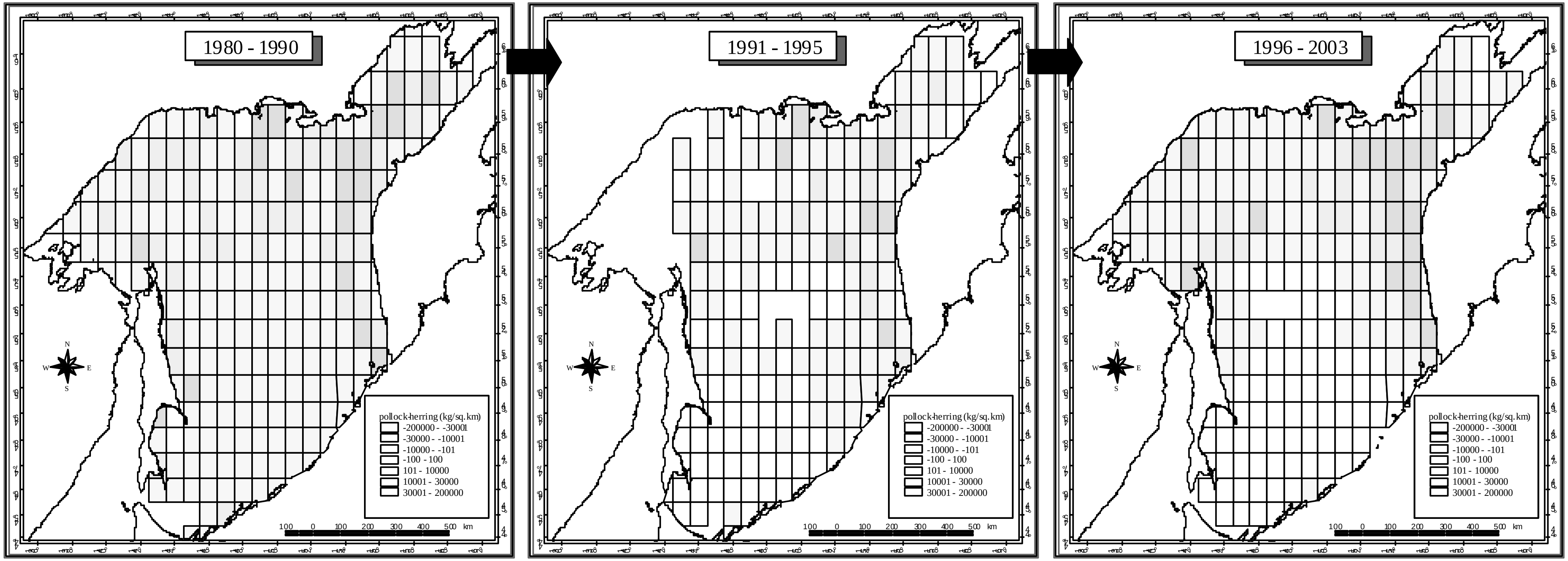


Fig. 4. The difference between walleye pollock and Pacific herring biomasses (kg/km^2) in pelagic water layers within different periods: in the 80s (on the left), in the first half of the 90s (in the center) and in 1996-2003 (on the right). Horizontal hatching shows prevalence of pollock, vertical – prevalence of herring, lack of hatching – a zone where the difference of two species biomass does not exceed ±100 kg/km^2

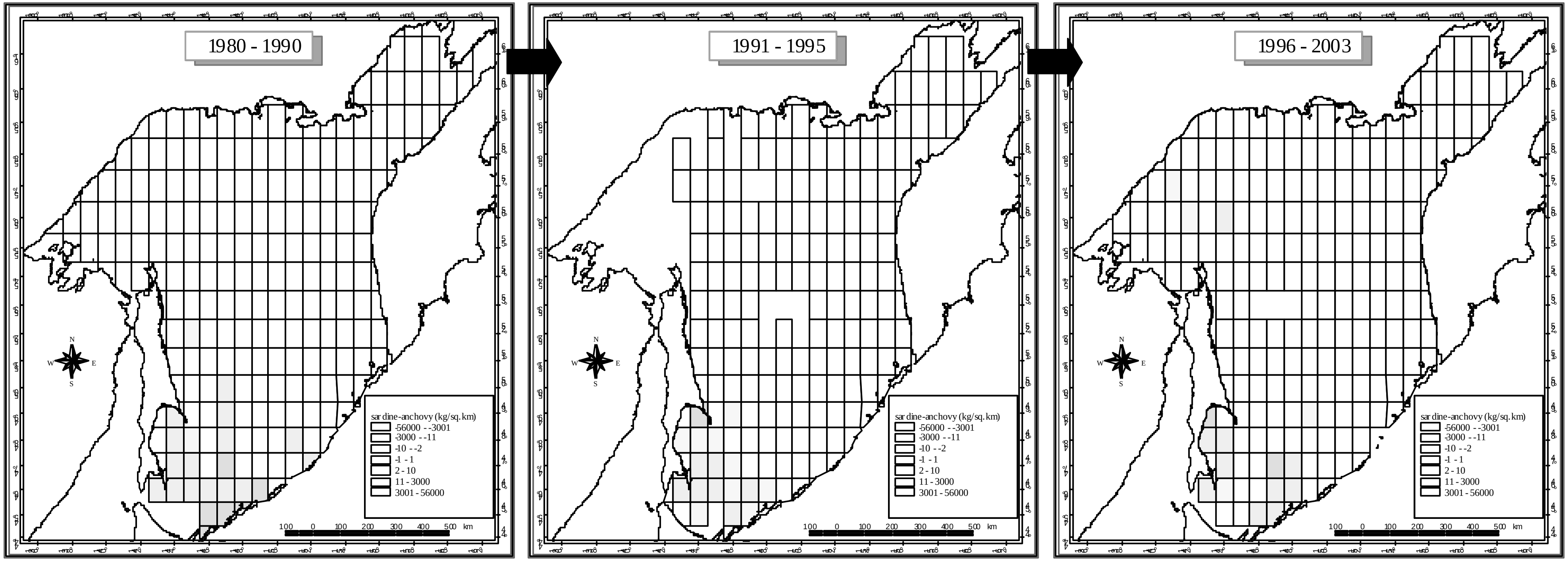


Fig. 5. The difference between Pacific sardine and Japanese anchovy biomasses (kg/km^2) in epipelagic water layers within different periods: in the 80s (on the left), in the first half of the 90s (in the center) and in 1996-2003 (on the right). Horizontal hatching shows prevalence of sardine, vertical – prevalence of anchovy, lack of hatching – a zone where the both species are absent or their biomass difference does not exceed ±1 kg/km^2

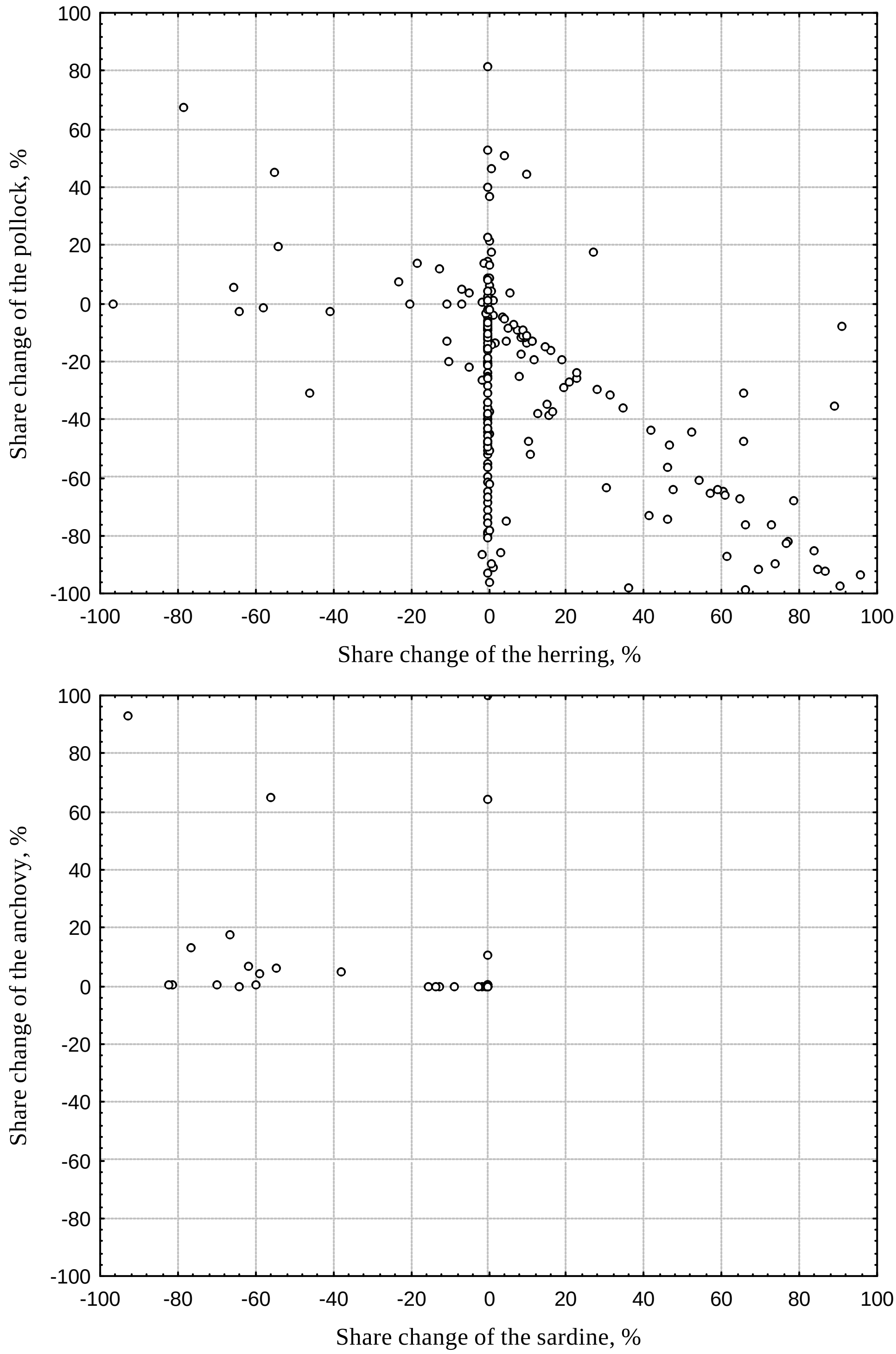


Fig. 6. Correlation of shares variations (%) of Walleye pollock and Pacific herring in all nekton biomass (on the upper plot), and that of Japanese anchovy and Pacific sardine in nekton biomass of epipelagic water layers of the Okhotsk Sea (on the lower plot) within the period from 1980-1990 to 1996-2003. Here and on Fig. 9 every dot corresponds to 1 one-degree trapezium

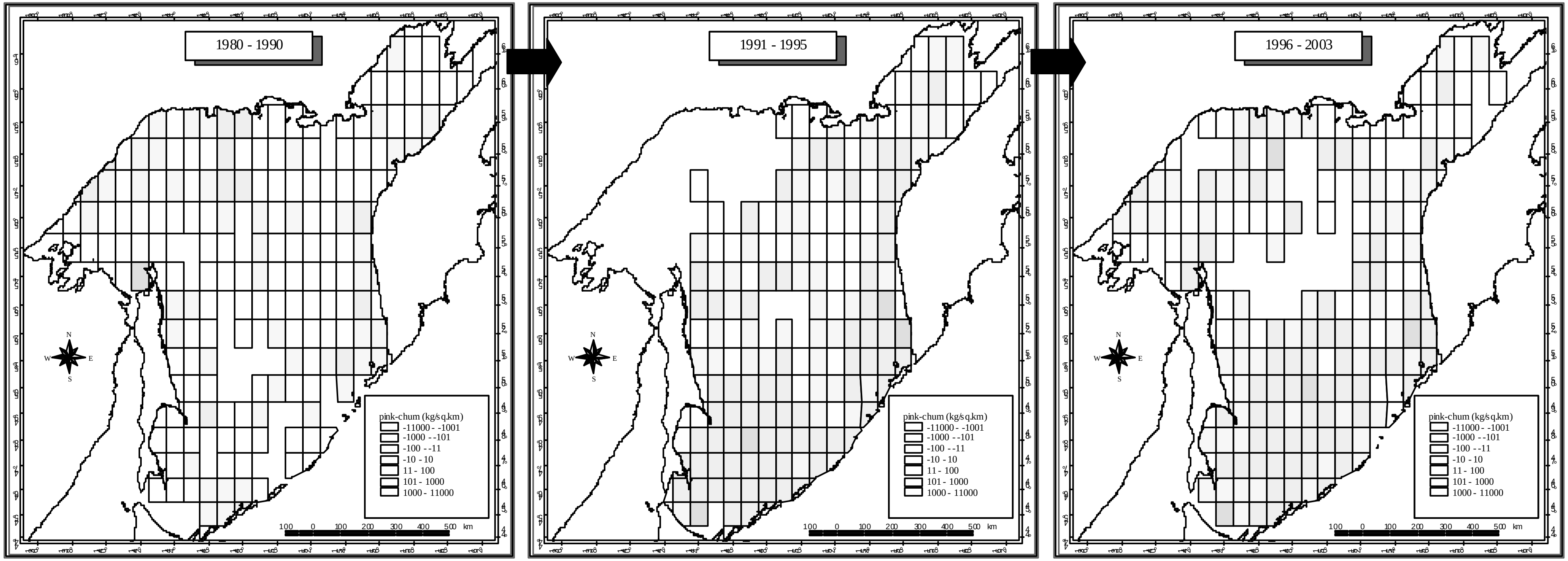


Fig. 7. The difference between pink salmon and chum salmon biomasses (kg/km^2) in epipelagic water layers within different periods: in the 80s (on the left), in the first half of the 90s (in the center) and in 1996-2003 (on the right). Horizontal hatching shows prevalence of pink, vertical – prevalence of chum, lack of hatching – a zone where their biomass difference does not exceed ±10 kg/km^2

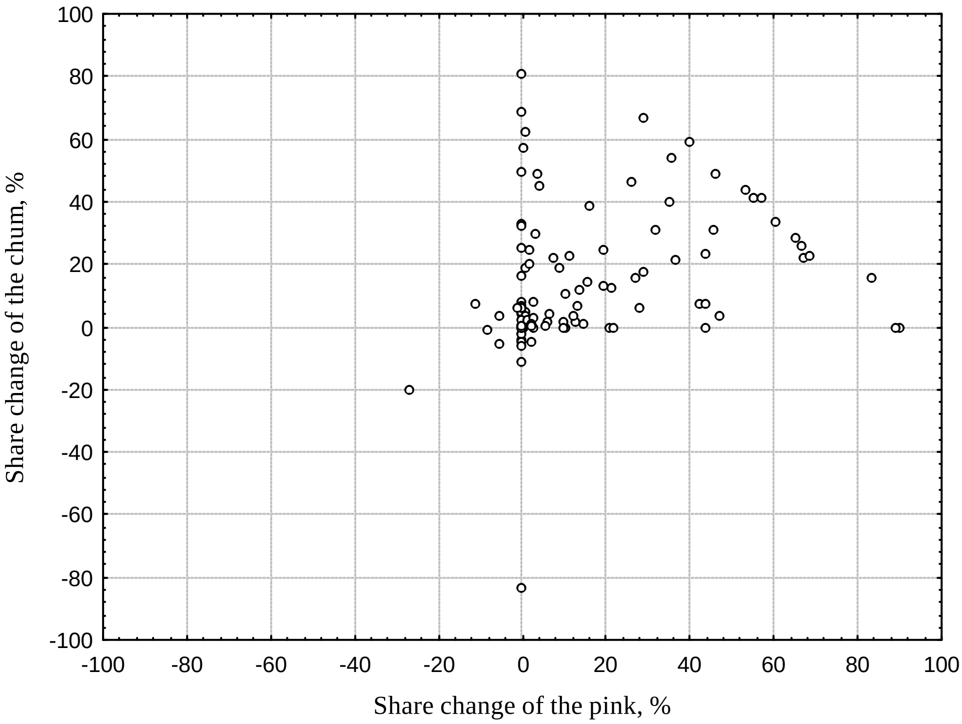


Fig. 8. Ratio of shares variations (%) of pink and chum salmon in ichthyocene biomass of the upper epipelagic water layers of the Sea of Okhotsk within the period from 1980-1990 to 1996-2003

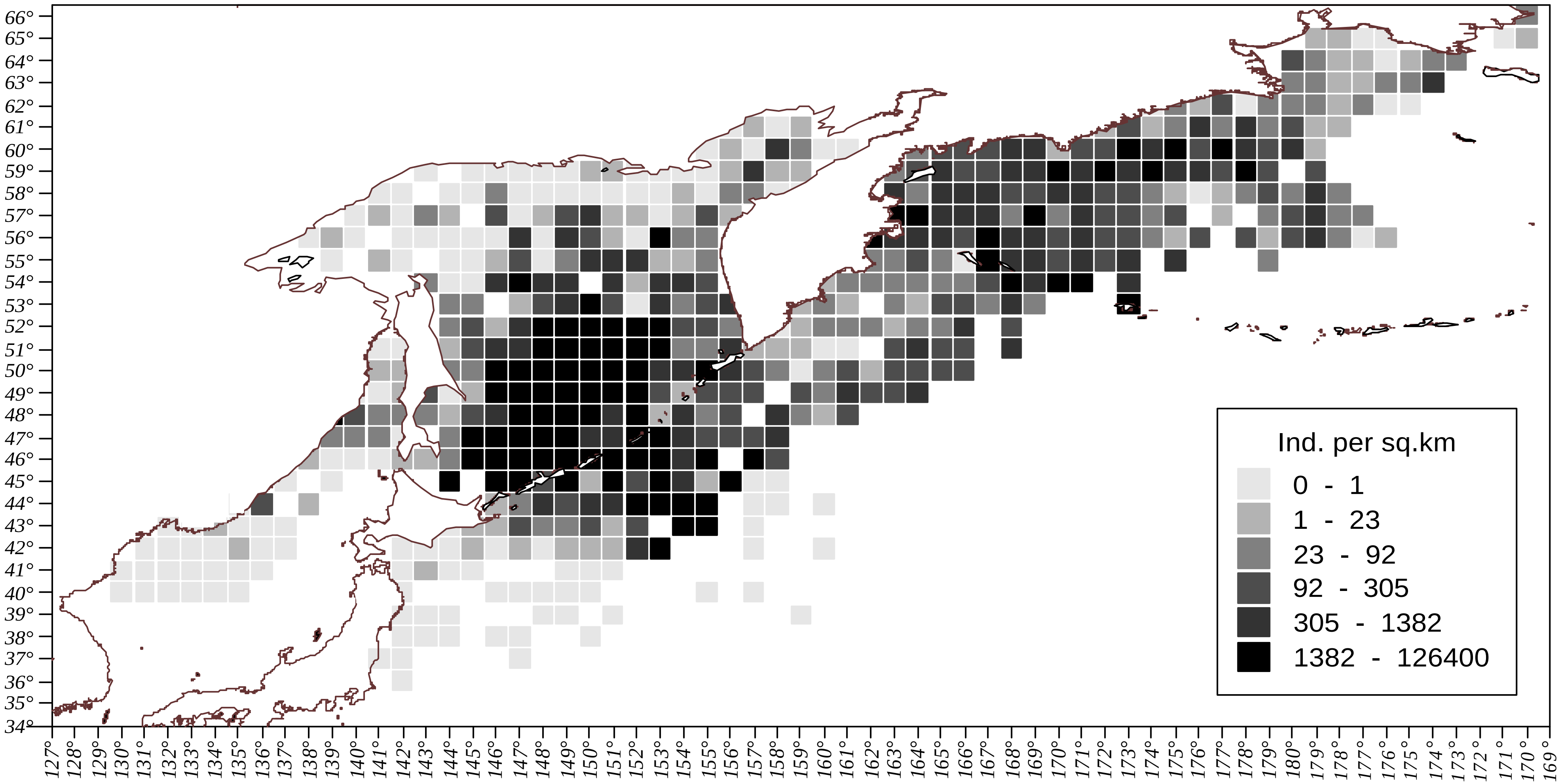


Fig. 9. Approximate picture of spatial distribution of total density (ind./ km^2) of all salmon species in the upper epipelagic water layers of the northwestern Pacific in autumn. The map is based on unchecked and unedited mean long-term data collected during 190 research cruises in 1980-2002

References

Atlas of quantitative distribution of nekton species in the Okhotsk Sea /edited by V.P. Shuntov and L.N. Bocharov. – Moscow: "Natsionalnye rybnye resursy" Publisher, 2003. - 1031 p. (In rus., in press)

Beamish R.J., Bouillon D.R. Pacific salmon production trends in relation to climate // J. Fish. Aquatic Sci. - 1993. - V. 50. – P. 1002-1016.

Bocharov L.N., Ozerin V.K. Works for creation the bank of fishery, biological and oceanological data in TINRO // TINRO-70. - Vladivostok: TINRO-Center, 1995. - P. 10-19. (In rus.)

Davydov I.V. The nature of long-term changes of fish abundance and possibility of their prevision // Dynamics of the commercial animals abundance in the Far East seas. - Vladivostok: TINRO, 1986. - P. 5-16. (In rus.)

DeMers M.N. Fundamentals of Geographic Information Systems. Rus. Edition. - Moscow: Data+, 1999. - 489 p.

Dulepova E.P., Volvenko I.V. Nekton, zooplankton, zoobenthos and trophic levels' bioproductivity databases for the North Pacific // PICES XI Abstracts. - Qingdao, China, October 20-24, 2002. - P. 176.

Gritsenko O.F., Klovach N.V. Self-Regulation of Japan Chum Salmon Abundance // NPAFC Technical Report 4. - Vancouver, Canada, 2002. - P. 45-47.

Gritsenko O.F., Klovach N.V., Bogdanov M.A. A new era of Pacific salmon being in the northwestern Pacific Ocean // Rybnoye hozaystvo (Fisheries). - 2002. - ? 1. - P. 24-26. (In rus.)

Gritsenko O.F., Klovach N.V., Urusova L.E. A new epoch for Salmon stocks in the north-western Pacific. - NPAFC Doc. 503, 2002. - 9 p.

Kafanov A.I., Volvenko I.V. Ichthyofaunistic biogeography of the Japan (East) Sea: the comparison of various rank taxa for zoning // Journal of Biogeography. - 2001. - V. 28, N 10. - P. 1255-1269.

Kafanov A.I., Volvenko I.V., Fedorov V.V, Pitruk, D.L. Ichthyofaunistic biogeography of the Sea of Japan (East Sea) // Journal of Biogeography. - 2000. - V. 27, N 4. - P. 915-934.

Kafanov A.I., Volvenko I.V., Pitruk, D.L. Ichthyofaunistic biogeography of the East sea: Comparison between bental and pelagial zonalities // Ocean and polar research. - 2001. - V. 23, N 1. - P. 35-49.

Klovach N.V. Degeneration of Tissue in Chum Salmon as an Indicator of Exceeding the Ecological Capacity of the North Pacific in Respect of Salmon // NPAFC International Symposium Abstracts, November 1-2, 1999. - Juneau, Alaska, USA. - P. 12-13.

Klovach N.V. Tissue Degeneration in Chum Salmon and Carrying Capacity of the North Pacific Ocean // NPAFC Bulletin. - Vancouver, Canada, 2000. - N 2. - P. 83-88.

Klovach N.V. Spatial and temporal dynamics of occurrence of the Chum *Oncorhynchus keta* (*Salmoniformes, Salmonidae*) with softened muscles and factors responsible for their softening // Zoologichesky zhurnal (Zoological J.). - 2001. - V. 80, N 6. - P. 703-709. (In rus.)

Klovach N.V. Ecological Consequences of Large-Scale Propagation of Chum Salmon. -Moscow: VNIRO Publishing, 2003. - 164 p. (In rus.)

Klovach N.V., Rzhannikova L.A., Gorodovskaya S.B. Biological characteristics of the chum salmon *Oncorhynchus keta* during the summer fattening at sea // Voprosy ihtiologii (J. of Ichthyology). - 1996. - V. 36, N 5. - P. 622-630. (In rus.)

Ozerin V., Sidorenko L., Tatarchuk G., Korostyleva Z., Saveleva L., Danilova T., Elagin V. Catalogue of fishery, biological and hydrological data (1980-1992 years). - Vladivostok: TINRO, 1995. - 52 p.

Shuntov V.P. The state of knowledge of long-term cyclic fluctuations of fish abundance in the far-eastern seas // Biologia morya (Marine biology). - 1986. - ? 3. - P. 3-14. (In rus.)

Shuntov V.P. Review of Research into Macroecosystems of the Far-Eastern Seas: Results, Objectives, Doubts // PICES Annual Report. IX Meeting. Vladivostok, Russia - Sidney, British Columbia, Canada. - 1999. - P. 15-23.

Shuntov V.P., Dulepova E.P. Current status and interannual dynamics of the demersal and pelagic communities in the ecosystem of Okhotsk Sea // Izv. TINRO. - 1996. - V. 119. - P. 3-32. (In

rus.)
Temnykh O.S., Starovoytov A.N., Glebov I.I., Merzlyakov A.Yu., Sviridov V.V. Pacific salmon in the epipelagic fish communities of the south Okhotsk Sea // Izv. TINRO. - 2003. - V. 132. - P. 112-153. (In rus.)
Volobuev V.V. Local Chum Salmon Stocks of the Sea of Okhotsk Continental Area and their Long-Term Changes // NPAFC International Symposium Abstracts, November 1-2, 1999. - Juneau, Alaska, USA. - P. 19.
Volobuev V.V. Long-term Changes in the Biological Parameters of Chum Salmon of the Okhotsk Sea // NPAFC Bulletin. - Vancouver, Canada, 2000. - N 2. - P. 175-180.
Volobuev V.V., Volobuev M.V. Ecology and population structure as basic elements of life strategy formation in the chum salmon *Oncorhynchus keta* from the Okhotsk Sea // Voprosy ihtiologii (J. of Ichthyology). - 2000. - V. 40, N 4. - P. 516-529. (In rus.)
Volvenko I.V. Some algorithms of data processing on an abundance and size-weight structure of catches // Izv. TINRO. - 1999. - V. 126. - P. 58-81. (In rus.)
Volvenko I.V. Problems in estimation of fish abundance by trawl sampling. - NPAFC Doc. 506, 2000. - 29 p.
Volvenko I.V. Dynamics of integrated characteristics of macrofaunal assemblages in the northern part of the Okhotsk Sea at the end of XX century // Izv. TINRO. - 2001. - V. 128. - P. 3-44. (In rus.)
Volvenko I.V. GIS and Atlas of Salmons spatial-temporal distribution in the Okhotsk Sea. - NPAFC Doc. 729, 2003a. - 32 p.
Volvenko I.V. Knowledge Base and Catalogue of Salmons abundance in the Okhotsk Sea. - NPAFC Doc. 731, 2003b. - 67 p.
Volvenko I.V., Titiayeva E.A. Dominance in nekton and macroplankton fauna of epipelagic water layer of the northern Okhotsk Sea // Izv. TINRO. - 1999. - V. 126. - P. 58-81. (In rus.)