Journal of Science Innovare
https://journal.unpak.ac.id/index.php/jsi

Volume 05, Number 02, September 2022, Page 40-44
e-ISSN: 2615-3750 ; p-ISSN: 2615-3769

SPATIAL ANALYSIS OF ENVIRONMENTAL SENSITIVITY FOR MITIGATION OF OIL SPILL DISASTERS IN THE SERIBU ISLANDS NATIONAL PARK

Rokhmad Khabibi [a*)], Rosadi [a)], Sata Yoshida Srie Rahayu [a)]

[a)]*Universitas Pakuan, Bogor, Indonesia*

[*)]*Corresponding Author : rokhmad,khabibi@gmail.com*

***Article history**: received 08 August 2022; revised 17 August 2022; accepted 29 August 2022* *DOI: https://doi.org/10.33751/jsi.v5i2.6349*

Abstrak. The Seribu Islands National Park (*Taman Nasional Kepulauan Seribu - TNKpS*) which has a marine ecosystem area that has the potential to be affected by oil spills originating from oil discharges from ships passing through the Sunda Strait and ship accidents in and out of Tanjung Priuk Port. In addition, in the TNKpS area there are also oil and gas mining companies as well as oil distribution through pipelines which have the potential to cause oil pollution due to leakage of oil distribution pipelines. The availability of maps of Environmental Sensitivity Index and comprehensive environmental data is important for the government to understand the condition of sensitive areas around oil and gas mining areas to mitigate environmental pollution due to oil spills, and can then take priority actions. to protect areas deemed sensitive. The compilation of thematic maps related to environmental sensitivity to oil spills in TNKpS shows that the beach type is not sensitive to oil spills, where the dominant beach type is gently sloping sand which is a substrate that is easy to clean when an oil spill occurs. While the component of biodiversity has the highest sensitivity. The most sensitive socioeconomic components affected by the oil spill are fish farming and marine tourism (snorkeling and diving), both of which are the main livelihoods for the people in TNKpS, especially from the tourism sector. Mitigation of oil spills in TNKpS should focus on dealing with oil spills before reaching sensitive areas where oil collection with skimmers and spraying of dispersants can be carried out before entering the coral reef area. The next step is the protection of sensitive areas from oil spills where this protection can be done by dispelling using an oil boom and directing the oil spill to a less sensitive area. The final step is cleaning the beach area in accordance with oil spill emergency response procedures. Spill simulations carried out with a duration of 3 hours, 5 hours and 24 hours showed that the oil spill had not yet reached the sensitive area when it was <3 hours, so that the ideal anticipatory oil response is to have an oil control exercise with a duration of <3 hours to protect sensitive areas.

Keywords: environmental sensitivity index; oil spill; Seribu Islands national park; biodiversity

I. INTRODUCTION

The Seribu Islands National Park (*Taman Nasional Kepulauan Seribu* - TNKpS) has been designated as a marine national park since 2002, legally located in the Seribu Islands Administrative District, DKI Jakarta Province. The Seribu Islands National Park has an area of 107,489 hectares (Sambali **[1]**). The number of offshore activities around TNKpS makes this area vulnerable to pollution from offshore activities. The most significant offshore activities around TNKpS are oil and gas mining and shipping activities. Both of these activities have the potential to pollute the environment, one of which is the incident of oil spills either from pipe leakage activities or from sinking shiploads **[2]**. Cases of oil spills in the Seribu Islands National Park are very common because the location of TNKpS is close to the location of oil exploitation and shipping lanes. However, there is no comprehensive Environmental Sensitivity Map that can be used as a basis for handling oil spills. Analysis of the environmental sensitivity index is one of the sources of information needed to determine an effective and efficient oil pollution control strategy **[3]**.

The availability of maps of Environmental Sensitivity Index (*Indeks Kepekaan Lingkungan* - IKL) and comprehensive environmental data is important for the government to understand the condition of sensitive areas around oil and gas mining areas to mitigate environmental pollution due to oil spills, and can then take priority actions. to protect areas that are considered sensitive (Putra **[4]**). Environmental Sensitivity Index requires a study to describe the characteristics of the environment. This study will also identify and evaluate sensitive areas around oil and gas concession areas as a guide in developing oil spill mitigation strategies **[5]**.

The research objectives are (1) obtaining data related to resources in coastal areas that are sensitive to oil pollution in the Seribu Islands National Park, (2) preparing Environmental Sensitivity Map and Environmental Sensitivity Index (IKL) by conducting a Study of Environmental and Socio-Economic Resources that are at risk of oil spills, and (3) determining and prioritize resources at risk based on the worst case oil spill scenario (oil spill risks-worst case discharge scenario).

II. RESEARCH METHODS

This research was conducted using descriptive exploratory method with quantitative and qualitative

Volume 05, Number 02, September 2022, Page 40-44
e-ISSN: 2615-3750 ; p-ISSN: 2615-3769

approaches. Descriptive research aims to describe the nature of something that is ongoing during research carried out and examine the causes of a certain symptom (Sugiyono **[6]**). The data taken in this study consisted of primary data and secondary data. The secondary data collected from the TNKpS Center as well as research related to biodiversity and socio-economics in TNKpS in the last 5 years. While the primary data was taken when the researchers verified the biodiversity and socio-economics in the TNKpS area.

Mapping of the Environmental Sensitivity Index in TNKpS was carried out by considering 3 (three) thematic sensitivities, namely:

1. Beach type and general environmental sensitivity to oil spills;
2. Biodiversity in the form of sensitive ecosystems, habitats, species and key natural resources;
3. Sensitive socioeconomic features;

The beach type is currently identified with the Sentinel 2B satellite image at resolution 10 meters supported by high resolution images obtained from Google Earth and online ESRI image data **[7]**. These data sources represent the most recent satellite images available for the study area. Mapping (profile) of biodiversity resources, including:

1. Protected areas and areas with important biodiversity (regulated in laws and regulations at the national, provincial and provincial levels, governed by traditional wisdom or customary law)
2. Various types of habitats/coastal ecosystems (mangroves, coral reefs, non-mangroves such as riverbank forests and others.); and
3. Protected and endangered species.

The sensitive socio-economic features that are mapped should include: non-living resources that could be directly affected by oil, areas of human use that are economically affected, such as hampered use in the event of an oil spill, and areas that could be useful. when a spill occurs for access or equipment installation activities **[8]**. These features can be grouped into various categories:

1. Subsistence fisheries (fishing activities or businesses that are carried out just to support family life), traditional and commercial, and fishing villages;
2. Aquaculture;
3. Water intake (salt factories, seawater desalination plants, aquaculture and salt production, industrial estates);
4. Tourism and recreation areas (hotels, restaurants, marinas, beaches, recreational fishing, diving, etc.);
5. Ports (including activities and infrastructure);
6. Industrial activities (dependence on sea transportation);
7. Infrastructure related to oil exploration, production and transportation activities; and
8. Cultural sites (archaeology, history, religion, etc.)

The collection of data on socio-economic features of an area is obtained from the Ministry of Maritime Affairs and Fisheries, the Ministry of Tourism and related agencies at the district-city level within the scope of the study area, sub-district profiles, village profiles, population data in figures, field checks and interviews with stakeholders related. The creation of an IKL for the well-known Environmental Sensitivity Index (IKL) beach type can be adapted for each country. ranges from 1 (low sensitivity) to 10 (very high sensitivity) based on:

1. The type of beach (grain size, slope) that determines the penetration and/or stockpiling capacity on the coast, and the movement of oil;
2. Exposure to wave (and tidal energy) which determines the time of the natural resistance of oil on the coast; and
3. Productivity and general biological sensitivity.

Sensitive natural resources can be ranked by recovery time after an oil spill incident. Various classifications or existing lists can also be used to rank it: IUCN red list (conservation status and distribution information of endangered species), list of endangered, endangered and rare species and habitats, etc. Ranking of socio-economic features is carried out based on patterns of socioeconomic activity located at the study site. As for in this study, a ranking will be carried out on 5 main activities that may be affected if there is an oil spill, namely: Fishing Fishermen Activities, Cultivating Fishermen, Settlement, Ports and Tourism **[9]**.

III. RESULTS AND DISCUSSION

Beach Type

One of the components assessed as the basis for calculating environmental sensitivity is the type of beach. The coastal-type interpretation area in the Seribu Islands National Park area is only identified on islands that are under the administration of TNKpS. There are 4 types of beaches in the study area. The most dominant type of floor is a gently sloping sandy beach, this is in line with the results of site verification. The most common type of beach found in TNKpS is sloping sandy beach with a percentage of 79.41%.

Table 1 Length of Beach Type (m)

No.	Tipe Pantai	Jenis	Panjang (m)	Persentase
1.	1B	Pantai berbatu terbuka	6.172,73	6,04
2.	3A	Pantai berpasir landai	81.202,74	79,41
3.	3B	Lereng dan Lereng Curam (Pasir)	10.205,08	9,98
4.	10F	Mangrove	4.673,42	4,57

With so many sandy beaches on the mainland, there is not much living mangrove vegetation. Mangrove vegetation really needs a substrate with a high organic content which is usually contained in a mud substrate. If we look at the percentage of mangroves in TNKpS, it is only 4.57%. The results of the interpretation are in table 1

Biodiversity

A. Mangroves

Based on observations, the condition of the mangroves in the 3 survey locations is still in good condition. The

Volume 05, Number 02, September 2022, Page 40-44
e-ISSN: 2615-3750 ; p-ISSN: 2615-3769

thickness of mangroves generally ranges from 50 - 100 m with the dominant mangrove species *Rhizophora* sp., *Sonneratia* sp., and *Avicennia* sp. According to Salminah et al. **[10]** these mangrove species can grow well on substrates that are always inundated with seawater. The dominant mangrove substrate is sand and sandy mud with several types of mangroves. The result of area calculation based on satellite image shows that the mangrove area in TNKpS is 31.41 Ha. The island with the largest mangrove area is Sebaru Besar Island with an area of 8.96 Ha. This area is native mangrove and not from transplantation. Areas with a large number of transplanted mangroves are found on Pulau Kelapa and Harapan. Mangrove transplantation is carried out by the community or from the Company's CSR program.

B. Seagrass

Satellite image results show that the seagrass area in TNKpS is 98.54 Ha. The area with the highest seagrass area is Pulau Bira Kecil with an area of 4.17 Ha. This location is indeed very ideal for seagrass growth where the location tends to be flat with a depth of 0.5-2 meters and the sand substrate is an ideal habitat for seagrass. TNKpS Balai has a history of continuous monitoring of mangrove ecosystems. This monitoring is carried out every 2 years. In 2021 TNKpS will carry out monitoring but the results have not yet been published. The most updated results are monitoring in 2019. The results of the 2019 monitoring show that the condition of the mangrove ecosystem in the study location tends to have low and very low cover. This condition is possible because some seagrass locations are used as boat mooring areas and construction of piers.

C. Coral Reef

Based on the distribution map of coral reefs as a result of the interpretation of Sentinel 2B satellite imagery, the location of reefs is evenly distributed in all areas of the Seribu Islands National Park. The area of coral reefs interpreted in satellite imagery is 3161.68 Ha. This area covers the entire National Park from Pramuka Island to Dua Island. In addition to interpretation via satellite imagery, data related to the percentage of coral cover in the TNKpS area were obtained from routine monitoring of the Seribu Islands National Park Office in 2019. The number of samples taken was 40 locations spread throughout the National Park area. The monitoring results showed that the live coral cover at these two depths had an average coral cover at a depth of 3-5 meters which was better than at a depth of 7-9 meters, which was in the range of 3.1– 67.68% with an average cover value of 37.8%

D. Marine Mammals

The observation time of marine mammals at the survey location is 24 hours, from 27 September to 29 September 2021 and the duration of observation is 8 hours / day (08.00 - 16.00 WIB). The encounter with cetaceans at the time of observation was dolphins in 1 location (117° 41' 43,561" East Longitude and 01° 1' 39.36" South Latitude) at 13.08 WIB on September 29, 2021. The behavioral patterns of dolphins observed at the time of observation at the survey site can be described as follows:

1. Spyhop, face facing the water surface. This movement serves to observe the surroundings because visibility above water is greater than underwater.
2. Logging, dolphins do nothing, half of their bodies appear above sea level. Based on the observation data above, it can be concluded that the type of dolphin is the bottlenose dolphin (Tursiops truncatus), which is often found in Indonesian waters. The observer team was unable to observe in more detail because the mammals were far from the boat and the encounter was short-lived.

E. Turtle

East Peteloran Island and Kayu Angin Bira Island are the islands with the most hawksbill nesting habitats in the TNKpS area. A total of 3,782 eggs were found on East Peteloran Island (49.64%) and 771 eggs on Kayu Angin Bira Island (10.12%) (Seribu Islands National Park Hall, 2018). These two islands are small uninhabited islands located in the core conservation zone of TNKpS. The management of this area is carried out by the Management Section of the National Park Region II Harapan Island. The egg-laying season according to Suharsono **[11]**, is from February to April. In addition to laying eggs, TNKpS is also one of the migration routes for sea turtles in the Java Sea.

Socio-Economic

A. Capture Fisheries

Capture fisheries in TNKpS are only found on 3 islands, namely Panggang Island, Harapan Island and Kelapa Island. The highest number of fishermen is on Kelapa Island with 895 fishermen, while the smallest is on Harapan Island, which is 344 people. In contrast to the largest number of fishermen on Kelapa Island, the highest number of boats was found on Panggang Island, which was 381 boats. This is because on Panggang Island there are many small ships with only 1-2 people operating each ship, while on Kelapa Island the ships are relatively larger with 3-4 people operating per ship. From the interview results, it is shown that many fishing fishermen are currently switching professions as tour guides so that their activities as fishermen are only a side livelihood. The most widely used fishing gear in the TNKpS area is fishing line, while the types of fishing gear that are often used are hand and simple hand line fishing rods, long line fishing rods (troll line) and pulled fishing rods (draglines) (Ardisastra et al. **[12]**). The number of fishing rods in all national park locations is 709 units.

B. Aquaculture

Marine aquaculture is one form of effort to increase fishery production because marine capture fisheries have been more caught. The waters of the Seribu Islands have developed aquaculture fisheries for seaweed, grouper and shellfish commodities. Based on the criteria for aquaculture activities in the form of geophysical physical conditions (protection, water depth, and seabed substrate), oceanographic (current speed) and water quality (brightness and salinity), the capacity of the Seribu Islands for the development of marine aquaculture covers an area of 904.17 ha, including 622.49 ha (66%) within the Seribu Islands National Park (BTNKpS, 2021)

Volume 05, Number 02, September 2022, Page 40-44
e-ISSN: 2615-3750 ; p-ISSN: 2615-3769

C. Port

Public ports are managed by port business entities, while special ports are usually managed by local governments **[13]**. The negative impacts that can be caused by oil spill pollution in the port area include the potential for fires that can be caused by oil spills. The results of image interpretation and field verification show that there are several ports/piers in TNKpS which managed by the local government such as ports on resident islands (Pramuka Island, Kelapa and Harapan) as well as ports/piers that are specifically managed by resorts or privately (Sepa Island, Putri Island, etc.).

D. Tourism

Tourist islands that have marine tourism potential are located on all islands in the Seribu Islands, but this discussion focuses on residential islands which are tourist destinations with the highest number of visitors, namely Untung Jawa Island, Pramuka Island, Tidung Island, and Harapan Island. Each island has almost uniform tourism potentials, but has differences due to different locations, the characteristics of the northern part of the Seribu Islands are much more natural because they are far from the bay of Jakarta. The potential of islands that have marine tourism potential makes this area a major tourist activity in the development of integrated tourism areas in the Seribu Islands. The study of the sensitivity of the tourism area to oil spills focuses on marine tourism which has a very significant impact if it is affected by an oil spill. Thick black oil material is something that interferes with tourist aesthetics and can pose a danger to tourist visitors, both physical hazards (possibility of fire) and contamination (B3 waste content). Information related to the mapping of marine tourism is obtained from the RZWP3K map of DKI Province for 2018-2038 where the information in it describes diving tourism as one part of tourism that is heavily affected by the oil spill.

E. Settlements

Of the 78 islands within the TNKpS area, of which 6 are residential areas and the rest are managed by individuals or business entities. Population settlements in the Seribu Islands region are classified as very dense with a density of 2,820/Km2 with only 6 inhabited islands, so the population density on these islands is getting higher. From the results of observations in the field, it shows that the residential areas in the Seribu Islands are classified as permanent settlements located some distance from the coast, while for settlements close to the coast the most are semi-permanent buildings made on stilts so that they are not affected by the tides. Settlements affected by oil spill pollution are settlements located on the coast or settlements jutting into the middle of the sea. This is because the potential associated with oil spill contamination will be dominant towards the beach so that houses on the beach have a great potential to be affected by oil spill contamination.

Environmental Sensitivity Index

The combination of environmental sensitivity from components of coastal type, biodiversity and socio-economics shows that the component of biodiversity is the most sensitive component compared to other components. The components of biodiversity that are most sensitive to the impact of oil pollution are turtle migration areas and turtle releases and reefs coral **[14]**. Where both of these are ecosystems protected by TNKpS. Besides being used as a protected area, coral reefs and turtles are also used for tourism at the study site. In addition to the biodiversity component, another component that is also very sensitive to oil contamination is the cultivation of floating net cages and tourism, especially diving tourism sites. The high sensitivity at the study site requires special handling in the event of an oil spill so that the oil spill response process does not cause damage to components that are sensitive to oil contamination. There needs to be good cooperation between stakeholders in dealing with oil spills, both from the government as a regulator or the private sector as industry players in areas bordering TNKpS.

Oil Spill Mitigation

Study sites that have a high sensitivity to oil contamination can be handled by several combinations of methods. The first method used is to localize an oil spill in the middle of the sea using an oil boom, then the localized oil is collected for later management on land. This method can only deal with 10% of oil spills, the rest can use absorbent as a solidifying agent to make it easier for oil contaminants to be moved. If there is still an oil spill, then the absorbent can be used to break down the oil molecules so that they can decompose naturally in the waters. This method must be taken immediately to prevent the oil spill into sensitive areas. The use of dispersants on sub-tidal coral reefs is not recommended, except where the oil will hit the mangrove forest or where the water depth exceeds 20 meters. The use of dispersants is recommended to prevent oil from hitting exposed coral reefs, provided that the application area is sufficiently spaced to allow for complete dispersion. Tides and currents are also needed in determining the distance. In addition, the application of dispersants is also not recommended in areas with a lot of aquaculture because the substances contained in the dispersants can poison the cultured fish or coral reefs that are directly exposed to the dispersant substances. For the on-site burning method, it is not recommended at the study location because the study location is an area which is crowded with shipping and fishing areas. Localization of identified sensitive areas must be carried out to prevent oil spills from entering the sensitive area. Localization can be done by extending the oil boom and directing the oil spill to a less sensitive area.

In addition to mitigating the mitigation of oil at sea, mitigation of oil spills that have entered the coast also needs to be considered. Security measures need to be taken if oil contamination reaches the coast so that people are protected from the potential for direct exposure or other potential such as fires. Handling oil on land must also have proper procedures such as trained collection personnel, wearing appropriate personal protective equipment so that waste collectors are not directly exposed to oil spills. The procedures that can be carried out for handling oil on the coast are as follows:

Volume 05, Number 02, September 2022, Page 40-44
e-ISSN: 2615-3750 ; p-ISSN: 2615-3769

1. Solid waste is placed in the beach area for further removal from the area, then processed, and disposed of.
2. Provision of temporary storage of oil-contaminated material will be in closed plastic bags, all separated along the waste localization area.
3. Waste that has accumulated at the temporary storage location will be separated by category, inventoried and transported out of the site for recycling or disposal by a B3 waste manager who has a permit from the Ministry of Environment and Forestry (KLHK).

Post-oil spill management is carried out if residual oil is considered unlikely to affect sensitive resources. What needs to be done is to ensure that all oil spill waste has been managed with the correct procedure and verified by the Ministry of Environment and Forestry. After the oil spill operation, an assessment is made of whether further cleaning actions will increase the environmental damage (Net Environmental Benefit). This activity will involve academics and professionals to get the value needed for advanced cleaning in sensitive areas. At the final stage of the oil spill mitigation activity, a compensation process is carried out for sensitive components damaged by the oil spill.

The modeling results show that after 3 hours the oil spill distribution has not yet reached the islands in the TNKpS area, after 5 hours the oil has reached Penjaliran Barat Island, while 24 hours if it is not handled it has the potential to pollute Penjaliran Barat Island, East Penjaliran, Pelelaran West, Pelelaran East and Corn Island. From the existing simulations, protection against sensitive areas should be carried out for < 3 hours when an oil spill occurs. With this simulation, oil and gas operators around TNKpS need to anticipate the existence of oil control exercises with a duration of < 3 hours to protect sensitive areas.

IV. CONCLUSION

Based on the results of the Environmental Sensitivity Index study, it can be concluded that the thematic map related to environmental sensitivity to oil spills in the Seribu Islands National Park shows that the type of beach is not sensitive to oil spills where the dominant beach type is sloping sand which is a substrate that is easy to clean when an oil spill occurs. While the component of biodiversity has the highest sensitivity. The most sensitive socio-economic components affected by the oil spill are fish farming and marine tourism (snorkeling and diving), both of which are the main livelihoods of the people in TNKpS, especially from the tourism sector. Mitigation of oil spills in TNKpS should focus on preventing oil spills before reaching sensitive areas where oil collection by skimmers and spraying of dispersants can be carried out before entering the coral reef area. The next step is the protection of sensitive areas from oil spills where this protection can be done by dispelling using an oil boom and directing the oil spill to a less sensitive area. The last step is cleaning the beach area according to the procedure

REFERENCES

[1] Sambali, H., Yulianda, F., Bengen, D. G., & Kamal, M. M. Institutional analysis of the "Kepulauan Seribu" National Marine Park Management. TT Analisis kelembagaan pengelola Taman Nasional Laut Kepulauan Seribu. *Jurnal Sosial Ekonomi Kelautan Dan Perikanan*, 9 (1), 105–113. 2014.

[2] Rochmady, R. Rehabilitasi Ekosistem Padang Lamun (Rehabilitation of Seagrass Ecosystems). *SSRN Electronic Journal*, July. 2018.

[3] Mckenzie, L., & Yoshida, R. (Seagrass-Watch: Proceedings of a Workshop for Monitoring Seagrass Habitats in Indonesia. *The Nature Conservancy, Coral Triangle Center*, Sanur, Bali, 9th May 2009, 56. 2009.

[4] Putra, I. E. *Analisis Indeks Kepekaan Lingkungan (IKL) Pesisir Pantai Timur Kabupaten* The analysis of Environmental Sensitivity Index in Jambi Province-East Tanjung Jabung Timur Coast towards Oil Spill Potency. Universitas Jambi, 1–15. 2017.

[5] IPIECA. *Sensitivity Mapping. Sensitivity Mapping in Visual Analysis*, 2012(1), 95–102. 2012.

[6] Sugiyono. *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Bandung: Alfabeta, CV. 2017.

[7] Gorelick, Noel, et al. Google Earth Engine: Planetary-scale Geospatial Analysis for Everyone. *Remote Sensing of Environment*. 202, 18-27. 2017.

[8] Utomo, Ayub Torry Satriyo. "Optimalisasi Pengelolaan dan Pemberdayaan Pulau-Pulau Terluar dalam Rangka Mempertahankan Keutuhan Negara Kesatuan Republik Indonesia". *Jurnal Dinamika Hukum*. 10 (3), 327-337. 2010.

[9] Yulius. Identifikasi Pulau-pulau di Kabupaten Lingga Provinsi Kepulauan Riau Berdasarkan Kaidah Toponimi. *E-Jurnal Ilmu dan Teknologi Kelautan Tropis*. 1 (2), 42-49. 2009.

[10] Salminah, M., Priatna, D. & Rochmayanto, Y. Arahan Strategi Restorasi Ekosistem Hutan Mangrove Sungai Lumpur. Di dalam: Priatna, D., Rochmayanto, Y., Ginoga, K.L., Muttaqin, M.Z., editors. *Strategi dan Teknik Restorasi Ekosistem Hutan Mangrove*. IPB Press. Hlm 80-94. 2021.

[11] Hadi, T. A., Abrar, M., Giyanto, Prayudha, B., Johan, O., Budiyanto, A., Dzumalek, A. R., Alifatri, L. O., Sulha, S., & Suharsono. *The Status Of Indonesian Coral Reefs* 2019.

[12] Ardisastra, A., Istiadi, Y. & Mansyur, U. Comparison of illegal unreported-unregulated fishing practices based on port type in Jakarta Bay. *Journal of Science Innovare*, 5(1): 23-29. 2022.

[13] National Oceanic and Atmospheric Administration (NOAA). *Environmental Sensitivity Index Guidelines*, Version 4.0. April. 2019.

[14] Nurjaya, I. W. Kajian Risiko Penangulangan Tumpahan Minyak: Studi Kasus Di Laut Jawa Bagian Barat. *Journal of Natural Resources and Environmental Management*, 9(3), 826–839.