SEISMOCONDITIONALITY OF REPRODUCTION AND DEVELOPMENT OF FISH CONGESTIONS IN NORTHERN WATERS

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In the 16th–19th centuries already, fishermen noted the impact of earthquakes on fish: "fish try to hide away and many of them throw themselves out of the water. Sometimes fish get injured: their bladder explodes because of fast changes in pressure". This is associated with lithospheric emissions of methane, to which many aerophilic aquatic organisms have not become adapted evolutionally. In places with massive discharge of methane during earthquakes, juveniles and older fish die. The survivors disperse for several weeks and up to 1.5 months depending on the intensity of mixing, and migrate from seismic-active waters or stick to remote water flanks or "liquid" boundaries of the habitat (temperature and salinity fronts, ice margin, or deep pools). Thus, it may be concluded that after receiving information about observed seismic disturbances one should not go fishing in the affected areas because the catch will be much lower than forecasted, and economically inefficient. One should seek for the margins of the seismic-pressure areas, where survivor fish concentrate. Survived juvenile become unviable. Reproductive functions fail in the breeding part of the population, i.e. a decline in the number of fingerlings, down to the collapse, would follow in spite of any biotic and abiotic conditions. Simultaneously, the catches of mollusks also decrease, whereas the catches of crustaceans increase.

For over 50 years hydrobiologists have tried to explain the development of congestions of the majority of commercial marine organisms from the "aquarium" point of view. Spawning stock, water temperature, oxygen, availability and abundance of food items, predation pressure are considered to be the main factors limiting reproduction and survival rate. For specific organisms, ice conditions, sea level, waves, and benthic vegetation are also taken into account. When decrease in reproduction or massive mortalities are inexplicable from the "aquarium" point of view, pollution, undocumented fishery, poor-quality statistics, invader species feeding on native species, genetically dependent periodicity in the development of the organisms are referred to. Hydrobiologists are immensely perplexed when there is no recruitment in well-fed fish stocks with plentiful supply of food and heat, whereas in the situation of very low food availability fish are exceptionally fat; when the declared "genetic" periodicity in reproduction changes; and genetically dependent post-spawning mortality of fish gets no confirmation in control series.

The fact that hydrobiologists do not budget the costs of questionnaires among local people concerning the behavior of aquatic organisms adds to this situation. E.g., there is no information about extraordinary behaviors on the eve of the Gazli, Parakar, and Paravani earthquakes, when fish stuck to the shore opposite the earthquake centers, and small fish beached themselves (Lushvin, 2008). Such situations are not new and quite explainable. Since olden times people have noticed that peatland gas (mostly made up of methane) was destructive for aerophilic fish. It is manifest in unusually excited fish behavior during floods, in shelf and slope sea areas in the vicinity of earthquake centers and active faults of the Earth's crust. Economically, this is used by Melanesians on the Fiji Islands where saline lakes are inhabited by a mackerel species, yellow eye. They strictly follow a ceremony when on a certain day all inhabitants of the village enter the lakes and stir the bottom silt in every possible way. Natural gas mixed with hydrogen sulfide comes out. The half-poisoned fish emerge and are killed. The rite is in agreement with ichthyologic requirements: it takes place after spawning. After that, oxygen re-appears in the water, and the suspended water silt provides the young with first food [http://botinok.co.il/node/48542].

Methane emissions on days of earthquakes and floods are always displayed through outbreaks of methane content in bottom sediments and lower troposphere over the subsurface fields of hydrocarbons and the soft sedimentary sheath (Fig.1).

In the present study we analyze typical situations of development of aquatic organism congestions in northern aquatories in periods of seismic stress.

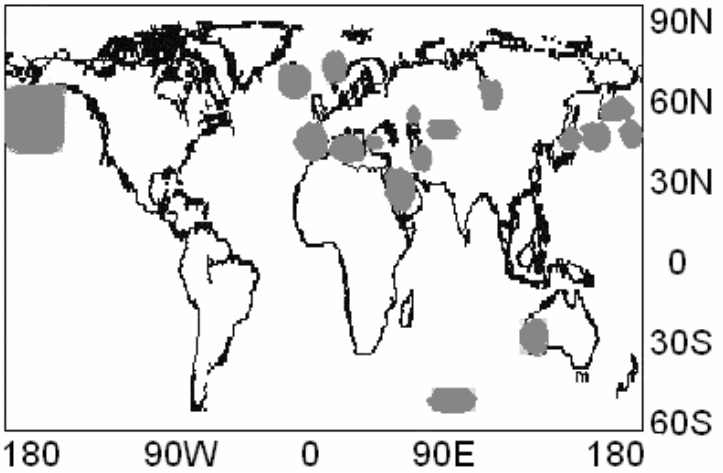

Fig.1. Local maxima of methane content in the atmosphere on the 681-hPa surface, according to the AIRS data obtained at the time of earthquakes in 2004–2006 (ftp://l4ftl01.larc.nasa.gov/TES/TL3CH4D.002/)

Comparison of aquatic organism congestion patterns with seismic activity in the Norwegian and the western Barents Seas

The absence of correlation of Atlantic cod reproduction with water temperature and zooplankton biomass (Karammushko, Mukhina, 2007) is associated with the fact that the bulk of cod spawning takes place on the inner side of the Lofoten Islands, which is inaccessible to Russian hydrobiologists, as well as with the presence of a soft sedimentary sheath with high content of methane, emitted into the water at earthquakes, off the coast of Norway (Fig. 2). The latter is indirectly confirmed by the presence of local methane maxima in the atmosphere over the region after earthquakes. The consequences of seismic stresses are disturbances of reproductive functions in 20÷100% of generations of earlier spawned fish (resorption of eggs, longer ripening) (Oganesyan, 1993). Nevertheless, hydrobiologists are very reluctant to take these facts into account, and persist in forecasting yield proceeding from the population fecundity only (Bondarenko et al., 2003).

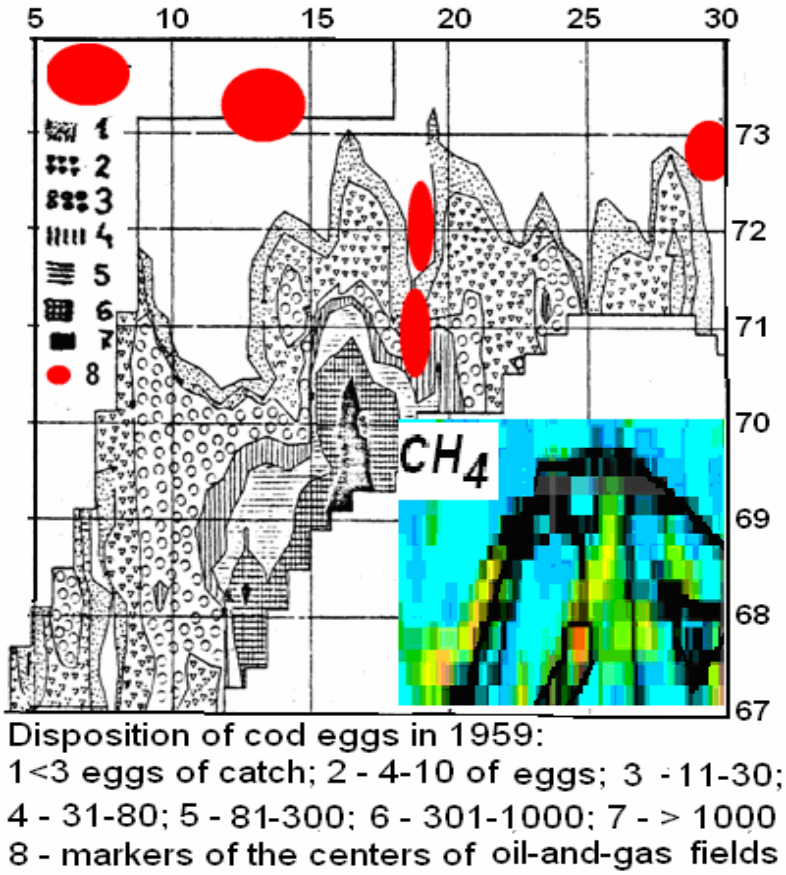

Fig. 2. Markers of the centers of presumed oil and oil-and-gas fields [http://geolib.narod.ru/OilGasGeo/1996/11/Stat/stat06.html] against the distribution of cod eggs in 1959. The insert shows methane content in the atmosphere (a.a.tronin@ecosafety-spb.ru)

Capelin suffocations have been recorded in the sea dozens of times, but neither histological analyses were made nor samples for methane determination were taken. It was assumed that capelin is genetically programmed to post-spawning death. However, the group taken out demonstrated no loss for 90 days. Cod and capelin reproduction in the region declines sharply after intensification of earthquakes in the winter and spring (spawning and post-spawning) seasons (Lushvin, 2008; Lushvin, Sapozhnikov, 2006). Specialists from PINRO specialists (Boitsov, Kovrova, 1993) believe that "the roles of biotic and abiotic factors in formation of the productivity of the Barents Sea flounder generations, including factors such as population fecundity and brood stock numbers" are yet unclear (Fig. 3). The vulnerability of flounder to the impact of lithosphere-generated toxicants was, however, mentioned in paper (Patin, 1997) already. The survival rate of flounder in the Barents Sea is low on the spawning years with increased seismic activity and vice versa. The catches of sprat and ling in the Norwegian Sea are also limited by seismic stress (Fig. 4).

Comparison of aquatic organisms and marine mammals congestion patterns with seismic activity in the White Sea

Herring reproduction in the White Sea is limited by water temperature and seismic stresses, because food and oxygen reserves are sufficient (Fig. 5). In earthquake years, and sometimes in the subsequent year, herring yield is always low! As energy consumption for reproduction decreases, the fish weight grows (Lushvin, 2008). The catches (reproduction) of navaga in the White Sea are also limited by seismic activity (Fig. 6). One or two years after earthquakes navaga catches exhibit local minima. In years with low seismic activity, 70 to 100% of individuals are ready to spawn at an age of 2^{+}. In seismoactive years, their proportion decreases to 30%. Six-eight years after intensification of seismic activity, the take of seals collapses as a consequence of decline in the food resources (navaga) during the periods of puppying, nursing, and feeding of the young (Yakovenko, 1963).

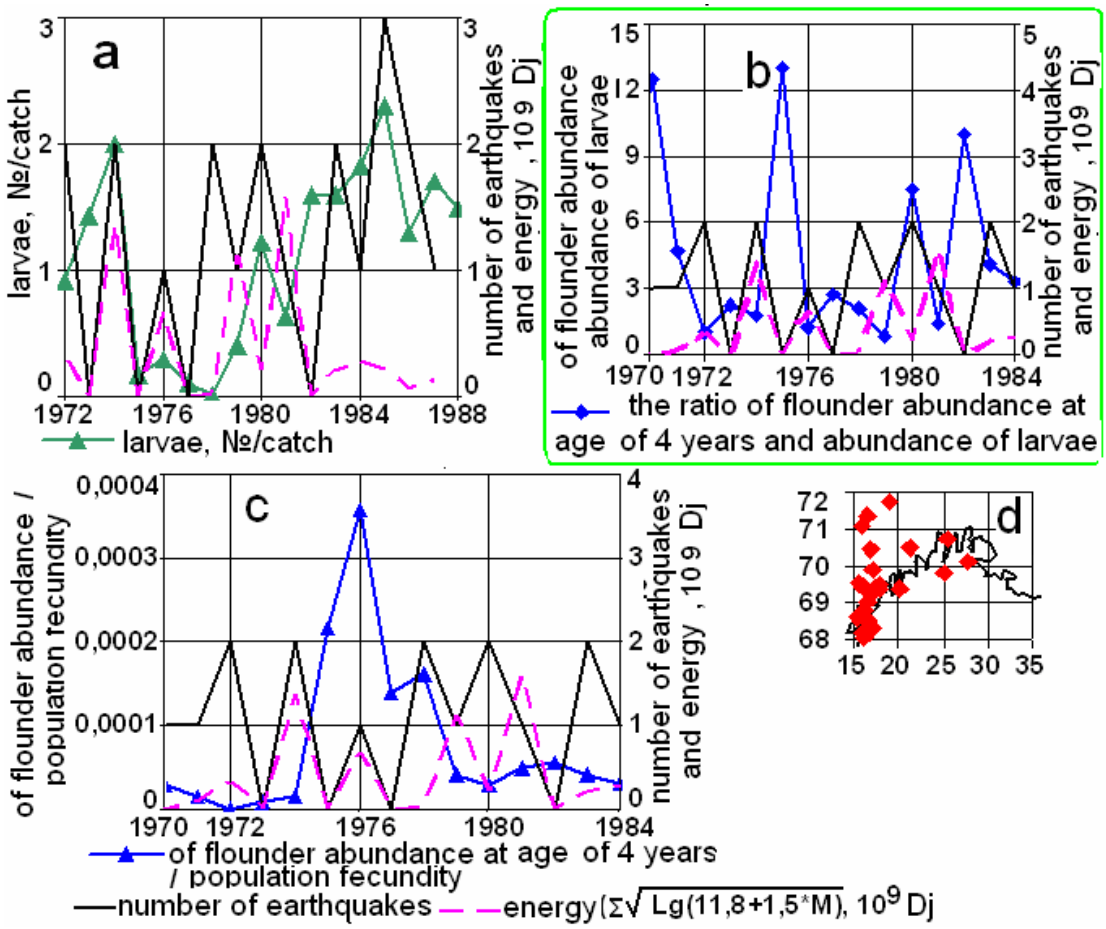

Fig.3. Comparison of seismic activity in the region (with the 4-year lag) with the flounder abundance at an age of 4 years/larvae abundance ratio. The insert shows earthquake epicenters

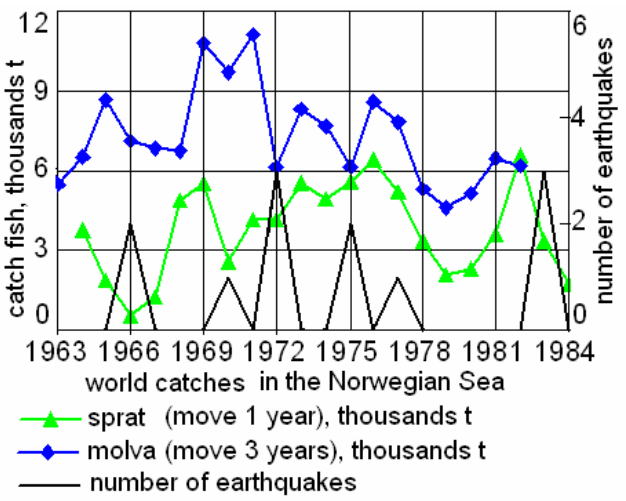

Fig.4 Comparison of world catches of ling and sprat in the Norwegian Sea with regional seismic activity

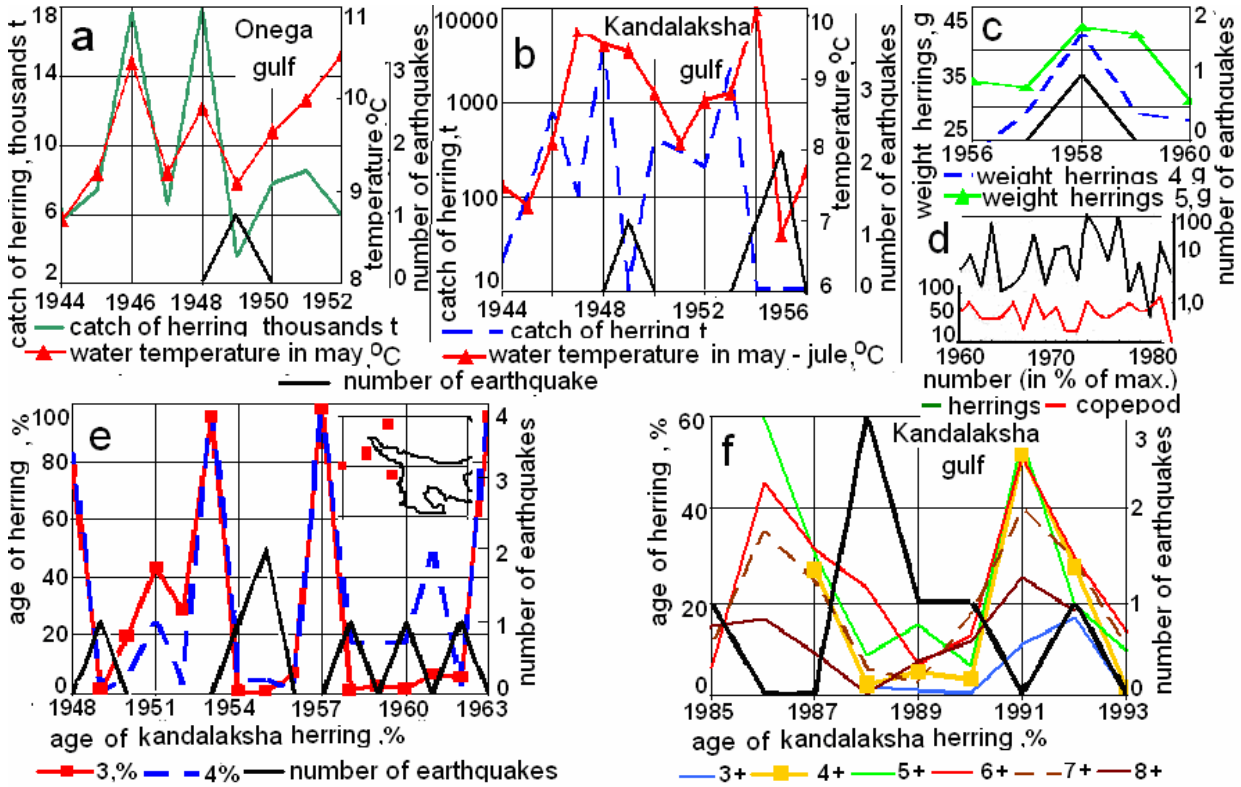

Fig. 5. Comparison of herring catches (a, b), herring weight, and copepod abundance (c), as well as the age structure of herring (d, e) with the number of earthquakes

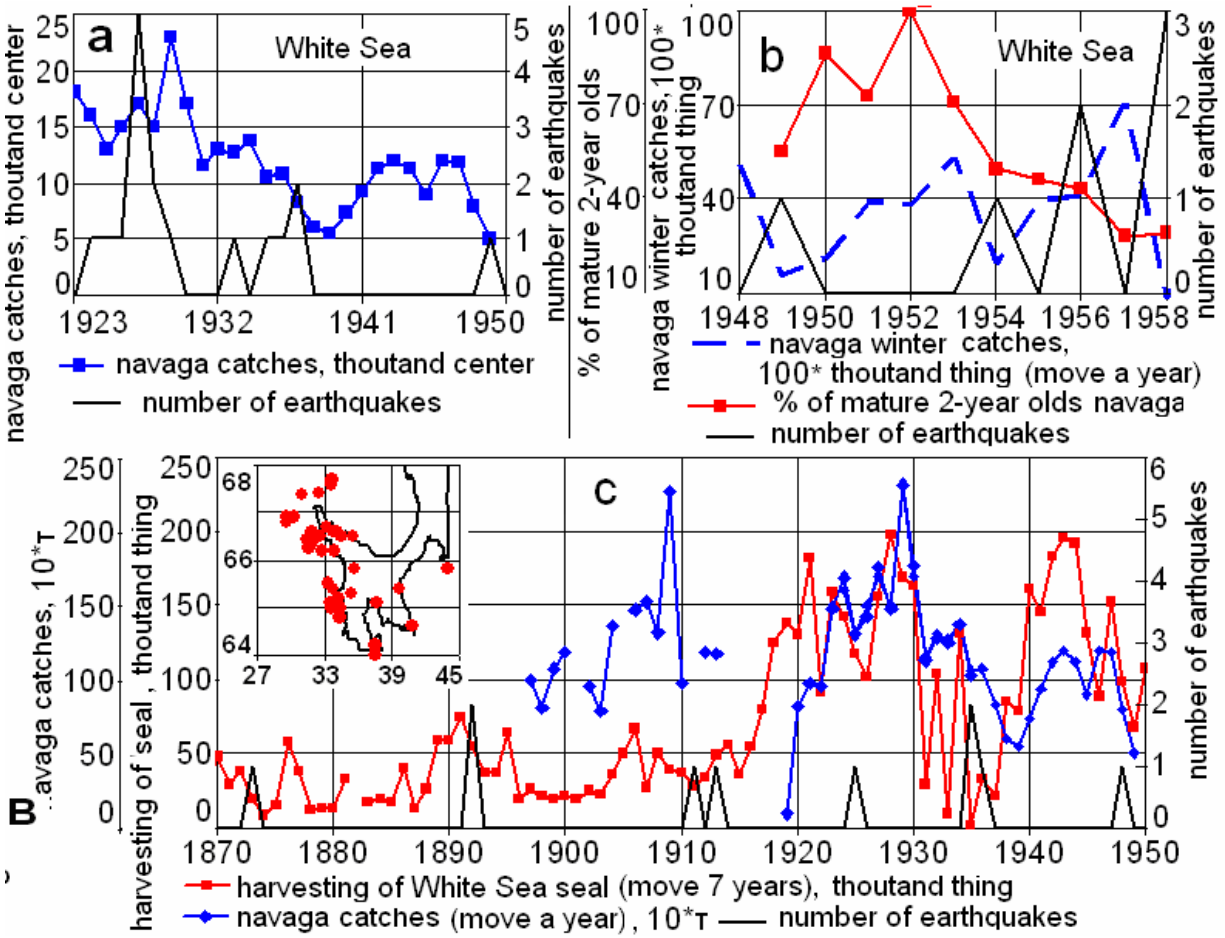

Fig. 6. Comparison of the number of earthquakes with navaga catches,% of mature 2-year olds, and harvesting of the White Sea seal (insert shows epicenters of recorded earthquakes)

Seismogenic emission of methane causes replacement of salmonids with coregonids, and further with less aerophilic osmerids and cyprinids (Klyashtorin, 1982; Reshetnikov, 1986). Peak discharges from water engineering facilities also promote this process because, carried out on dates not justified by the nature, abruptly raising the level and accelerating the flow, they stir up floodplain silts and methane contained there is carried into the reservoirs. Comparison of benthos biomass with methane content indicated the extremely negative response of zoobenthos to methane (Fig. 7) (Sergeeva, Gulin, 2007). In water areas with temporarily impoverished benthos, fatness of benthophage fishes decreases, their visits to these places become fewer, even though they may be the traditional feeding areas, and hypoxia tends to develop in the near-bottom water layers (Lushvin, Karpitsky, 2009).

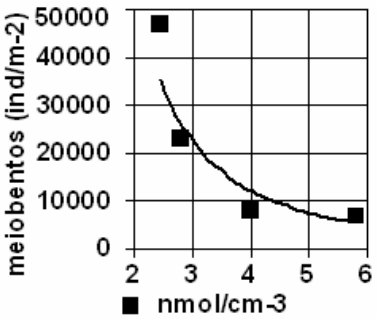

Fig.7. Ratio between meiobenthos (0.1÷1 mm) abundance in the top 5-cm layer of sediments and methane content in the top 25-cm layer of sediments in the paleobed of the Dnieper Canyon (eam of the Donuzlav Bay)

Comparison of aquatic organisms congestion patterns with seismic activity in the Pechora region

In the Pechora region, reproduction, survival rate and catches of polar cod, Atlantic salmon and navaga are determined, alongside with thermal conditions, by seismic stresses (Fig. 8a). In his presentation at the Azov Conference G. Matishov described rather unusual behavior of polar cod on days of the Novaya Zemlya earthquakes – the fish huddled up to brackish Pechora waters (Lushvin, Sapozhnikov, 2006) (other fishery actors also mentioned this fact). The percentage of 3-year old navaga under low seismicity conditions is higher than a year later, and vice versa (Fig. 8b). In years with earthquakes, Atlantic salmon reproduction is below the average, irrespective of the water temperature, and its catches decrease subsequently (Fig. 8c). Fish catches in the downstream of the Pechora River are also in many respects determined by seismic stresses. The catches of aerophilic grayling, whitefish, and pike decrease after a seismic stress, while the catches of crucian carp and vendace, on the contrary, increase in the absence of predators (Fig. 8d).

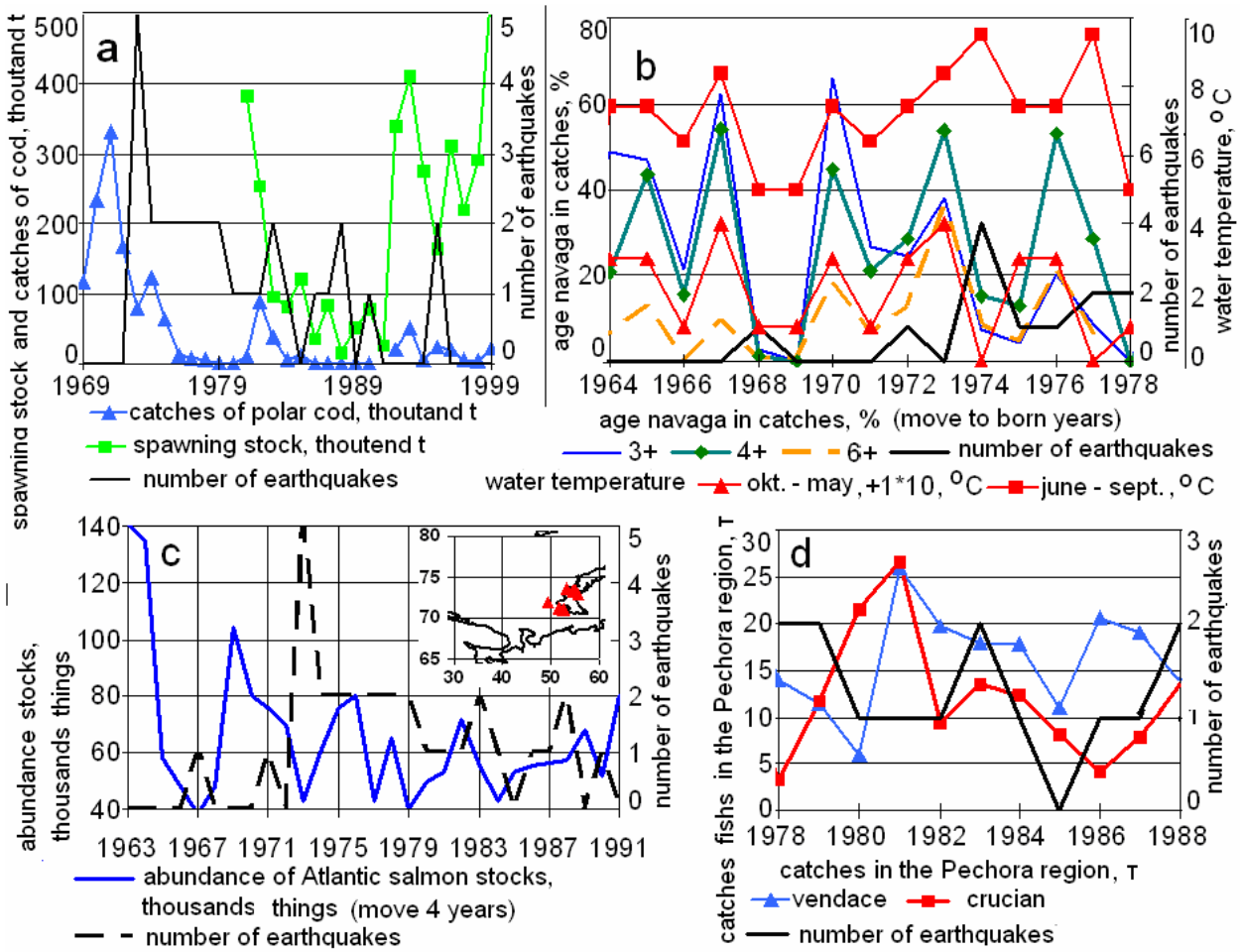

Fig. 8. Comparison of the recorded number of earthquakes with catches of polar cod, navaga, abundance of Atlantic salmon stocks, catches of vendace and crucian carp in the Pechora region (a-d)

Current redfish catches

Current redfish catches in the Norwegian and Barents Seas after seismic stresses decline relative to the monthly average by 20–60%. Such "undercatches" occur either in the beginning (1997) or at the end (2001) of the fishing season. Seismic stresses even "split" the usually unimodal peak of catches into a bimodal one (1999, 2002, 2003), thus extending the fishing season from 3 to 4–5 months (Fig. 9). March and April earthquakes are the most harmful for fishery.

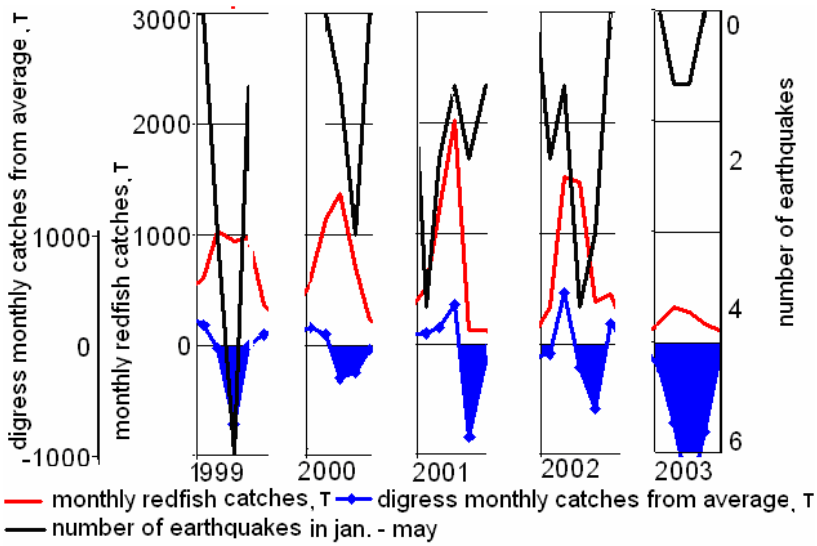

Fig. 9. Comparison of monthly redfish catches by Russian vessels in the Barents and Norwegian Seas with the number of earthquakes from February-March to May-July

Conclusions

In waters subject to massive discharge of lithospheric fluids from seismic activity:

1. Juveniles of many aerophilic commercial species die.
2. Whatever the biotic and abiotic conditions are, the reproductive functions in survivor juveniles are disturbed (decrease in juvenile resilience, sharp decline in fingerling abundance).
3. Commercial congestions of fish temporarily disappear. This implies that after receiving information that an earthquakes has happened, the fishery in the "infected" areas should not be halted because the catches will be much lower than forecasted, and economically unprofitable (or else, one should find areas differing in temperature, salinity or depth, and otherwise not wonted by fish, where the fish had migrated).
4. After anomalous seismicity years, it is necessary to plan potential catches for years ahead, taking the collapse of fish reproduction into account.

References

Lushvin P.V. 2008. Stress and comfortable conditions of fish population development // Rybnoye Khozyaistvo. No. 6. P. 42–50. [in Russian]

Karamushko O.B. and N.B. Mukhina. 2007. Use of indirect indicators of feeding conditions in analysis of the dynamics of fish abundance at early ontogenetic stages // Rybnoye Khozyaistvo. No. 1. P. 65–67. [in Russian]

Oganesyan S.A. 1993. On periodicity of Barents Sea cod reproduction / Proceedings of the Reporting Session on PINRO Research Activities in 1992 // Murmansk, PINRO. 1993. P. 76–90. [in Russian]

Bondarenko M.V., A.S. Krovnin, and V.P. Serebryakov. 2003. Ranking year-class productivity and survival rates during early life history of commercial Barents Sea fishes to establish biological reference points and evaluate environmental effects // Moscow, VNIRO Publishing, 2003. 187 p.

Lushvin P.V. and V.V. Sapozhnikov. 2006. State of aquatic organisms populations in the marginal seas, and seismic activity of regions // Rybnoye Khozyaistvo. No. 4. P. 45–49. [in Russian]

Boitsov V.D. and M.V. Kovrova. 1993. Relationship of population fecundity and survival conditions of Barents Sea flounder (*Hleuronectes platessa l.*) at early stages of development with its recruitment. Proceedings of the Reporting Session on PINRO Research Activities in 1993 // Murmansk, PINRO, 1993. P. 68–78. [in Russian]

Patin S.A. 1997. Ecological problems of oil-and-gas resource development on sea shelf // Moscow, VNIRO, 1997. 349 p. [in Russian]

Yakovenko M.Ya. 1963. Development of harvesting, and the problem of abundance of the White Sea harp seal // Trudy PINRO, 1963, 15. P. 199–214. [in Russian]

Klyashtorin L.B. 1982. Water respiration and oxygen demands of fishes // Moscow, Legkaya and Pishchevaya Promyshlennost, 1982. 168 p. (in Russian)

Reshetnikov Yu.S. 1986. Synecological approach to fish abundance dynamics. In: Dynamics of Fish Abundance // Moscow, Nauka, 1986, P. 22–36. [in Russian]

Sergeeva N.G., Gulin M.B. 2007. Meobenthos from an active methane seepage area in the NW Black Sea // Marine Ecology. Vol. 28. P.152–159.

Lushvin P.V and M.G. Karpinsky. 2009. Causes of sharp reductions in zoobenthos biomass, and their consequences // Rybnoye Khozyaistvo. No. 5, P. 65–69. [in Russian]

Lushvin P.V. and V.V. Sapozhnikov. 2006. Dependence of the state of aquatic organism populations in the Arctic and arid aquatories on seismic activity of the regions. Abstracts of the International Scientific Conference on Present-day Climatic and Ecosystem Processes in Vulnerable Natural Zones (Arctic, Arid, Mountain), 5–7 September, 2006 // Rostov-on-Don, 2006. P. 132–134. [in Russian]

WATER ORGANISMS AS A SOURCE OF PROTEASES AND ITS INHIBITORS. CALCIUM-DEPENDENT PROTEASES (CALPAINS)

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Proteases are enzymes that are essential to all life. They are biology's version of Swiss army knives (Seife, 1997) that cut up biological polymers. Proteases regulate the fate, localization, and activity of many proteins, modulate protein-protein interactions, create new bioactive molecules, contribute to the processing of cellular information, and generate, transduce, and amplify molecular signals. As a direct result of these multiple actions, proteases influence DNA replication and transcription, cell proliferation and differentiation, tissue morphogenesis and remodeling, heat shock and unfolded protein responses, angiogenesis, neurogenesis, ovulation, fertilization, wound repair, stem cell mobilization, hemostasis, blood coagulation, inflammation, immunity, autophagy, senescence, necrosis, and apoptosis (López-Otín and Bond, 2008). Proteases are also essential in viruses, bacteria and parasites for their replication and the spread of infectious diseases, as well as for effective transmission of disease, and in animal hosts for the mediation and sustenance of diseases (Turk, 2006).

The recent availability of the genome sequence of different organisms has allowed the identification of their entire protease repertoire (termed degradome) (Quesada et al., 2009) (table). Thus, the human degradome contains over 500 human proteases (561 known proteases, 175 putative proteases and pseudogenes, 400 inactive homologues), accounting for 2% of structural genes in humans.

Table. Complexity of degradomes (data from *MEROPS* and *Degradome* Databases)

Organisms	Representative species	Number of proteases
Mammals	Homo sapiens	561
	Rattus norvegicus	646
	Mus musculus	656
	Ornithorhynchus anatinus (platypus)	>500
Birds	Gallus gallus	382
Fish	Danio rerio	503
Amphibia	Xenopus tropicalis	278
Insects	Drosophila melanogaster	558
Nematodes	Caenorhabditis elegans	403
Plants	Arabidopsis thaliana	723
	Populus trichocarpa	955

Many families of human proteases are also clearly recognizable in the genomes of *D. melanogaster*, *C. elegans* and *A. thaliana*. This indicates the existence of universal proteolytic routines in these organisms, although they are frequently expanded in vertebrates. It has become evident that, in addition to highly conserved proteolytic routines, there are also specific roles played by unique proteases in different species. These comparative genomic studies have also provided valuable insights into the conservation, evolution, and functional relevance of this group of enzymes.

Proteases likely arose at the earliest stages of protein evolution as simple destructive enzymes necessary for protein catabolism and the generation of amino acids in primitive organisms. Through evolution, proteases have adapted to the wide range of conditions found in complex organisms