OIL POLLUTION OF THE SOUTHEASTERN BALTIC SEA SURFACE AND POSSIBLE DIRECTIONS OF ITS PROPAGATION

Alexander Krek, Immanuel Kant Baltic Federal University, Atlantic Branch of P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Russia
Elena Bulycheva, Atlantic Branch of P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Russia
Andrey Kostianoy, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Immanuel Kant Baltic Federal University, Russia

alexander.krek@gmail.com

Ships, seeps from the seabed, municipal and industrial waste waters, and the atmosphere are the main sources of sea water contamination with oil and oil products. During the satellite monitoring of the Kravtsovskoe oilfield (D-6) (2004-2015) the area west of Sambia Peninsula and anchorage in front of entrance to Kaliningrad Sea Canal were localized as the most polluted area of the Southeastern Baltic Sea. Oil spill drift forecast from these areas with a help of Seatrack Web model (SMHI, HELCOM) has shown that the average annual direction of oil pollution drift is directed to the North-East. In some cases, leakage of oil or oil products from ships west of Sambia Peninsula could be a reason of oil contamination of beaches of the "Curonian Spit" National Park.

Key words: Southeastern Baltic Sea, oil pollution, satellite imagery, oil spill drift forecast, Seatrack Web model

I. INTRODUCTION

The Baltic Sea is one of the busiest waterways in the World Ocean. It has about 40 ports and oil terminals. Increasing maritime transportation threatens fragile ecosystems and the livelihoods of the many people who depend on the sea. During the last decade shipping has steadily increased, reflecting intensifying co-operation and economic prosperity around the Baltic Sea Region. On average 2,000 ships are at sea every day, including 200 tankers carrying oil or other potentially harmful products. It is estimated that the transportation of goods by sea will double by 2017 in the Baltic Region [1].

The main sources of oil pollution in the sea are natural hydrocarbon seeps, rivers, waste waters, shipping and atmosphere [2-9]. In the Baltic Sea, ships play a key role in the transportation of goods, oil and oil products, passengers and cars, as well as in fishery. At the same time shipping activities creates operational environmental pressures in the form of exhaust gas pollution, illegal discharges of oil, sewage from passenger, ferry and fishery ships, as well as introduction of invasive alien species via ships' ballast water [10].

Oil production on the shelf of the Southeastern Baltic Sea also represents a risk of oil pollution and a potential threat to the environment.

II. DATA

Data on oil pollution of the Southeastern Baltic Sea surface were obtained during operational satellite monitoring of the Kravtsovskoye oilfield (D-6) from June 2004 to December

2015. The monitoring was based on the analysis of satellite images from the following satellites: ENVISAT (European Space Agency (ESA)), RADARSAT-1 (Canadian Space Agency (CSA)), RADARSAT-2 (McDonald, Dettwiler & Associates (MDA, Canada)), TerraSAR-X (German Aerospace Center (DLR), Germany), and four satellites of the Italian Space Agency (ASI) Cosmo-SkyMED-1, -2, -3, -4.

In total 1946 radar images were analyzed, and 1232 oil spills were detected during the analysis of satellite radar images (Fig. 1). “Tail”-shaped oil spills are prevailed, what means that these spills are originated from moving ships [11].

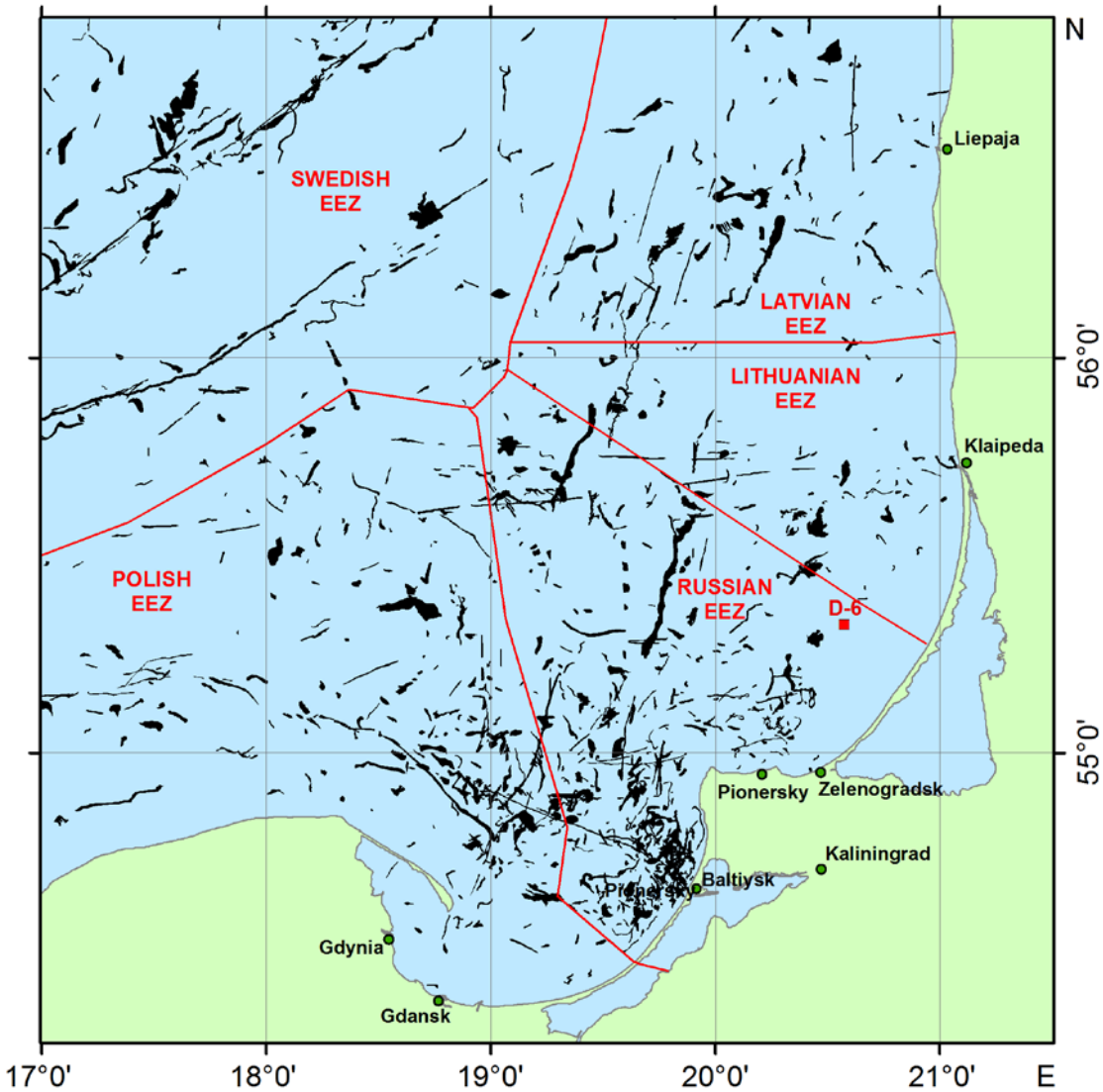


Fig. 1. Distribution of oil spills on the sea surface in the Southeastern Baltic Sea detected by satellite observations from June 2004 to December 2015.

III. Numerical modelling

The Seatrack Web numerical model was used for prediction of drift and transformation of oil pollution. Seatrack Web is the HELCOM operational oil spill drift forecasting system which is based on operational weather and hydrodynamics forecasts. Oil spill drift model calculates the drift and spreading of oil spills using a Lagrangian particle tracking technique. Weathering processes such as evaporation, vertical dispersion and formation of water-in-oil emulsions are also calculated based on the standard formulae.

The system uses two different operational weather models ECMWF and HIRLAM (HIgh Resolution Limited Area Model, 22 km grid) and circulation model HIROMB (HIgh Resolution Operational Model for the Baltic Sea, 24 layers, driven by the two weather models respectively), which calculates the current field at 3 nm grid with 15 min time step. The model allows to forecast the oil drift for five days ahead or to make a backward calculation for 30 days for the whole Baltic Sea. Seatrack Web is in operational use in all the Baltic States [12-15].

Two modeling areas were selected west of Sambia Peninsula for numerical experiments of oil spill drift forecast (Fig. 2). The area #1 is the area of location of huge oil spill, composed of several separate parts, detected from ENVISAT (27.06.2008, 09:03 UTC) (Fig. 3). Results of forward calculations using Seatrack Web model showed, that this oil spill could be a source of observed oil pollution of the Curonian Spit beaches [12]. This is a reason why this area was selected as the modeling area #1. Area #2 is a 50 km long line along the main shipping route directed to Kaliningrad Sea Canal which corresponds to the concentration of the “tail”-shaped oil spills originated from moving ships (see Figs. 1 and 2).

Forecasts of potential oil spills drift originated from modeling areas #1 and #2 were calculated for every day of 2015 for 48 hours. 365 daily forecasts for both regions were combined in the probability maps of oil contamination of the sea surface during 48 hours after appearance of an oil slick (Fig. 4, 5). These maps show that during the first 48 h after a release of oil from ships, in most cases, oil pollution will drift to the North-East, what corresponds to the general wind direction in this region as registered at Autonomous Hydro Meteorological Station (AHMS) installed on D-6 platform (Fig. 6). The main direction of the contamination propagation is also in agreement with local currents and the direction of mean annual transport of substances in the Gdansk Basin [16-18].

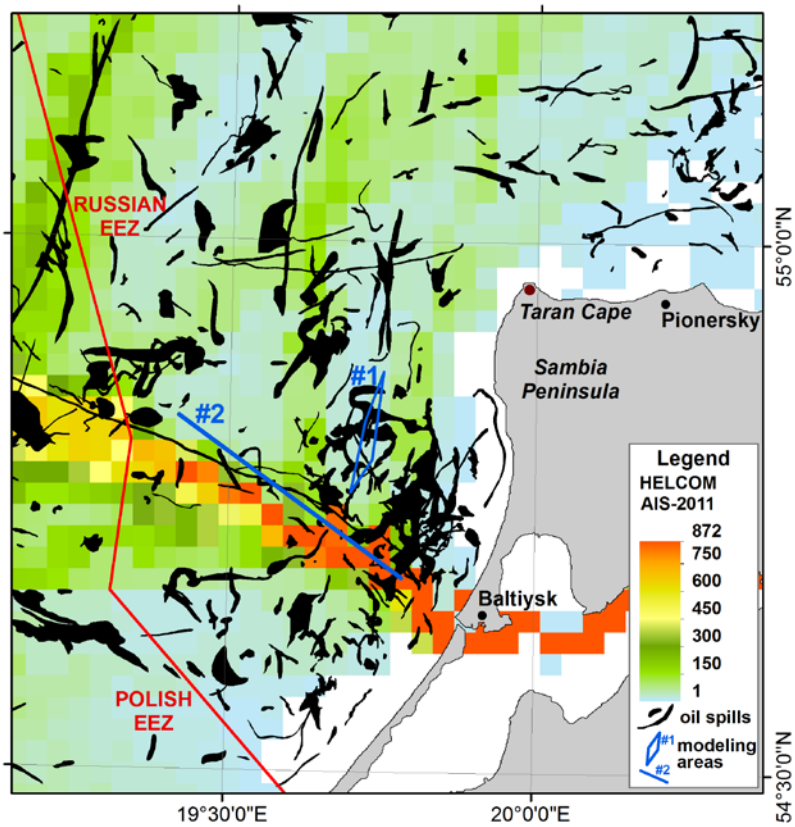


Fig. 2. Location of modeling areas #1 and #2 (blue lines) west of Sambia Peninsula.

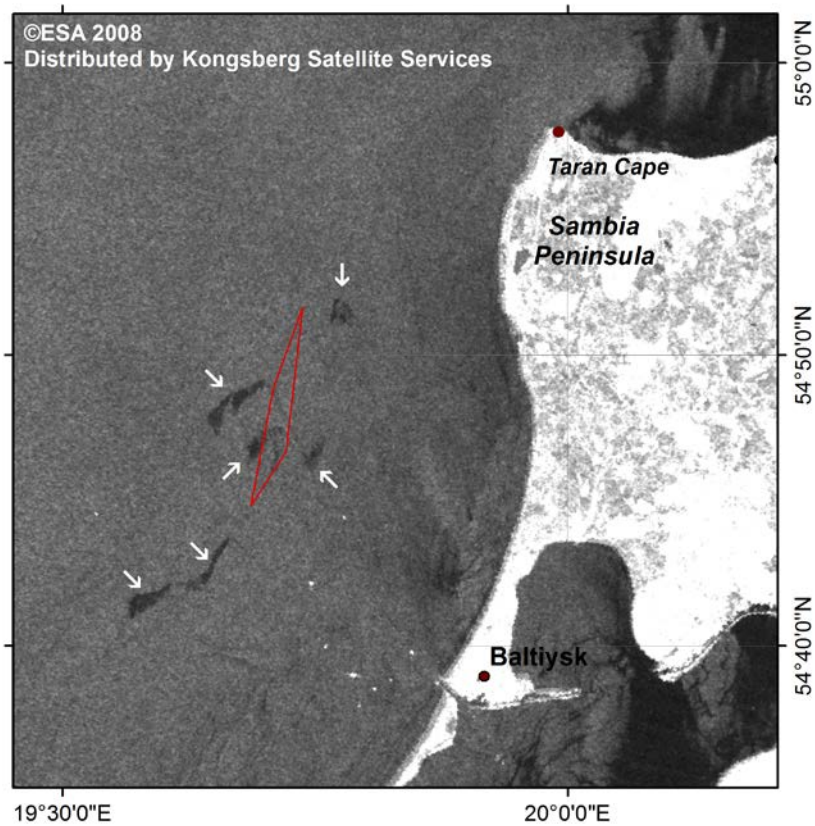


Fig. 3. Fragment of ENVISAT image on 27.06.2008 (09:03 UTC). Parts of oil spill are shown by arrows. Red area corresponds to the modeling area #1.

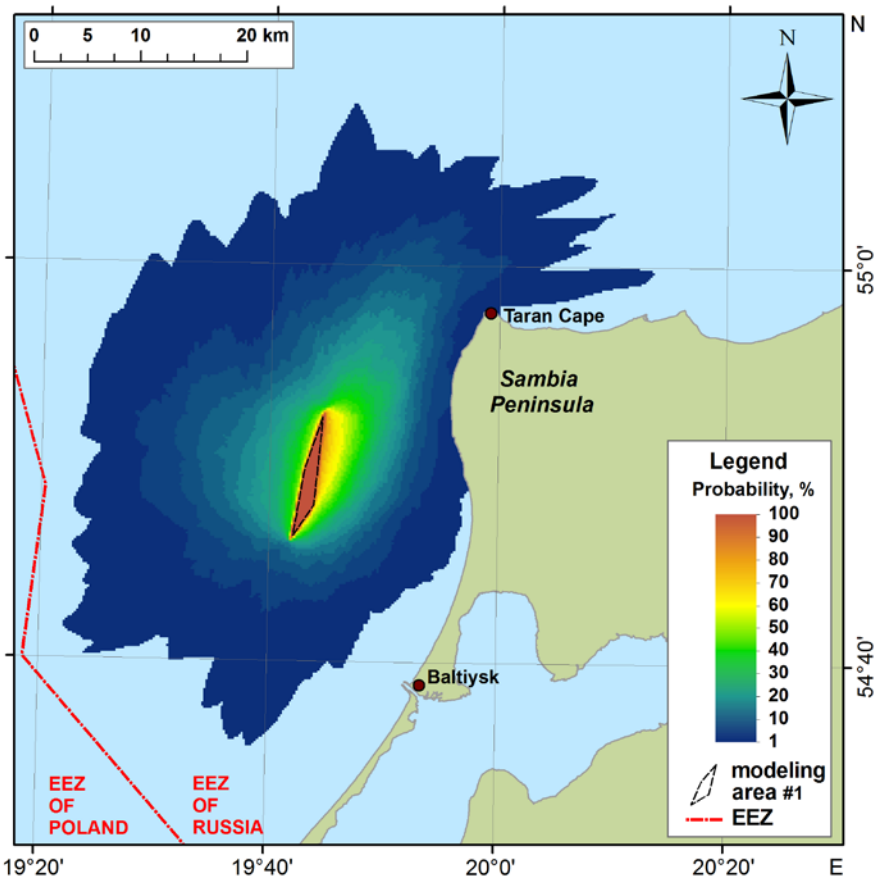


Fig. 4. Probability of propagation of oil pollution originated from the modeling area #1 for the next 48 h after leakage of oil for 2015.

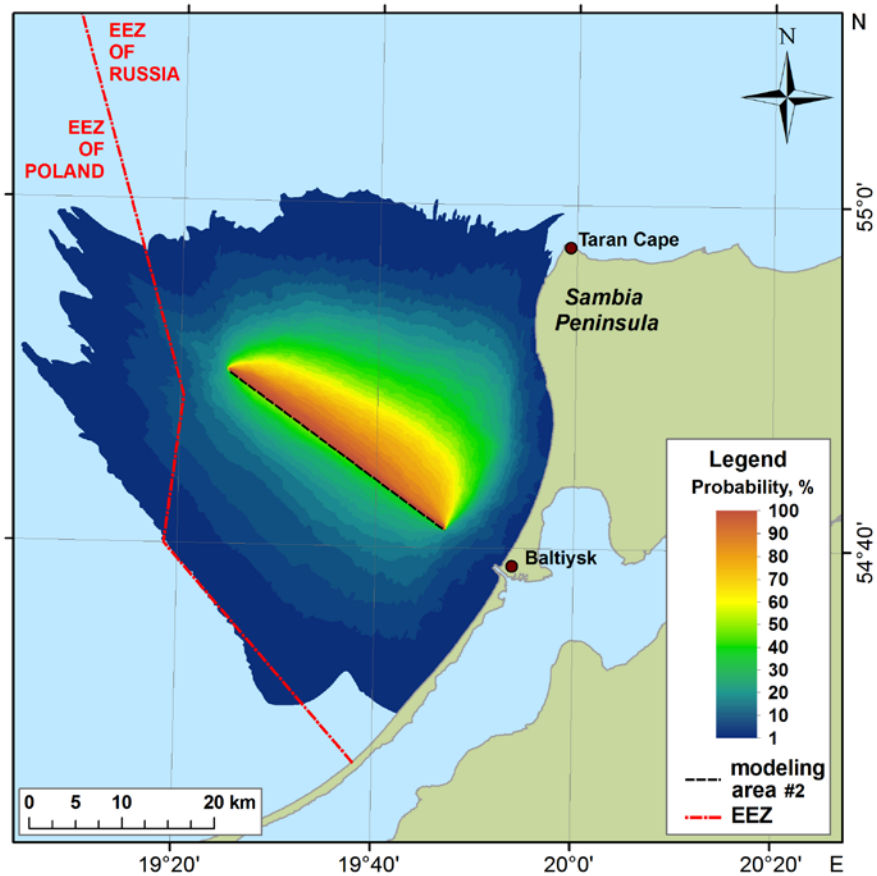
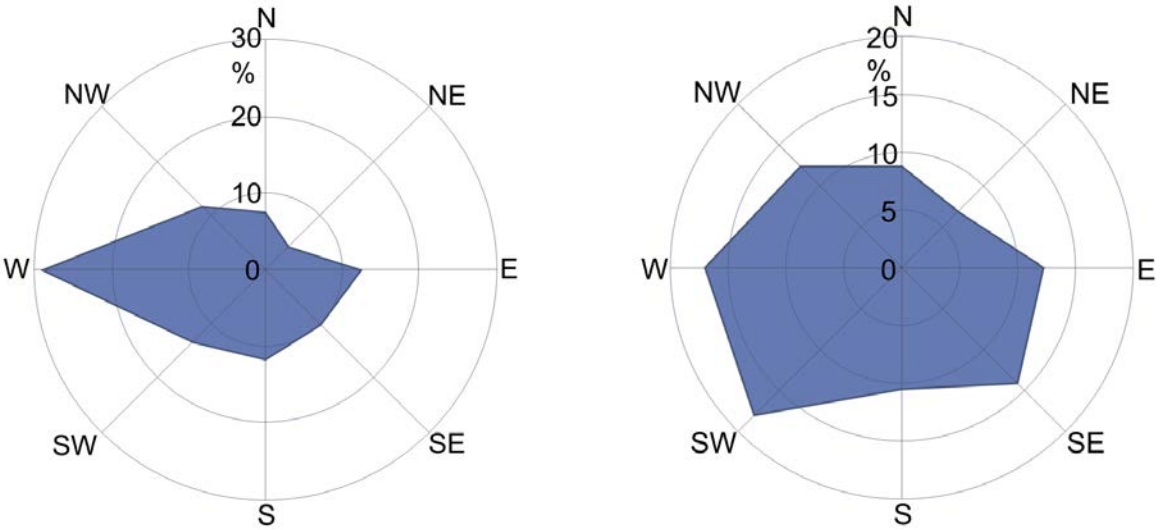


Fig. 5. Probability of propagation of oil pollution originated from the modeling area #2 for the next 48 h after leakage of oil for 2015.

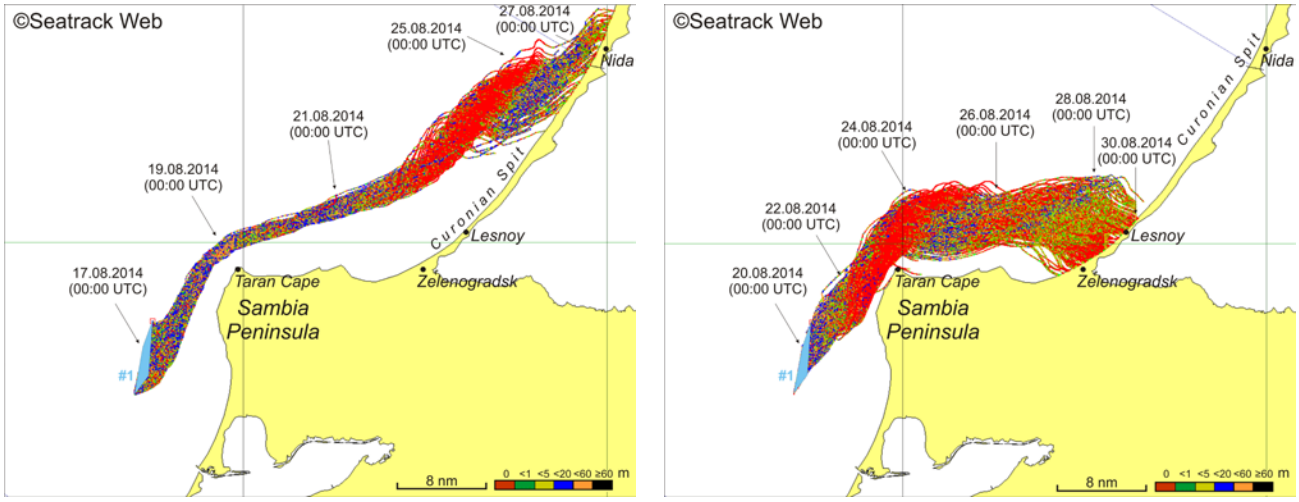


(a) **(b)**

Fig. 6. Wind rose calculated by data from AHMS installed on D-6 platform: a) for 2015; b) for 2006-2014.

In particular cases, oil pollution appearing from the modeling area #1 during 11 days after leakage may reach Curonian Spit beach (Fig. 7). Thus, at specific meteo and hydrological conditions for periods of 17-27 August and 20-30 August 2014 the oil spill could reach the Curonian Spit shore near Nida (Fig. 7a), or the area from Zelenogradsk to Lesnoy (Fig. 7b). These examples show that oil released west of Sambia Peninsula can be a reason of oil pollution

of the Curonian Spit shore. For instance, during July 2008 oily sands were observed along the all Russian part of the Curonian Spit, i.e. several days – weeks after an oil spill was observed in the area #1 on 27 June 2008 [12].



(a) **(b)**

Fig. 7. Propagation of oil pollution from the modeling area #1:
a) for a period of 17-27 August 2014; b) for a period of 20-30 August 2014.

As discussed in [19], the observed oil spills are shifted from the shipping route (area #2) northeastward (see Fig. 2). The results of numerical simulation of potential oil pollution from the shipping route leading to the Port of Baltiysk may explain this discrepancy by a general drift of oil spills to the North-East (see Fig. 5).

IV. Conclusions

Numerical simulations using Seatrack Web model for two areas of appearance of oil spills west of Sambia Peninsula allow to establish the main directions of their propagation. Oil products and other harmful substances released from ships in the area west of Sambia Peninsula will propagate to the North-East. In particular cases oil released in the area #1 can turn around Sambia Peninsula and washed ashore the Curonian Spit, the Natural and Cultural Heritage of UNESCO.

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