



Mapping of sensitivity to oil spills in the Lithuanian Baltic Sea coast

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Abstract This research develops an integrated environmental assessment tool for Lithuanian coastal area that takes due account of the major oil spill risks posed by the D-6 oil drilling platform, vessel traffic in the south-eastern Baltic Sea, and operation of the Būtingė oil terminal. The goal of this paper is to present an environmental sensitivity index (ESI) mapping approach based on four specific indexes: coastal features (ESI_C), socio-economic aspects (ESI_{SE}), biological (ESI_B) and fishery resources (ESI_F). The relevant methodology approach was selected. The core dataset is provided by GIS-based environmental atlas updated with other relevant GIS data of Lithuanian coastal resources. Four ESI maps were developed and an overall environmental sensitivity index (OESI) map produced. Results indicate that in the case of an oil spill, two areas need to be prioritized due to their biologic and socio-economic resources: the 25 km long shoreline between the settlements of Nida–Juodkrantė on the Curonian Spit (CS) and the mainland coast (MC) between the settlements Palanga and Šventoji.

Keywords *Environmental sensitivity, oil spill risk, coastal area, oil terminal, oil platform, Būtingė, Kravtsovskoye D-6, Lithuania.*

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INTRODUCTION

Since the 1980's the Lithuanian coastal area is threatened by major pollution risks from oil extraction, transportation and handling in harbours. The Klaipėda seaport gate, the Būtingė oil terminal and the Kravtsovskoye offshore oilfield D-6 in the Kaliningrad district (Russia) are a constant threat to coastal resources (Fig. 1). Klaipėda (*Klaipėdos naftos terminalas*) and Būtingė (*Būtingės naftos terminalas*) oil terminals belong to the large oil import/export enterprises in the Baltic Sea region (BSR). In 2009, the annual amount of transportation of oil products was 33% of total cargo handled in the port of Klaipėda (~9.2 mill. tons). The harbour's entrance is dredged up to 14 m allowing accept the tankers with up to 100 000 tons capacity within an allowable draught down to 12.5 m. Two jetties at the port entrance ensure a loading rate of

2000 m³ for light oil, 4000 m³ for heavy oil and 3800 m³ for crude oil (Klaipėdos nafta 2010).

Ship casualties registered from 1989 to 2006 show that the Klaipėda seaport gate presents a critical area for shipping accidents (Helcom 2003). Berthing masters face difficulties in manoeuvring ships into the port entrance, especially during adverse weather conditions (Kriaučiūnienė *et al.* 2006). In fact, the biggest oil spill in the Baltic Sea's trade history, the cargo tank *Globe Assimi* wreck, took place in the Klaipėda port call in 1981 (Pustelnikov, Nesterova 1984; Olenin 1990).

The Būtingė oil terminal is located north of Palanga close to the Latvian border. The single point mooring buoy is connected to the onshore terminal via submerged pipeline (9.8 km long) and lies 7 km offshore (at the depth of ~20 m) from the coast. As noted in an internal report by the refinery *Mažeikių nafta* (from 2004), the terminal can export up to 14 million tons/year of crude oil. Several oil spills have been registered

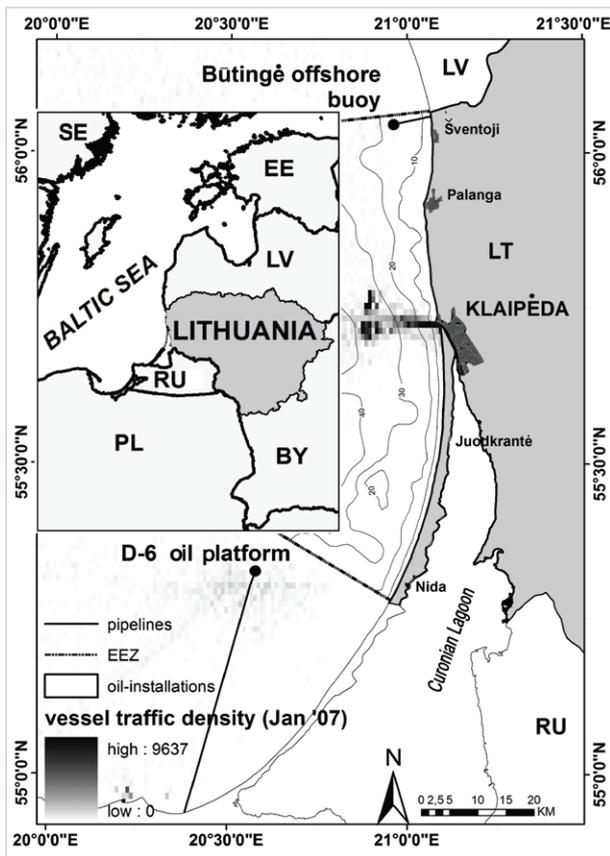


Fig. 1. Location of oil installations, pipelines and vessel traffic. Compiled by D. Depellegrin, 2010.

in the terminal since 1999. The big accident occurred in 2005, releasing 59 tons of crude oil. Other accidents happened in 1999 (3.4 tons), 2001 (48.2 and 3 tons), and in 2008 (6.5 tons) as reported in the response plan of Būtingė oil terminal (in 2009).

The Kravtsovskoye drilling platform D-6 is located 22.5 km from the Curonian Spit coast and close (7 km) to the Lithuanian–Russian border. 14 300 barrels of crude oil are daily extracted and transported via a 47 km long underwater pipeline to the oil-gathering unit in Romanovo (Kaliningrad district) (Lukoil 2010). Prevailing south-westerly wind conditions from S, SW, and W in the summer and winter periods make highly probable impact of possible oil spill from D-6 to the Curonian Spit coast. Drift modelling with *SMHI's Seatrack Web* estimates 67% probability of potential oil spills drifting to the Lithuanian part of the Curonian Spit (Kostianoy *et al.* 2006).

Therefore, the anthropogenic pressure exposes coastal, biological and socio-economic resources to a constant pollution risk. In this context the environmental sensitivity index (ESI) maps offer a rational, integrated and sustainable tool for national and regional oil spill response plan supporting the development and implementation of preparedness, response, clean up and remediation strategies (Adler, Inbar 2007). A first

attempt to develop a comprehensive environmental atlas for oil spill management, including ESI maps, was undertaken by the Lithuanian authorities and the Swedish Coast Guard, in 1994. Four years later ESI maps became part of the Lithuanian oil spill contingency plan. In 1998, the Institute of Ecology (Vilnius) released the first and since then only *Environmental Management Atlas* that constitutes the core dataset for present research.

The study aims to acquaint with a state-of-art of GIS-based ESI mapping approach for oil spills response planning in the Lithuanian coastal area taking into account the coastal features, fishery, biological and socio-economic resources (Castanedo *et al.* 2009). ESI maps would provide a quick reference for oil spill response teams and favour the decision making process by prioritizing response efforts in particularly sensitive coastal areas (Chen, O'Yang 2006). The research was partly carried out within the Baltic Master project (EU INTERREG Programme), which aims to improve maritime safety by focusing on pollution prevention, coastal zone management and on-land response capacity to an oil spills at sea (Baltic Master 2007).

MATERIAL AND METHODS

Study area

The Lithuanian coastal area facing the open sea is divided into two main parts: Curonian Spit (CS) in the south, and mainland coast (MC) in the north (Fig. 2). The Curonian Spit is a narrow over 99 kilometres long sandy peninsula, which separates the Curonian Lagoon from the open Baltic Sea. It is included into the UNESCO World Heritage list due to its valuable nature and cultural heritage. Northern part of the spit (52 km) belongs to Lithuania, and the southern one (46 km) – to Russia. The Curonian Spit is separated from the mainland by the Klaipėda strait, which serves as outlet for the Nemunas River and as seaport gate for Klaipėda city. The mainland coast of the Baltic Sea extends over a length of 46 km, from the Klaipėda strait to the border of the Latvian Republic.

Setup of environmental sensitivity index (ESI) maps

The New Zealand sensitivity analysis (Roberts, Crawford 2004) was chosen as the most versatile methodological approach to the study area. The development of ESI maps requires identification of four indexes representing the most important coastal resources: for coastal features (ESI_C), for socio-economic (ESI_{SE}), for biological (ESI_B), and for fishery resources (ESI_F). As the core dataset is used the *Environmental Management Atlas*, a GIS-based database set up by L. Lazauskienė and G. Vaitkus in 1999 (Institute of Ecology, Vilnius). The information

on annual landings of eight major fish species in Klaipėda port was obtained from the Lithuanian Fishery Department in Klaipėda, and data on daily amount of visitors on beaches was obtained by R. Povilanskas (reported in EUROSION, 2002) and N. Blažauskas *et al.* 2007 (Baltic Master 2007). Seasonal variation of resources is only partly used in the analysis, due to the incompleteness of GIS datasets. However, the spatial dynamics of birds in autumn and winter seasons have been integrated in the assessment.

The first step was to develop a grid system covering study area. As defined in the Coastal Stripe Law of the Republic of Lithuania (2002), the coastal stripe was identified as a spatial domain, embracing the area within the seawaters up to 20 m isobath and 300 m inland area (including the terrestrial part of the Curonian Spit). As a result 87 spatial “coastal cells” were developed. Each cell has a constant length of 1 km representing the extension of the coastline and a width ranging from 3 to 13 km indicating various extent of the coastal stripe along the coast (Fig. 2).

The next step is an application of the ranking system

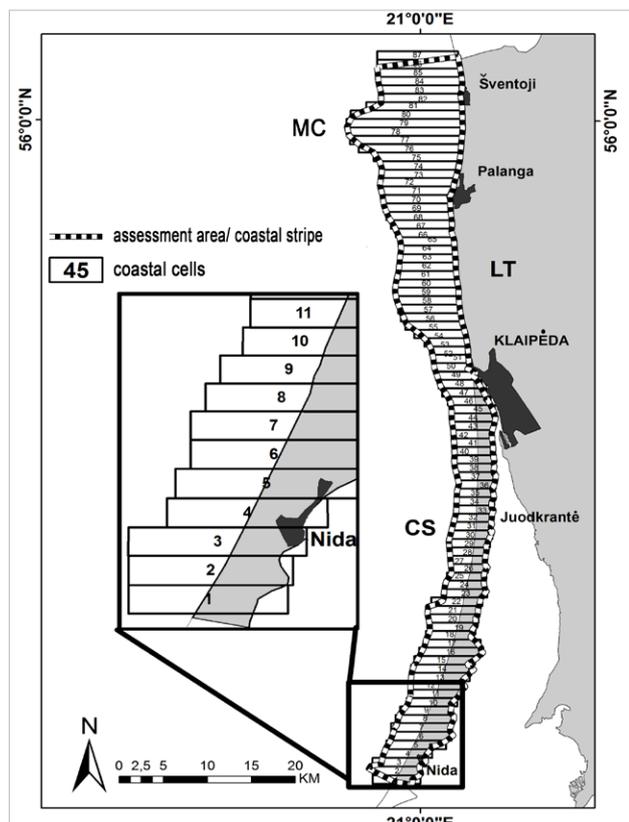


Fig. 2: The study area and 87 coastal cells grid. (CS – Curonian Spit, MC – mainland coast). Compiled by D. Depelgrin, 2010.

to score the sensitivity of pre-selected coast resources to oil spills. The ranking of resources was obtained through an expert-based judgement approach (Table). Experts in different fields of environmental interests at Klaipėda University have been asked to compile a

ranking matrix, composed by a weighted value (WV) and an assigned value (AV). In authors assessment the values for AV range from 2 to 10. The judgement shows that the highly ranked resources/features are recreational areas, spawning grounds, densely populated bird areas and geodynamic regimes.

The generic index ESI_i for a coastal resource “i” is defined as:

$$ESI_i = (AV_1 + AV_2 + AV_3 + \dots + AV_N) \times WV_i \quad (1),$$

where AV_i is the assigned value of “N” parameters and WV_i is the weighed value of coastal resource “i”. The index quantifies the relative importance of the four coastal resources assessed from a socio-economic or environmental point of view. The sum of all WV_i equals 1, indicating 100% of resources assessed in the study area. The AV defines the sensitivity of parameters to an oil spill at a scale from 1 to 10, with ten indicating the highest sensitivity (Roberts, Crawford 2004). In authors assessment the value ranks from the lowest 2 to the highest 10.

The index for coastal features, ESI_C , assesses the potential impact of an oil spill based on the natural persistence of oil and complexity of clean up operations. It is based on three parameters: (1) the shoreline slope ($tg\alpha < 5$ or $tg\alpha > 5$) as measure of relative steepness of the inter-tidal zone between maximum high and low tides; (2) the substrate type (grain coarseness, mm) indicating the medium diameter of sediments on the beach (NOAA’s¹ environmental sensitivity index guidelines); and (3) the physical processes of sediment dynamics ($m^3/year$), representing the pattern of long term cumulative accretion and/or erosion in the coastal zone (Žilinskas 2005).

The index for biological resources, ESI_B , was developed to assess sensitivity of species and biota to an oil spills: (1) birds (ind/km^2); (2) submerged macrophytes (presence/absence); (3) fish food resources (biomass g/m^2); and (4) plant habitats were included in the assessment. The index for fishery resources, ESI_P , represents the potential fish catches in the near shore zone. It is based on an estimation of two main parameters: (1) economic revenue from fish catches (LTL/year) of commercial species in four inshore regions for 2006; and (2) high or medium concentration of spawning grounds. Dataset provides no further quantitative information for spawning grounds. The index of socio-economic resources (ESI_{SE}) assess the recreational value of the coastal segments—the main parameters introduced in the evaluation: (1) marine recreational activities (amount of daily visitors in the peak season);

¹ National Oceanic and Atmospheric Administration.

(2) human settlements (amount of inhabitants); and (3) nature management areas (presence or absence).

Furthermore, the overall environmental sensitivity index (OESI) is defined which is the arithmetic sum of the four assessed coastal indexes:

$$OESI = ESI_C + ESI_B + ESI_F + ESI_{SE} \quad (2),$$

where OESI is an integrated ESI value for all coastal resources contained in the grid system. To mitigate uncertainties in the data a precautionary principle has

been adopted which is frequently used in marine pollution research (Santillo *et al.* 1998). The minimum requirement of the resource to be attributed with a sensitivity value should cover at least 25% of a single coastal cell area. In addition, a very high sensitivity to the most vulnerable resources is attached which compared with other coastal areas in the Baltic Sea region would probably not score with such a high ESI value. This lead to an overestimation of sensitivity but it is necessary in order to provide the complete ESI analysis. The colour palette is designed using standard ESI colours, representing four sensitivity scales: low

(green); medium (yellow); high (orange); and very high (red). The resource of specific ESI values resulted was divided into four ranges in order to designate an attribute value for a GIS based representation.

RESULTS

Coastal features

Based on standard ESI shoreline classification (NOAA 2002), Lithuania's coast is an unsheltered, high energy environment, exposed to a dynamic wave activity and sediment regime (Valdmann *et al.* 2008). The beaches are composed mainly of fine and medium grained quartz sand. Shores with large amounts of gravel, pebble and even boulders are rare (Povilanskas, Urbis 2004). The coastal features index (ESI_C) indicates that the most sensitive area on the mainland coast is located between the seaside resort of Palanga and Būtingė settlement (Fig. 3). This area is characterized by medium grained sand good sorted and intensive accretion, which constitutes favourable conditions for oil accumulation processes along the shoreline (Weslawski *et al.* 1997).

The 7 km coastline of the Curonian Spit from the Russian–Lithuanian border to the settlement Nida is defined as highly sensitive due to the prevailing accretion processes (+20 – +80

Table. Summary of scoring and ranking values. Compiled by D. Depellegrin, 2010.

Coastal resources	Parameters	Features	Unit	AV_i	WV_i
Coastal features	Grain size (mean-diameter)	Mixed sand-gravel	0.5-3.5 mm	6	0.2
		Fine-medium grained sand	0.21-0.64 mm	3	
	Geodynamic regime	Transitional	-20 - +20 m ³ /10 year	10	
		Accumulative	+20 - +80 m ³ /10 year	6	
		Erosional	-20 - -200 m ³ / 10 year	3	
	Shoreline slope (steepness)	Flat	$tg\alpha < 0,05$	10	
		Steep	$tg\alpha > 0,05$	6	
Biological resource	Birds	Gull and auk	> 30 ind./km ²	9	0.3
			20 – 30 ind./km ²	6	
			10 – 20 ind./km ²	3	
		Seaduck	> 300 ind./km ²	9	
			200 – 300 ind./km ²	6	
			100 – 200 ind./km ²	3	
	Submerged macro-phytes	Presence/absence	/	7	
	Fish food resources	Zoobenthos (g/m ²)	>2000	7	
			1000 – 2000	5	
			500 – 1000	3	
		Nectobenthos (g/m ²)	>100	7	
100 – 50			5		
10 – 50	3				
Plants habitats	Presence/absence	/	4		
Fishery resource	Commercial fish	Economic value (LTL per Region)	> 400 000 LTL	9	0.2
			350 000 – 400 000 LTL	6	
			300 000 – 350 000 LTL	4	
			< 300 000 LTL	2	
	Spawning grounds		High	9	
		Medium	7		
Socio-economic resource	Recreational areas	Recreational potential	Thousands of people contemporaneously on the beach	9	0.3
	Management areas	Presence/absence	/	6	
	Human settlements	No. of inhabitants	Persons	6	

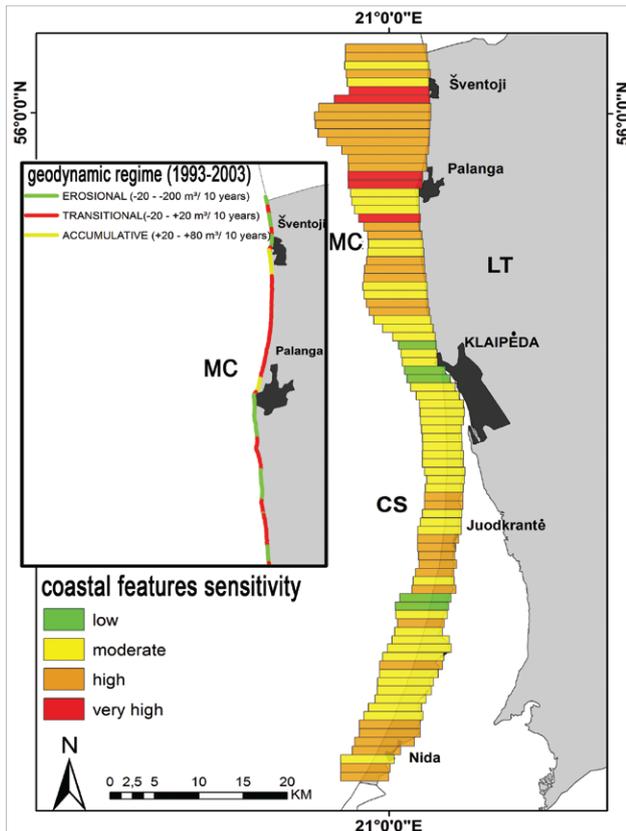


Fig. 3. Representation of the coastal features sensitivity and a detailed view of erosion and accumulation processes (sand volume refers to 1 m of coast line) between Palanga and Šventoji. Compiled by D. Depellegrin, 2010.

$\text{m}^3/10$ years). Similar conditions are evidenced in the south of Juodkrantė and Preila (Žilinskas 2008). The sand dynamics at the mainland coast from settlements Karklė to Palanga alternate in erosional (-20 -200 $\text{m}^3/10$ years) and transitional character (-20 to $+20$ $\text{m}^3/10$ years), whereas from Palanga northwards the Latvian border transitional and accumulative ($+20$ $- +80$ $\text{m}^3/10$ years) processes are dominant. In the ranking system transitional processes have the highest assigned value (see Table) due to the uncertainty in relation to shoreline oiling dynamics. In addition the entire shoreline is subjected to alongshore currents which reinforce transport of oil and oiled sediments to the beach, re-suspending sediments or incorporating the pollutant as a part of the sediment mass (Hayes *et al.* 1992; Jarmalavičius, Žilinskas 2006; Dubra 2006).

The shoreline slope is divided into relatively steep and flat according to the environmental atlas set up by L. Lazauskienė and G. Vaitkus in 1999. The study area has almost constant shoreline steepness. From Nida northwards to the southern outskirts of Palanga the shoreline is relatively steep ($\text{tg}\alpha > 0.05$) which enforces abrupt wave run up, breaking and reflection of the waves - enforcing natural clean up processes. From Palanga to the Latvian border the shoreline is flat ($\text{tg}\alpha < 0.05$), which promotes dissipation of wave

energy further offshore, inhibiting natural clean up phenomena.

Biological resources

Results from biological resources index (ESI_B) mapping point two very sensitive coastal areas (Fig. 4). The first area is characterized by drifting sand and soft bottoms embracing 12 km of coastline on the Curonian Spit between Nida and Juodkrantė, where solid concentrations of zoobenthic communities ($1,000$ – $2,000$ g/m^2) and high concentrations of nectobenthic communities (>100 g/m^2) are observed. On the mainland coast high sensitivity cells concentrate over 5 km of coastline north of Palanga. The area is characterized by mobile drifting sand, stony and mixed bottoms which have different physical and biological features determining the benthic species composition. This area contains biological resources such as algal beds (*Furcellaria lumbricalis*), spawning grounds, bird wintering areas and major benthic communities ($>2,000$ g/m^2) such as *Macoma baltica* (on soft bottom) and *Mytilus edulis* (on hard bottom).

The near shore area along the Curonian Spit, between Nida and Juodkrantė, accommodates benthic communities such as bivalve *Macoma baltica*, and benthic macrofauna species such as *Pygospio elegans*,

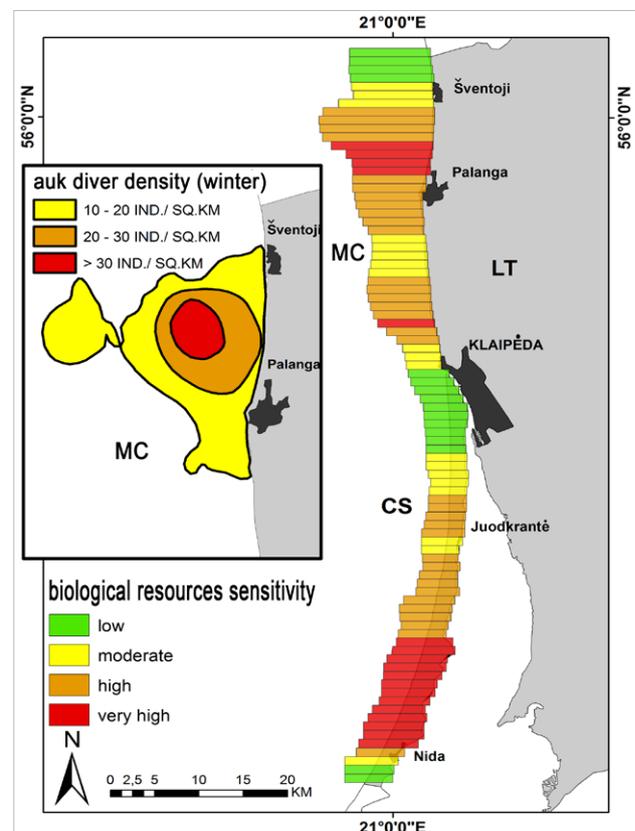


Fig. 4. Representation of the biological resources sensitivity and diver density at the nearshore between Palanga and Šventoji. Compiled by D. Depellegrin, 2010.

Nereis diversicolor, *Marenzelleria viridis*, *Mya arenaria*, *Cerastoderma lamarcki* and oligochaetes. *Macoma baltica* makes prevailing community constituting 40%–90% of the total biomass. The area is an important foraging area for sea birds and is functioning as a food resource for cod. *Mytilus edulis* serves as food resource and biological purifier in the deeper sea seats (Olenin, Daunys 2004).

The mainland coast is characterized by *Furcellaria lumbricalis*, a perennial submerged macrophyte threatened in the Baltic Sea. Suitable lithodynamic and geomorphologic conditions favoured the development of this algal bed in front of Palanga at a depth of 5 to 10 m extending over 26 km along the coastline. These red algae provide habitat and spawning ground to the Baltic herring, which, after two years cycle, constitute a fundamental fish stock for the fish market (Olenin, Daunys 2004; Bučas *et al.* 2009).

Lithuanian coastal waters are internationally recognized as important wintering and migrating habitats for water birds. In particular, the Curonian Spit is designated by the Lithuanian Government to a Special Protected Area (SPA) (Žydelis *et al.* 2006). The mainland coast is visited by dominant water bird species: the velvet scoter *Melanitta fusca* (1837 birds/km²), long-tailed ducks *Clangula hyemali* (142 birds/km²), whooper swan *Cygnus cygnus* (101 birds/km²). The most abundant gull species is the herring gull *Larus argentatus* (28 birds/km²; Žydelis *et al.* 1999). The available GIS information reveals high concentrations of auks and gulls (10–30 ind./km²) on the Curonian Spit, while sea ducks like to distribute between Nida and Juodkrantė in winter and autumn seasons. In particular, the most sensitive areas are in front of Preila and Pervalka due to high concentrations of auks (10–30 ind./km²) and sea ducks (100–>300 ind./km²) in the autumn period. Gulls are distributed in proximity of Klaipėda seaport gate (10–30 ind./km²) and in offshore areas outside the Coastal Stripe (2690 ind./km²).

The ESI_B mapping also covers rare plant species included in the *Red Book of Lithuania*. Especially, the rare species *Glaux maritima*, *Aster tripolium*, *Triglochin maritimum* and *Juncus gerardii* are abundant in the Smeltė peninsula in front of the Klaipėda port (Olšauskaitė–Urbonienė, Olšauskas 2005). According to the data available other important species are located close to the Latvian border.

Fishery resources

The fishery resources index (ESIF) assess the annual economic income (2006 data) from fish catches of the following species: cod (*Gadus marhua callaris*), herring (*Clupea harengus membras*), salmon (*Salmo Solar*), smelt (*Osmerus eperlanus*), bream (*Abramis brama*), pikeperch (*Sander lucioperca*), vimba (*Vimba*

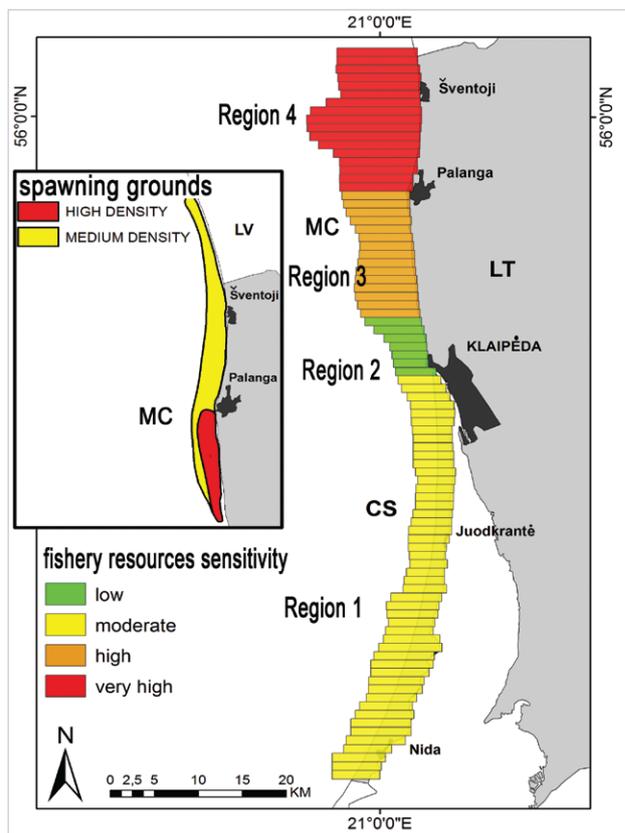


Fig. 5. Fishery resource sensitivity and spawning grounds along the mainland coast. Compiled by D. Depellegrin, 2010.

vimba) and whitefish (*Coregenus lavaretus balticus*) for a total of 316 000 tons of fish, where an estimated turnover is 1.32 mill. LTL/year just in the near-shore of the coastal stripe. According to ESI_F map (Fig. 5) the most profitable are third and fourth regions (381 000 and 420 000 LTL, respectively). The most abundant and therefore the most profit-making species are cod and smelt, exceeding an annual income of 550 000 LTL. Overall, cod is the most profitable fish species in the whole study area (Fig.6). In particular, the

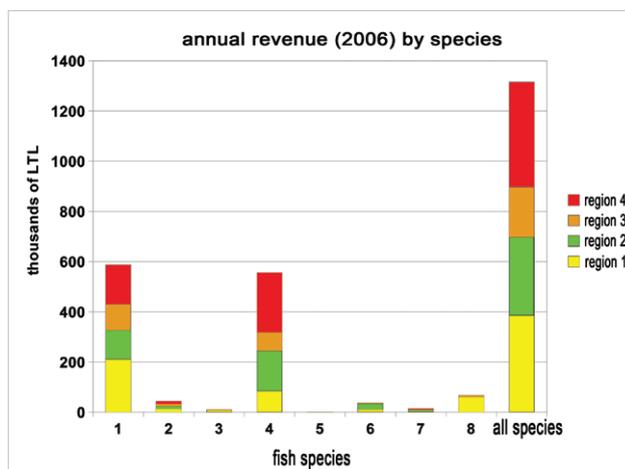


Fig. 6. Economic revenue of fish species: 1 – cod; 2 – herring; 3 – salmon; 4 – smelt; 5 – bream; 6 – pikeperch; 7 – vimba; 8 – whitefish. Compiled by D. Depellegrin, 2010.

first region aggregates the highest income from cod, over 200 000 LTL/year. According to the assessment of biological resources, the area between Nida and Juodkrantė is a fish foraging space. The area is rich in *Pygospio elegans*, *Macoma baltica*, *Mesidotea entomon* biocenoses, that constitute food resource for benthophagous fish species such as cod. At the depths of 5–10 m the area presents a similar zoobenthic structure like the segment from Klaipėda–Juodkrantė where a biomass get to about 82 g/m². At the depths of 11–20 m the biomass reaches 97 g/m², with an increasing abundance of mollusc *Macoma baltica* (Bubinas, Vaitonis 2007).

In addition, the ESI_F integrates data on spawning grounds. The dataset proved that spawning grounds are peculiar for third and fourth regions (within 32 km of shoreline), and for this reason contribute strongly to a very high sensitivity. Furthermore the spatial distribution of Baltic herring spawning grounds coincides with *Furcellaria lumbricalis* algal beds in front of the Palanga resort.

Socio-economic resources

Results of socio-economic resources index (ESI_{SE}) mapping highlight the importance of recreational areas at the coastal stripe (Fig. 7). Very high sensitivity cells are distributed in all major recreational areas as Nida, Preila, Pervalka, Juodkrantė, Smiltynė on the Spit;

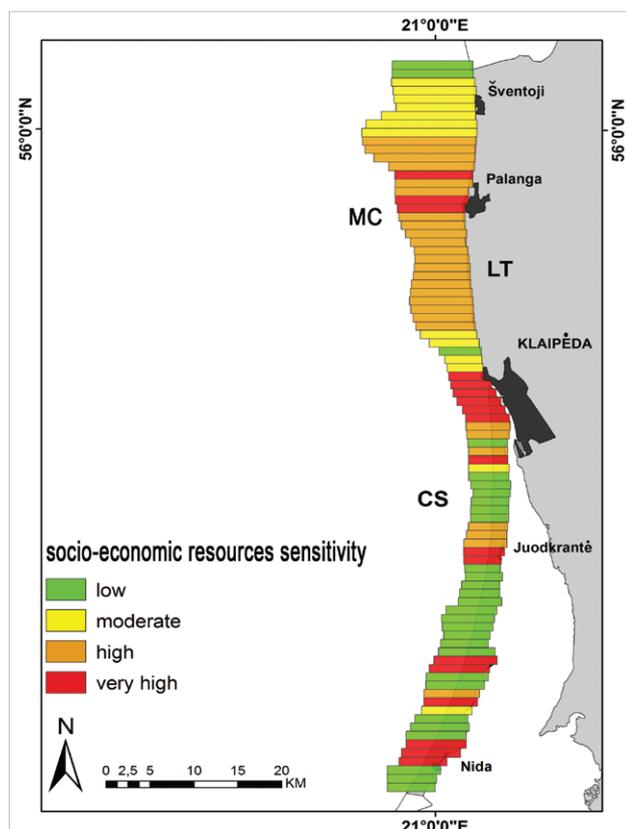


Fig. 7. Representation of socio-economic sensitivity. Compiled by D. Depellegrin, 2010.

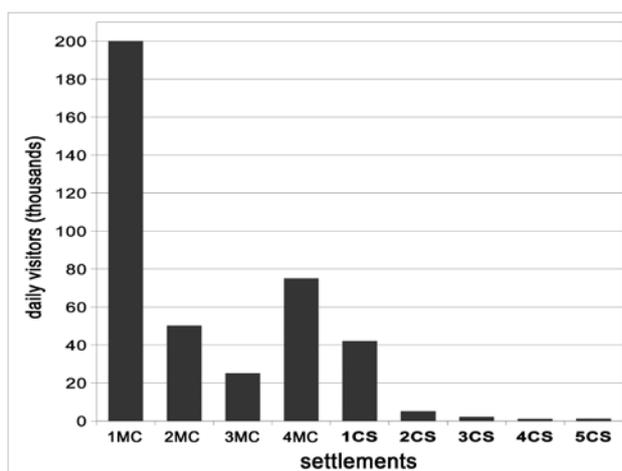


Fig. 8. Coastal settlements and their daily visitors (in thousands) during peak season (the summer season is defined from middle of June till the middle of September). Mainland coast (MC): 1 – Palanga; 2 – Šventoji; 3 – Karklė; 4 – Giruliai/ Melnragė. Curonian Spit (CS): 1 – Klaipėda / Smiltynė; 2 – Nida; 3 – Juodkrantė; 4 – Pervalka; 5 – Preila. Compiled by D. Depellegrin, 2010.

Giruliai–Melnragė and Palanga resorts on the mainland coast. Distribution of the high ESI_{SE} values on the mainland coast reflects an intensive tourism flow. The areas of Palanga, Giruliai and Klaipėda–Smiltynė experience the highest amount of daily visitors with respectively 200, 75 and 42 thousand daily visitors in the peak season (Fig. 8). About 20% of total coastal cells are estimated to be very sensitive and another 30% show to be sensitive to oil spills.

The mainland coast encompasses the special protected area—the Baltic Sea Offshore (17 096.7 ha), an International Bird Area (IBA; 101.2 ha), and two national protected areas, as the Baltic Sea Thalassological Reserve and Palanga Seaside Regional Park (421.9 ha). The Curonian Spit (Kuršių Nerija National Park; 24 995.9 ha) is under auspice of the Baltic Sea Protected Areas (HELCOM) and UNESCO World Heritage protection. This site enjoys particular management status, ensuring a harmonized social, economic and environmental development and planning. In addition, the high environmental, safety and water quality standard awarded to Nida Central Beach, Juodkrantė Central Beach and the Botanical Park Beach at Palanga marked by eco-label *Blue Flag beaches* (Blue Flag 2010).

Overall environmental sensitivity index (OESI)

The OESI map was designed in order to integrate the four coastal resources into a single comprehensive map. In general, the sensitivity of the Curonian Spit can be considered as medium high (Fig. 9). The sensitivity is steadily decreasing from the Russian border to Klaipėda. In particular the coastal area of 25 km from Nida to Juodkrantė is of a high sensitivity, due to its important biotope complexes, cod fish stocks, water birds density and recreational areas. Towards Klaipėda

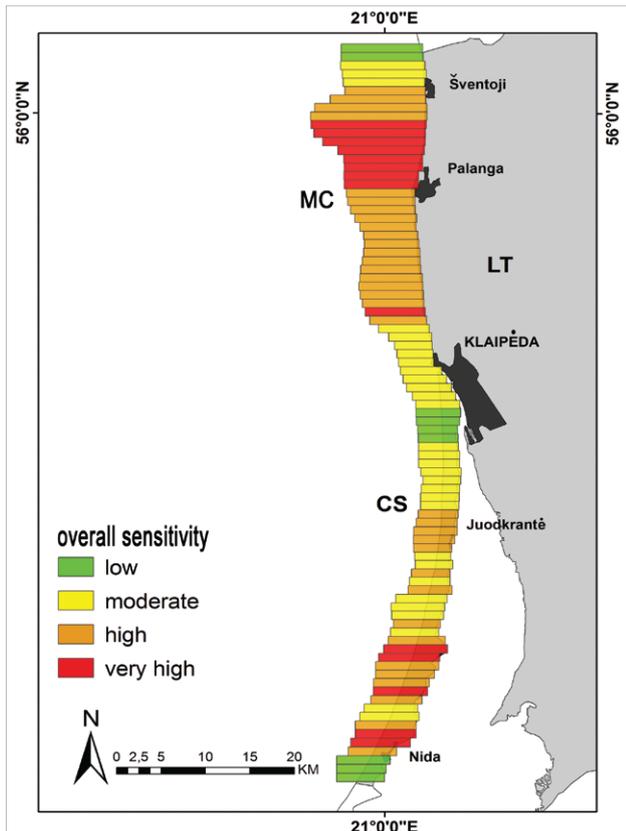


Fig. 9. Overall environmental sensitivity map. Compiled by D. Depellegrin, 2010.

seaport gate the sensitivity switches from moderate to low.

On the mainland coast there is an inverse pattern—the sensitivity to oil spills increases from Klaipėda towards the Latvian border. In general, the sensitivity of the mainland coast can be considered as high or very high. In fact 28 km of the coastal stripe between Karklė and Šventoji settlements follow this trend. The most important biological and socio-economic resources are here concentrated of the entire study area: *Furcellaria lumbricalis* algal beds, herring spawning grounds, im-

portant commercial fish stocks, bird wintering areas, the most important seaside resort of the south-eastern Baltic Sea, diverse nature reserves protected under national and international agreements.

The average contribution of the four indexes to each coastal cell in the study area is shown on the Fig. 10(a). The analysis of sensitivity ranking on the Curonian Spit (CS) and the mainland coast (MC) indicate that biological resources have a higher importance on the CS (50%) versus the MC (46%). Fishery resources are more significant on the MC due to important economic income from landings in third and fourth regions. Coastal features (22%) and socio-economic resources (19%) have a comparably equal contribution to sensitivity in both areas. On overall (CS + MC) biological resources are the most significant, making up to 50% of total sensitivity in each coastal cell.

The highest amount of very high sensitivity coastal cells is modelled for biological resources (21%), followed by fishery resources and socio-economic resources with 20% each, and at least for coastal features (7%; Fig. 10(b)). High sensitivity cells are most abundant in coastal features (55%) and biological resources (39%). This elevated contribution ratio is caused by erosion-accretion processes, which are significantly distributed along the entire coastline, and the multitude of biological resources, which include marine and terrestrial organisms within the coastal stripe. The ESI_{SE} map has the highest number of low sensitivity cells with 33% of the total grid. This is resulted from the available GIS data for ESI_{SE} (see Table). About 62% of coastal cells are attributed to ESI management areas, and further integration of ESI values in targeted areas, such as officially designated recreational areas in proximity to coastal settlements, determines this characteristic sensitivity distribution (see Fig. 7). In general the OESI map indicates predominance of high (42%) and moderate sensitivity (22%). Very high sensitivity cells are at 20% of the total grid similar to ESI_F and ESI_{SE} .

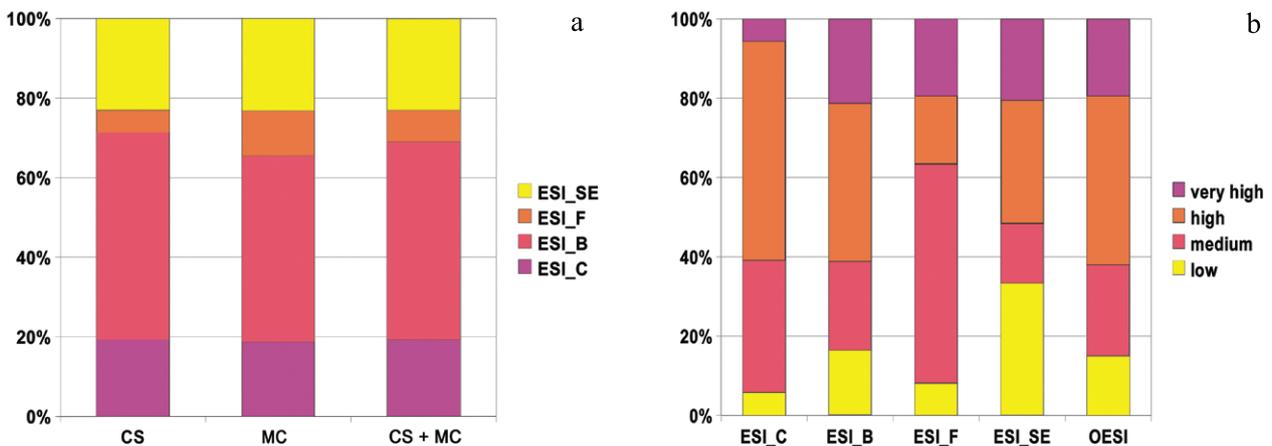


Figure 10. a) Average contribution of each ESI to the integrated environmental sensitivity in each coastal cell for different segments of the study area: Curonian Spit (CS), mainland coast (MC) and for all the coast (MC + CS); b) Percentile contribution of ESI rankings to each resource map. Compiled by D. Depellegrin, 2010.

DISCUSSION

Dramatic changes in the coastal zone management, such as the intensification of coastal fishery, in fact have induced variations of wintering bird dynamics and fish stock migration (G. Vaitkus, pers. com.) making the GIS datasets consistently out-dated. The nature of ESI maps represents an integrated approach, involving directly and indirectly a series of experts and coastal managers from different fields (Tortell 1992). The resulting amount of digital, geo-referenced databases needed in this study provides insights on completeness of the data sets, disclosing major shortcomings and uncertainties. A potential improvement of the database should primary focus on the water bird inventory, which is the most consistent dataset. Furthermore the fishery resources index requires (1) to be extended with additional time series on fish landings and (2) the monetary evaluation of fishery regions should be enhanced towards a higher spatial resolution.

The ESI maps concentrate consistent amounts of information and data that can be easily updated. The application of GIS tools enables to use information at any scale, satellite images, aerial photographs, topographic maps and other related information. The ESI maps allow one to depict the most relevant information needed for the effective response planning and operations as well as enabling a composite action among different stakeholders (Pincinato *et al.* 2009).

The ESI mapping provides an average contribution of each criterion and variables. This segmentation into coastal cells may not allow the identification of important values. Moreover a model-based algorithm provides a certain automatism in the identification of priority resources, which, if used improperly, can create conflicts between decision makers. The proposed methodological approach and its spatial uncertainty probably lead to an overestimation of sensitivity values. On the other hand the application of an algorithm based on an expert judgement approach leads to a quicker and less subjective assessment of resources to be prioritized.

CONCLUSIONS

The maps are an important part of successful oil spills response and planning. Coastal features, biological, socio-economic and fishery resources are indicators that characterize coastal areas due to their vulnerability to oil spills. They describe the level of reaction induced by an adverse change in safety, survival, reproduction and economic activities.

Despite the restricted availability or lack of relevant data, the method proved to be useful for developing the integrated ESI mapping. Considering the sparse

amount of information available, the method's output was an exhaustive, flexible approach allowing a reasonable integration of new GIS information.

Results from the methodology proposed for the Lithuanian coast reveal two major prioritization areas. First, a 25 km long coastal area between Nida–Juodkrantė is considered as high sensitive to oil spills due to its important biotope complexes, valuable socio-economic resources, such as the beaches of Nida, Preila, Pervalka and Juodkrantė and providing an essential economic revenue for local communities on the Curonian Spit. Second, the coastal area of 12 km between Palanga–ventoji on the mainland coast concentrates unique biological and socio-economic resources for the entire study area. This is the most visited recreational area of the south-eastern Baltic Sea. Moreover, the fishing grounds embrace the most profitable fishing resource of the entire study area. The oil spills in this area could have devastating effects on local fishing communities and the tourism sector.

The future development of the presented Lithuanian ESI maps require complex datasets, involving experts of the various research areas, from social to economic sciences, which potentially promote stakeholder involvement and participatory approaches.

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