УДК [551.46.09:504.5:665.71](261.243)«324»

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ЧУВСТВИТЕЛЬНОСТЬ ВОСТОЧНОЙ ЧАСТИ ФИНСКОГО ЗАЛИВА (БАЛТИЙСКОЕ МОРЕ) К РАЗЛИВАМ НЕФТИ В ЗИМНИЙ ПЕРИОД

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SENSITIVITY OF THE EASTERN GULF OF FINLAND (THE BALTIC SEA) TO THE OIL SPILLS IN THE ICE PERIOD OF YEAR

Приведены результаты исследований, выполненных в экологическом агентстве «Экопроект» (http://www.ecopro.spb.ru/) в рамках финско-российского проекта WINOIL (http://www.merikotka.fi/winoil/) в целях оценки суммарной экологической выгоды применения диспергентов при ликвидации аварийных разливов нефтепродуктов в Финском заливе в зимний период. Уязвимость побережий картирована на основе данных о распределении организмов бентоса, ихтиофауны, птиц и тюленей, с использованием индекса экологической чувствительности. На этой основе построены карты интегральной уязвимости и экологических рисков воздействия нефтяных разливов для зимнего времени с учетом долговременных последствий (по результатам проекта BRISK – http://www.brisk.helcom.fi/). Анализ успеха ликвидации аварийных разливов нефтепродуктов без использования и с использованием диспергентов показывает, что в зимний период (ноябрь–апрель) применение диспергентов в Финском заливе экологически оправдано (более эффективно в сравнении с механическими методами очистки и уменьшает суммарный экологический ущерб). Использование диспергентов находится в соответствии с действующими нормативными актами Российской Федерации и может быть рекомендовано при ликвидации разливов нефтепродуктов в Финском заливе в зимний период.

Ключевые слова: *экологическая чувствительность, разливы нефти, диспергенты, анализ суммарной экологической выгоды, Балтийское море, Финский залив.*

The study was carried out by the Environmental Agency ECOPROJECT (http://www.ecopro.spb.ru/) within the Finnish-Russian project WINOIL (http://www.merikotka.fi/winoil/). Environmental sensitivity (vulnerability) of the Russian part of the Gulf of Finland is assessed for the wintertime (November-April) basing on the distribution of benthos, fishes, birds and seals, using Environmental Sensitivity Index (ESI). These maps are created for both oil slick and dispersed oil in order to compare their impact on the ecosystem of the Eastern Gulf of Finland, as a part of preliminary Net Environmental Benefit Analysis (NEBA). Map of long-term average environmental damage due to accidental spills for the wintertime is created basing on the maps of the long-term average oil impact obtained in the BRISK Project (http://www.brisk.helcom.fi/). Results of the study had shown that application of dispersants in the Gulf of Finland in winter is ecologically preferable, when compared to the 'monitoring' option. From the environmental point of view, use of dispersants may be recommended as a method of the oil spill response (OSR).

Keywords: *environmental sensitivity, oil spill response (OSR), dispersants, Net Environmental Benefit Analysis (NEBA), Gulf of Finland, the Baltic Sea.*

Gulf of Finland (GoF) waters have perhaps the densest maritime traffic in Europe. Furthermore, it is a major oil transport route for the EU's energy demand due to the existing and planned oil terminals in the area: last year more than 150 million tons of oil was transported especially from Russian oil terminals, and there are estimations that the oil transport rate will be close to 200 million tons annually in 2018. Every day there are close to 20 tankers eastbound empty and westbound fully laden sailing through the GoF waters. The large numbers of tankers and other dense shipping in the area point out the need for good understanding on the risks and possible risk control measures to develop preparedness against the environmental pollution and human losses. On the other hand, the dense traffic poses the effective pollution response activities, where the cross-border co-operation between national authorities is having the uttermost importance.

In addition, GoF waters are covered by ice every year, where changing ice conditions, traffic restrictions and icebreaker-based assistance will totally have another traffic risk scenarios to be handled. If a collision or grounding in ice conditions will result an oil outflow, the effective oil combating measures are far from those used in open water conditions, thus the prevention measures to avoid accidents are more than important.

The WINOIL project (http://www.merikotka.fi/winoil/), which results are discussed in the paper, was focused on two main issues: (1) to update and develop the pollution combating contingency plan between Russia and Finland related to GoF waters, and (2) to carry out risk assessment of winter navigation with the understanding of proper risk control options. The last two winters in the Baltic have also pointed out the urgency for this project via the continuous news on dozens of ships being stuck in the ice with additional down-time costs adding up to more than hundreds of millions of Euros. In the spring 2011 alone, there were weeks when more than 60 ships were stuck in the ice waiting the icebreaker assistance to Russian ports.

The overall objective of the WINOIL project was to increase understanding of oil pollution prevention measures, improve the joint emergency cross-border procedures in oil accident, and to mitigate the risks related to ship navigation in ice conditions prevailing in the Gulf of Finland. Russian Environmental Agency ECOPROJECT was involved mainly in the studies on (1) updating the sensitivity mapping of the eastern part of the Gulf of Finland for the winter period, and (2) factors affecting on the use of dispersants in the GoF.

The task on sensitivity mapping of the eastern part of the Gulf of Finland for the winter period seems to be especially important since almost all studies and classifications defining the vulnerability of the area are based on the open water season. However, the eastern part of the GoF waters are ice covered 5 to 6 months every year, thus an analyses for the wintertime is needed:

– Arctic water fowls use the waters during their spring and autumn migration seasons; waters can be partly ice covered especially in the spring;

– Large seal populations have their haul-outs and migrating routes in the target area – seals have their reproduction areas in the fast ice zone;

– Dynamics of ice movement will decrease the successful oil recovery activities, thus any oil left into the ice can spread with moving ice to the vulnerable areas.

The task on factors affecting the use of dispersants in the GoF is important practically. Dispersants are widely used in oceanic environment due to their ability to disperse oil into the large water mass, which may decrease the oil impact in the coastline. In the case of sensitive and vulnerable areas, the use of dispersants may offer an option if mechanical recovery activities cannot be used. However, the use of dispersants for oil combating in the Baltic Sea area is not recommended by HELCOM. With reference to HELCOM Recommendation 22/2, it has been decided that, due to the sensitive ecological conditions in the Baltic Sea area, response to oil should take place by the use of mechanical means as far as possible. Response by using dispersants should be limited, sinking agents should not be used at all and absorbents only when appropriate. However, the use of dispersants is not prohibited, only recommended to be limited.

The task on factors affecting the use of dispersants in the GoF aims to assess the latest information and the best knowledge within the field of dispersants in order to come up with revised knowledge to promote the best environmental practices and best available technique within oil spill response. Here the Russian experiences and the guidelines of NEBA (Net Environmental Benefit Analyses) were used together with the sensitivity assessment made by HELCOM in the BRISK Project (http://www.brisk.helcom.fi/). The outcome is a state of the art review on the dispersants use in the Eastern Baltic Sea in relation to NEBA and sensitivity assessment [9, 10].

Methods

According to the data collected by the BRISK project, frequency of the ship-ship collisions north of 59° parallel is the highest in January–April with the highest frequency of the ship-icebreaker collisions in February–April [12]. In numbers, Gulf of Finland is expected to experience 9 % more collisions per sailed sea mile under ice conditions compared to ice-free conditions [12]. Taking the abovementioned into consideration as well as data presented below, we divided the ice period in our study into two periods: (1) beginning of winter: November–January, and (2) the height of the wintertime and its end: February–April.

Environmental sensitivity (vulnerability) is usually characterised according to the following parameters:

– presence of Protected Areas in the region;
– occurrence of Red Book species; and
– seasonal concentration of species according to their life cycle.

Many examples of how to present data on the vulnerability of marine areas can be found in publications of the International Petroleum Industry Environmental Conservation Association (www.ipieca.org). The standard results of this approach are atlases of animal distribution (usually showing fishes, birds, and marine mammals). Vulnerability is usually shown on maps by colour gradations, species are designated by special signs (similar to those in our maps), and seasonality, by special codes. However, this presentation method has certain limitations for decision-makers because of the large number of maps and the necessity to prioritise many heterogeneous species or groups.

A method of integral marine and coastal biota vulnerability mapping has been elaborated and used during the last decade by specialists of the Environmental Agency ECOPROJECT (www.ecopro.spb.ru), when decision-making was required for the

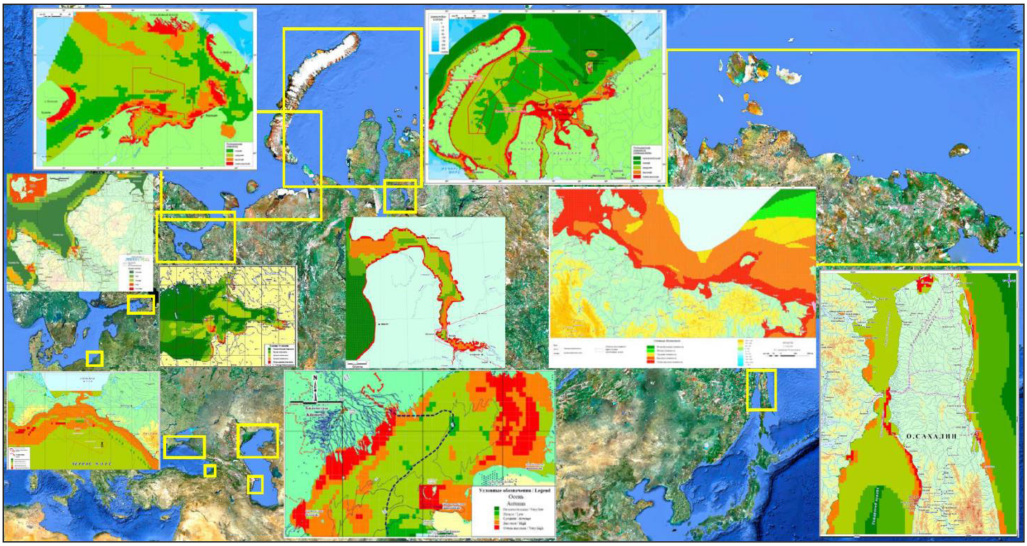

Fig. 1. ECOPROJECT's experience in the integral sensitivity mapping. Left to right, up to down: Pechora Sea, Kara Sea, White Sea, Gulf of Finland, Ob´-Tazovskaya Bay, Far-Eastern Region of Russia, north-eastern Black Sea, northern Caspian Sea, north of Sakhalin Island

development of large industrial projects in the coastal zone of Russia from the Baltic Sea to the Far East seas and from the Arctic to the Black Sea [5, 7]. At present, this method has already been tested for many sea areas of Russia (fig. 1).

Both environmentalists and professionals appreciated its results and it was used by WWF Russia as a base for 'Methodological approaches for the construction of maps, characterizing vulnerability and priority protection of water areas and coasts of Russian Federation in respect of the oil spills' [3]. This publication is not a document approved by authorities but it is the only one of its kind, where fundamental principles of integrated vulnerability mapping are discussed and procedure itself is described thoroughly, consistently and systematically.

The method proposed by ECOPROJECT is based on the following prerequisites:

– The objects under consideration are all main groups of plants and animals that inhabit the area described. This allows one to make a complex environmental characterization of the area and therefore lessens criticism from the public, expert organizations and professionals.

– Comparative vulnerability of the main elements of the biological community to the impact factors is assigned on the basis of the published data and corrected in coordination with local specialists.

– Seasonal changes in the vulnerability of separate groups of organisms are characterized on the basis of maps showing seasonal biota distribution.

– The Geographical Information Systems (GIS, in our case – MAPINFO 10.0 software package) are used in the construction of the thematic and summarizing maps.

– Integral vulnerability of the area is presented as a result of a summation of the vulnerabilities of separate groups of plants and animals, taking into account their individual vulnerability to a concrete impact, their restorative capacity, and their spatial and seasonal distribution.

The results of the integral data analysis are represented by a series of maps (usually four maps for the impact under consideration). Five colours show the integral vulnerability: from red – "very high vulnerability", through yellow – "moderate vulnerability", to green – "very low vulnerability". This way of data presentation is attained by a strictly formalized method. Advantages of such maps are their comprehensibility and the simultaneous spatiotemporal characterization of vulnerability. Decision-makers do not have to possess any special knowledge for their interpretation. To date, a series of maps showing integral vulnerability for the Russian Baltic Sea area have been produced not only for the entire Russian part of the Gulf of Finland but also for the Bay of Vyborg, Bjerkesund Strait and Luga Bay [8], as well as for the offshore areas of the Kaliningrad Region. These data are included into the results of the BRISK Project [15].

The total number of thematic maps, used for the creation of the integral maps-schemes in our previous studies [8], was about 50 and they included about 40 group objects (e.g., plankton, benthos, birds) or species objects (e.g., fishes, seals). Since they were created for four seasons, they had to be updated and detailed for the winter period in the Gulf of Finland.

In our study, data on the following groups and species were taken into account:

– Protected Areas.

– Benthic invertebrates (meiobenthos and macrobenthos).

– Lampreys (river lamprey and sea lamprey).

– Fishes (Atlantic sturgeon, Baltic herring, sprat, smelt, salmon, sea trout, vendace, whitefish, bream, roach, three-spined and nine-spined stickleback, ruff, perch).

– Birds (swans, sea and dabbling ducks, coots, divers, bluebills, gulls, sandpipers, terrestrial birds and the avifauna as a whole).

– Seals (ringed seal and grey seal).

– Shore mammals (mink).

Effects of oil spills have been studied in the form of: (1) surface oil slick, and (2) dispersed oil.

Maps of potential vulnerability of the GoF to the oil slick and dispersed oil were produced basing on the methodological approach presented above [3] with some amendments [5] (table 1).

Map of long-term average environmental damage due to accidental spills (measured in weighted grams of oil per square km) for the wintertime was created basing on the overlaying maps of (1) environmental sensitivity, and (2) maps of the long-term average oil impact based on the modelling results obtained in the BRISK Project (http://www.brisk.helcom.fi/). Twenty-one environmental maps were created in the course of the project [6] (a couple of them is presented below) and may be used by professionals in their practical work.

Some elements of a preliminary Net Environmental Benefit Analysis (NEBA) were carried out according the current regulations of the Russian Federation [13]. The use of NEBA involves weighing up the potential advantages (or benefits) of dispersant use

Table 1

Relative vulnerability of the Baltic Sea ecosystem components* and priorities of protection of marine water areas and shorelines** from spills of oil and oil products in respect of the oil slick and dispersed oil used for the Gulf of Finland [5]

Ecosystem components	Vulnerability coefficient	
	Oil slick	Dispersed oil
Coast (evaluated by ESI scale)	from 1 to 10	
Benthos at depth <10 m	2	3
Benthos at depth >10 m	1	1
Fishes at depth <10 m	2	3
Fishes at depth >10 m	1	1
Birds	5	2
Seals	5	3
Protected features	Priority ***	
Protected and recreation areas	5	1

Notes: * '1' – least vulnerable, '5' – most vulnerable'; ** '1' – least priority, '5' – top priority; *** All coefficients are corrected by experts in accordance with the principle of regionalization.

compared to the potential disadvantages (or risks) of dispersant use. The main task of NEBA for the issue under consideration is to give an answer on the questions: "Is the dispersant application in considered area and for considered scenario of oil spill will be profitable for environment or not? Will be injury to environment and regional economy less if we apply dispersants or not?" [16].

Results

Marine Protected Areas, legally speaking, are absent in the Russian part of the Gulf of Finland. At the same time, out of 89 protected areas (PAs), which are present and planned in St. Petersburg and the Leningrad Region, 15 PAs are located in the coastal part, many of them also including adjacent water areas. The largest marine areas are in the regional complex reserve "The Beryozovyye Islands" (total area 55 295 hectares, including 47 020 hectares of water area) and "Kurgalsky" (total area 59 950 hectares, including 38 400 hectares of water area). The nature reserve "Ingermanlandsky", located on the islands of the Gulf of Finland, is at last (after twenty years) approved by the authorities as a State Protected Area. Its total area is 17 901 hectares, including 16 980 hectares of water area. The above PAs or at least their segments should be the first areas to be included in the list of the Baltic Sea Protected Areas (BSPAs).

Red Book Species of the region are not easy to count. First, there are many different Red Books and second, different experts do not agree as to the status of some species. Nevertheless, an interval estimate is always possible. According to estimations, there are 126 protected plant species in the Gulf of Finland (22 algae, 43 lichens, 59 vascular plants and 2 mosses). The Red Books include 7 species of invertebrates, 8 species of fish, 2 species of reptiles and 2 of amphibians, 62–80 species of birds, 2 species of sea mammals and 17 species of terrestrial mammals.

The concentration of animals according to their life cycles (feeding, reproduction, migration, moulting) is one of the basic criteria of mapping sensitive zones (e.g., zone sensitive to oil spills). Some brief information on the main components of the GoF marine ecosystem is given below.

The bacterioplankton in the eastern part of the Gulf of Finland is most abundant in the shallow zone. Its abundance and biomass decrease westwards. High abundance of saprophyte bacteria indicates considerable water pollution. According to the microbiological indices, the shallow water area is polluted and the deep-water area is moderately polluted.

The phytoplankton of the Gulf of Finland is rather poor, salinity limiting the development of both marine and freshwater species. The diversity and the biomass of the phytoplankton decrease from east to west. Its dynamics are distinctly seasonal, with several peaks of mass development: in spring, in summer, and, sometimes, in autumn. The summer peak is the most important ecologically, since it is associated with an increase of blue-green algae, causing algal blooms.

The zooplankton has a high spatiotemporal variability. Its maximum biomass is observed in summer. The latest data indicate a general increase in zooplankton production and eutrophication of the eastern part of the Gulf of Finland.

The aquatic vegetation plays an important role in the coastal ecosystems. In summer, filamentous green algae develop abundantly. A cover of brown algae is well developed on the mixed sediments of some islands. Reeds and rushes occupy a considerable part of the shallow water areas, providing spawning places for fish, nesting places for waterfowl, and shelter for both. Numerous invertebrates developing in these biotopes serve as food for fish.

The meiobenthos (benthic organisms from 0.1 to 1 mm in size) in the eastern part of the Gulf of Finland has a low taxonomic diversity. At the same time, density of meiobenthos reaches 500,000 individuals per square meter. Structural indices of meiobenthos indicate unfavourable ecological conditions in the mouth of the Bay of Vyborg and the Kopora Bay.

The macrozoobenthos (benthic organisms over 1 mm in size) in the Gulf of Finland is rather poor. Most species are limited to warm and shallow freshwater areas, the deep-water areas being inhabited by only few species. Benthic communities, consisting of a handful of species, are unique in being very simple. Abundance of macrozoobenthos varies from year to year. Two factors influence the state of macrozoobenthos: a considerable human impact in the east and the entry of salty oxygen-poor water in the west. As a result, “eutrophic” communities dominate shallow areas. In the central parts of the deep-water area, where human impact is less, the benthos communities degrade because of low oxygen content. Certain bottom areas near Gogland are lifeless. The benthic communities are unstable since they consist of a small number of species.

The fish fauna of the Gulf of Finland number about 75 species of marine, anadromous and freshwater fishes [2]. The most abundant species is Baltic herring. It has the greatest commercial value in the Gulf of Finland, making up 56.5% of the average catch for the period 2005–2013 [recalculated by data: 17]. Other commercial fish species are sprat (17.9 %), ruff (5.6 %), smelt (5.5 %), roach (3 %), perch (2.8 %), bream (2.7 %), river lamprey (0.9 %), pikeperch (0.6 %), white bream (0.6 %), vendace (0.2 %), pike (0.2 %). Other fish (Baltic whitefish, salmon, sea trout, sichel, schneider, rudd, burbot, vimba, ide, flounder) make up 0.1 % of the catch or less. Cod is absent. Major seasonal events concerning the fish fauna of the Gulf of Finland are as follows:

– January–February: burbot spawns near the coasts and in rivers.

– April: smelt spawns in rivers and partly in the coastal areas as soon as the sea clears from ice; spawning of pike, ide, and perch.

– May: Baltic herring approaches the coast and starts spawning; salmon, sea trout, and river lamprey migrate into rivers; spawning of bream, pike, roach, perch, and ruff; spawning of smelt.

– June: Baltic herring spawns near the coasts and offshore, its young appears in plankton; sea trout migrates into rivers; spawning of bream (first half of June); spawning of ruff, pikeperch, and three-spine stickleback near the coasts; spawning of Baltic sprat offshore; spawning of Baltic river flounder.

– July: bleak spawns in brackish water bays; ruff spawns in coastal thickets; Baltic sprat spawns offshore; eggs and young of Baltic sprat appear in surface waters.

– August: "autumn" spawning of Baltic herring; migration of river lamprey into rivers; the young of European launce appear in surface coastal waters.

– September: whitefish forms pre-spawning concentrations.

– October: sea trout and river lamprey migrate into rivers; whitefish forms pre-spawning concentrations; salmon migrate into rivers.

– November: sea trout and river lamprey migrate into rivers; reproduction of four-horn sculpin.

The bird fauna of the Gulf of Finland region number over 260 species. From the point of view of sensitivity to the oil spills, the most dangerous human impact, we should consider 125 species associated with the aquatic environment and coastal biotopes. Out of this number, 62 to 80 species are included in the Red Books. The avifauna of the Gulf of Finland comprises marine birds typical of the Baltic Sea, freshwater birds, and some migratory birds using the coastal strip as stopover and feeding sites.

The association, Bird Life International, carries out a global program called "Important Bird Areas" (IBA) in order to highlight and preserve the most valuable sites, where rare and endangered species of birds occur and form mass gatherings. In the Russian part of the Gulf of Finland, there are 10 key ornithological territories of European or global significance. Some of them are located totally or partly in Protected Areas; others do not have any protection status yet, though their ornithological significance is equally important. The IBA system in the Gulf of Finland may serve as the integral description of the spatial distribution of the most important components of the sea and coastal avifauna. At the same time, certain groups of birds have their own characteristic features of spatial and temporal distribution.

Some general features of the avifauna of the Gulf of Finland are associated with the geographical position, landscape, and ecology of the region. First, the eastern border of the distribution area of many Baltic Sea birds follows the line Beryozovye Islands – Seskar Island – Luga Bay. Therefore, their numbers fluctuate considerably from year to year, especially in the case of the big cormorant, the scoter, the eider duck, the guillemot, and the black dovekey. Local populations of these birds are unstable and have to be especially protected. Secondly, the wellbeing of numerous colonies of waterfowl and shore birds in the eastern part of the Gulf of Finland depend entirely on the quality of the aquatic environment. Finally, accumulations of migratory waterfowl birds are very important components of the Gulf of Finland's ecosystems. From 40% to 80% of the populations of the birds wintering in Western Europe fly over the Russian part of the Gulf of Finland. Their preservation has international significance as one of the measures of maintaining biodiversity. In spring, the Gulf of Finland is a natural "funnel", where the streams of migrants are drawn from the south-west. They reach maximum concentrations in the Neva Bay and the Bay of Vyborg. During seasonal migrations, thousands of swans, geese, ducks, sandpipers, gulls, and terns concentrate along the southern coast of the Gulf of Finland. Large gatherings of migratory sea ducks are found in the Gulf of Finland far from the coast too.

Marine mammals in the Russian part of the Gulf of Finland are represented by the Baltic subspecies of ringed seal (*Phoca hispida botnica*) and grey seal (*Halichoerus grypus*). Both species are included in the Red Books. In the beginning of the 20th century, the total number of seals in the Baltic Sea was about 200 thousand. In the middle of the century, a catastrophic decrease began. It was caused not only by hunting but also by the use of DDT in agriculture. At present, there are less than 100 ringed seals in the Russian part of the Gulf of Finland [18, 19]. The numbers of grey seals are increasing but do not exceed 500–600 individuals [20, 21]. Grey seals are rare in the Russian sector of the Gulf of Finland in the ice period; sometimes they are brought here by the drifting ices.

The ringed seal occurs in the Gulf of Finland all year round, although seasonal changes in habitats take place too. When the sea surface is free from ice, the seals stay in the southern part of the Gulf of Finland but not further eastwards than Seskar Island, although still in 1977 fishermen and hunters came across seals near Chyornaya Lakhta. The largest haul-outs of the ringed seal are near the islands Vigrund and Khitamatola. In May–June and in September–November, the ringed seal forms haul-outs of several dozens of individuals near Remisaar Island and on the Kiskolsky Reef. Small groups of 10–15 seals are common on the islands Maly Tyuters and Maly, and single animals climb the stones along the coast of Kurgalsky Peninsula and the islands Bolshoy Tyuters, Moshchny and sometimes Seskar Island. The ringed seals cub on ice to the south and southeast of the Beryozovye Islands. Holes with cubs were found at the coast of the Kurgalsky Peninsula. Thus, the seals migrate to the northern coast of the Gulf of Finland for cubing and moulting, and move to the southern coast in summer. In the middle of summer, they migrate from the coast to the deep areas.

Recent research has shown that the population of ringed seals in the Gulf of Finland is local and rather isolated [22]. In 1991–1992 mass mortality of ringed seals was registered: more than 150 dead bodies of mostly adult seals were found along the coasts and on the islands of the Gulf of Finland. The present decrease in the number of seals is associated chiefly with warming of climate and reduction of the ice cover in eastern Gulf of Finland [23].

In winter, the grey seal can be found in the Russian part of the Gulf of Finland, being sometimes brought with the drifting ice from the west. In summer, the grey seals can be seen at the southern coast of the Gulf of Finland. In the north, only single individuals are found in the region of the Khalikarty reefs. In the southern part of the Gulf of Finland, the breeding grounds of the grey seal can be found on the Maly Tyuters Island, on the reefs near the Vigrund Island and in the Khitamatola Island, which is a part of the Kurgalsky Reef.

Sensitivity of coasts in the course of work was mapped using Environmental Sensitivity Index (ESI) [14]. The ESI, ranging from 1, low sensitivity, to 10, very high sensitivity, integrates the following:

– shoreline type (grain size, slope) which determines the capacity of oil penetration and/or burial on the shore, and movement;

– exposure to wave (and tidal energy) which determines the natural persistence time of oil on the shoreline; and

– general biological productivity and sensitivity.

The 10 levels of the Environmental Sensitivity Index are colour coded from cool colours to warm colours indicating increased sensitivity. Each colour corresponds to a particular type of coast allowing identification of the type and relative sensitivity at a glance [9, 10].

Application of the 'Methodological approaches for mapping of ecologically vulnerable zones…' [3] to the data from the Russian part of the Gulf of Finland had shown that potential vulnerability of the Russian part of the GoF to the oil slick is 3–4 times higher as compared to its vulnerability to the dispersed oil (this part of work is considered as a part of a preliminary Net Environmental Benefit Analysis – NEBA). However, it became clear also that the ecosystem of the Gulf of Finland reacts to possible negative impacts mostly in a non-specific way. This is expressed in the high similarity of the seasonal maps of integral vulnerability to the studied types of effects. Such kind of reaction is similar to the non-specific stress reaction of a single organism, when different stimuli can cause similar symptoms (e.g., high temperature, weakness, fever, etc.). The differences in the spatiotemporal structure of the reaction of the Gulf of Finland's ecosystem to the effects studied are so small during the year that they can be considered for all types of effects at once.

The analysis of the spatial distribution of the integral vulnerability (fig. 2) has shown that the following regions of the Gulf of Finland are the most vulnerable to the expected or possible impacts:

– the coastal shallow water areas (in different seasons they are limited to depths of 30 to 50 m);

– the areas of the Gulf of Finland adjacent to the archipelagos and separate islands, the most sensitive being the coast of the islands of the Kurgalsky Reef and the islands in the open part of the Gulf of Finland;

– the tops of the secondary bays (first of all, the Luga Bay, Kopora Bay and, to a lesser extent, Narva Bay and the Bay of Vyborg).

Ranking of the seasons in decreasing order of ecological sensitivity is as follows: summer > spring ≥ autumn > winter. Interestingly, when creating the maps showing integral ecological sensitivity, we found spring is the most sensitive season in the Russian part of the Gulf of Finland for only three groups (fish, birds and seals). This is explained by the diminished evaluation of the role of such highly sensitive groups of organisms as algae, higher aquatic plants and zooplankton, which develop, or have a peak of development, in summer. Meanwhile, all these organisms are important not only in themselves but also as an important part of the ecosystem of the water basin. For example, algae and higher aquatic plants are substrates for fish spawning and a nesting biotope for

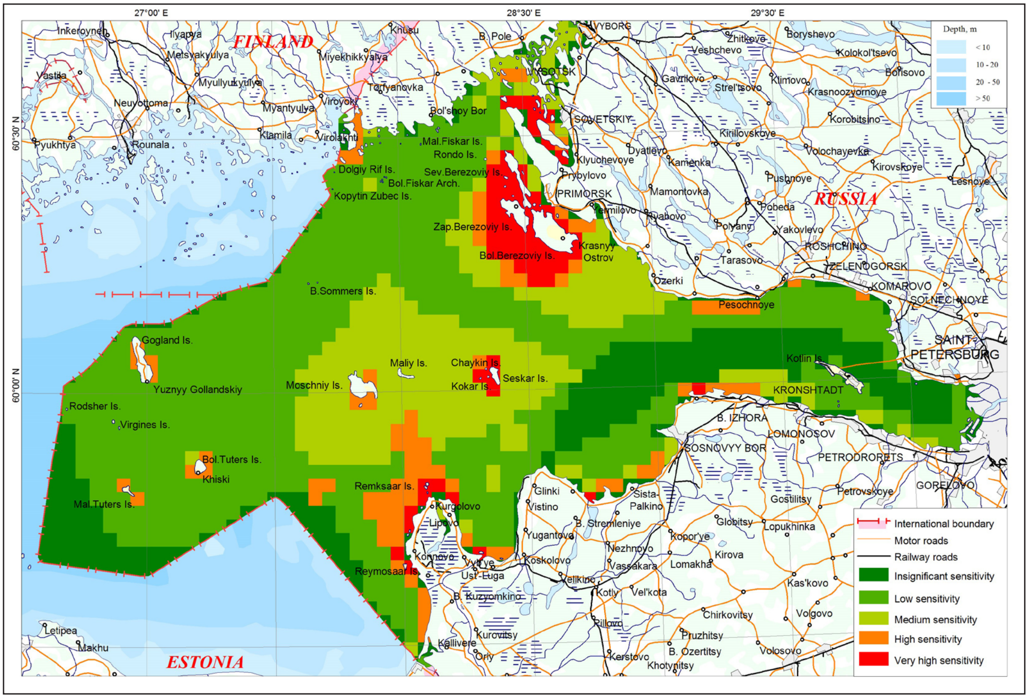

Fig. 2. Integral vulnerability of the Russian part of the Gulf of Finland to the oil sick in winter (November–April)

birds. Zooplankton forms the forage basis of all commercial species of fish. This example shows that in order to obtain an *integral* assessment, we should consider *all* main components of the ecosystem of the water body, and not only a small sample of them.

Assessment of long-term average environmental damage due to accidental spills measured for the ice period according to the methodology used in the BRISK Project [1, 11] (fig. 3) had shown that risk of environmental damage is higher in the vicinity of Beryozoviye Islands, Kurgalsky Reef and islands of the central part of the GoF. Map of long-term average environmental damage resembles the vulnerability map only to some extent but does not reproduce it completely. Practical value of mapping the long-term average environmental damage as compared to the mapping of environmental vulnerability should be assessed by the OSR specialists. According to our opinion, assessment of the approach practical value needs more cases for study and analysis. In any case, one may conclude that application of dispersants in the GoF is ecologically justified and, from the environmental point of view, may be recommended as a method of the oil spill response in compliance with the current regulations of the Russian Federation [13].

Discussion

Past experience at several major oil spill incidents has shown that any negative effects on marine organisms caused by the elevated dispersed oil concentrations due

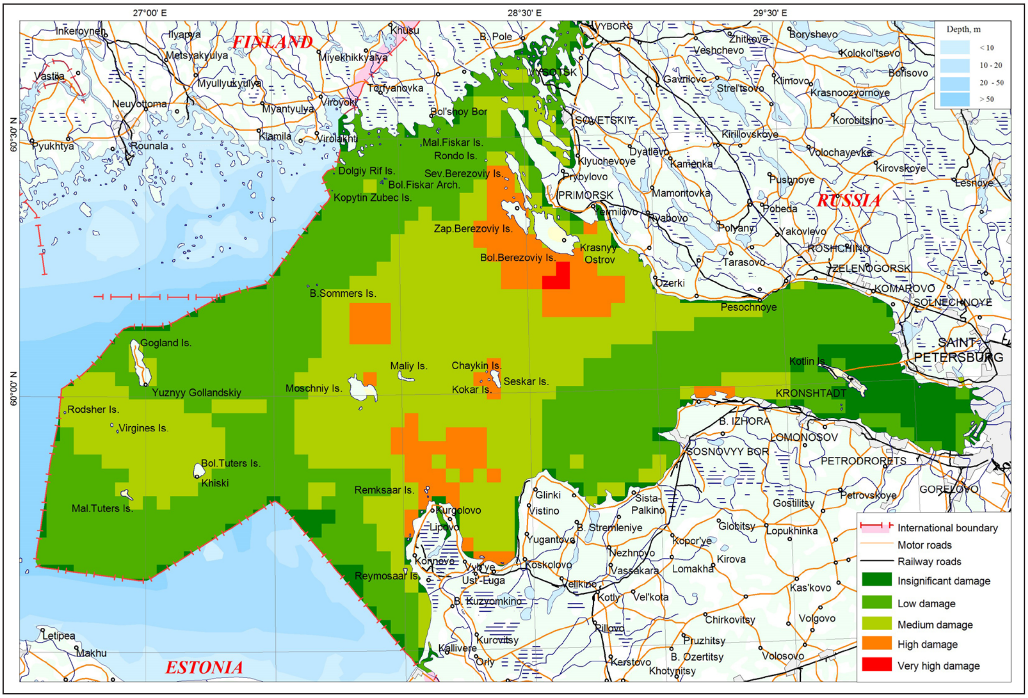

Fig. 3. Distribution of long-term average environmental damage due to accidental spills (measured in weighted grams of oil per square km) from all accident size classes in winter (November–April)

to dispersant use were often localized and of short duration [4]. Ecological studies and monitoring following major oil spills have repeatedly shown that the populations and communities of water column organisms (the algae and zooplankton, larger invertebrates and fish) can recover much more quickly from brief exposure to dispersed oil in the water than the populations and communities of birds, mammals, sea-grasses, or mangroves that may be exposed to oil that comes ashore. It can take years to decades for some of these shoreline communities to recover from oiling, whereas many water column communities can recover in weeks to months. The marine environment is, in general, more resilient that the coastal environment and natural recovery will take far less time.

If a particularly oil-sensitive coastal habitat is threatened by spilled oil and the sea conditions make other oil spill response options unfeasible, dispersant use might be justified in even in shallow water [4]. The advantage, or benefit, of using dispersant use to minimise shoreline oiling and therefore prevent a lot of persistent and long-lasting damage could be very high compared to the significant, albeit short-term, damage that might be caused to the marine organisms.

Our own study had shown that potential biota vulnerability of the GoF to the oil slick is at least three times higher as compared to the potential biota vulnerability to the dispersed oil. Therefore, summarizing the work results, one may conclude that application of dispersants in the GoF is ecologically justified and, from the environmental point of view, may be recommended as a method of the oil spill response.

Acknowledgements

The study was carried out as a part of a Project entitled 'WINOIL: Winter navigation risks and oil contingency plan'. The grant No. 2011-086-SE680 was financed from the European Neighbourhood and Partnership Instrument in the framework of the South-East Finland-Russia ENPI CBC programme 2007–2013. More than a dozen of specialists had made their input into the project results. We are especially thankful to Doctor of Geology Svyatoslav M. Usenkov (coastline, seabed sediments), Nick V. Dmitriyev (GIS cartography) and Anton Yu. Krummet (translation).

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