International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

A Framework for Screening of Variables of Ecological Sensitivity Index (ESI) of Mangrove Ecosystems to Oil Spills

Muarif [a]*, Ario Damar[b], Sigid Hariyadi[c], Dewayani Sutrisno[d], Mennofatria Boer[e]

[a]*Student of Post Graduate School, Bogor Agricultural University, Dramaga, Bogor, Indonesia*

[b]*Centre for Coastal and Marine Resources Studies (PKSPL), Bogor Agricultural University*

[b,c,e]*Faculty of Fisheries and Marine Science, Bogor Agricultural University, Dramaga, Bogor, Indonesia*

[d]*Geospatial Information Agency/BIG, Jl. Raya Cibinong, Bogor, Indonesia*

[a]*Email: muarif2010@gmail.com*

[b]*Email: adamar@pksplipb.or.id*

[c]*Email: sigidh100@yahoo.com*

[d]*Email: dewayany@big.go.id*

[e]*Email: mboer@centrin.net.id*

Abstract

Mangrove is a coastal ecosystem that is vulnerable when it is exposed to oil spills. Cleaning up oil spills in mangrove ecosystems is very difficult and highly costly. Ecological sensitivity index (ESI) of mangrove ecosystem is an alternative tool to control oil spill by protecting highly sensitive areas from oil spill. One of the problems found in the development of ecological sensitivity index (ESI) of mangrove ecosystem is large numbers of variables of ecological sensitivity. Screening methods of variables can reduce the numbers of variables and result in the key variables of ecological sensitivity index (ESI) of mangrove ecosystems to oil spill.

---

* Corresponding author.

The variables screening includes four steps (selecting variables, screening variables, clustering variables, and reducing variables), and six methods to analyze variables (literature study, expert survey, correlation analysis, variable grouping, PCA, and BEST analysis).

Keywords: screening of variables; ecological sensitivity index (ESI); mangrove ecosystems; oil spill**.**

1. Introduction

Mangrove is a coastal ecosystem that is vulnerable when it is exposed to oil spills. Oil spill can cause death to mangrove and aquatic biota that live in mangrove habitat. The damage of mangrove ecosystem means the destruction of habitat and all the ecological functions and life support systems that exist in the mangrove areas [1].

Cleaning up oilspill in mangrove ecosystems is very difficult. The difficulty of eliminating oil spill in the mangrove ecosystem is caused by the facts that: (a) mangrove ecosystems are difficult to access [2] Hoff, 2002), (b) mud substrate makes oil trapped in mangrove ecosystem and this trapped oil is difficult to clean [3,4], (c) dispersants increase the toxicity to the biota that live in the mangrove and coastal communities around mangrove areas [5,6], and (d) cleaning up the oil on the beach is highly costly [3].

The difficulty in handling oil spill in mangrove ecosystem indicated the importance of efforts to avoid oil spills from entering into mangrove ecosystem. The preventive efforts can be done through detection sensitivity level of each mangrove zone to the oil spill so that the sensitivity zones are given priority to protected from oil spills.

The tool that can be used to evaluate the sensitivity zone of mangrove ecosystem is the ecological sensitivity index (ESI) of mangrove ecosystems to oil spills. The application of mangrove ecosystems ESI will not only give positif effects on ecological value of coastal area, but it also brings benefits to the economic value of coastal area. Ecologically, mangrove ecosystem has a functional relationship with other coastal ecosystems, such as seagrass, coral reefs, estuaries, and marine ecosystems, thus the protecting mangrove ecosystem from oil spills will guarantee the sustainability of other coastal ecosystems. Mangrove ecosystem also holds the economic and social functions that are important to coastal human communities, such as the economic value of timber, the economic value of fauna, protected settlement from waves and tsunamis, and other functions; thus avoiding mangrove ecosystem from oil spill will also support the well-being of coastal human communities.

One of the problems found in building the ecological sensitivity index (ESI) of mangrove ecosystems to oil spills is a large number of variables. Review of literatures has resulted in 26 variables determining the environmental sensitivity index (ESI) of mangrove ecosystems to oil spills (Table 1). Large number of variables is not practical because it needs long research, it needs very expensive research cost, it potentially creates overlaping between variables, and it makes it difficult to make decision. The best index has simple variables [7].

Screening of variables is an alternative method to simplify variables of ecological sensitivity index (ESI) of mangrove ecosystems to oil spills. This paper intends to provide an overview of variables ecological sensitivity of mangrove ecosystem to oil spills and methods to screen these variables, to obtain the small number of key

variables but represents the all environmental characteristics of sensitivity variables of the mangrove ecosystem.

The Constrains of the study are development of framework for Screening of Variables. The framework presented is designed to be a guide for practice, and consists of a series of steps for screening variables of ecological sensitivity index (ESI) of mangrove ecosystems to oil spills.

2. The Best Criteria of Variables of Mangrove Ecosystem ESI

An oil spill would cause a disruption to the mangrove ecosystem. Heavy or light impact of oil spills depends on the sensitivity of the mangrove ecosystem to oil spills. Sensitive or insensitive of mangrove ecosystems to oil spills can be measured by an index. Ecological sensitivity index (ESI) of mangrove ecosystems to oil spills is an approach that aims to describe the environmental response of mangrove ecosystems to oil spills. The responses are very sensitive, sensitive, moderate sensitive, low sensitive, or not sensitive to the oil spill. The index must be able to represent and describe correctly the mangrove ecological sensitivity to the oil spill in a mangrove area. The ecosystem has complex and unpredictable characteristics [8], so the suites of index variables has to describe all characteristics of ecosyatem.

The precision of an index to describe the condition of ecosystem is determined by the accuracy in selecting variables. The relevant variables would guarantee an accuracy of assessing the mangrove ecological sensitivity. The basic criteria to determine the variables of mangrove ecosystem ESI are criteria of best index variables. There are four criteria to determine the best variables of mangrove ecosystem ESI as follows.

1. The variables are objective [9]

2. The variables are measurable [10]

3. No overlap between variables [11]

4. The index variables are simple but able to present the complexity of ecosystem [7]

The first criterion of best variable is objectivity variable. The Variables that objective must be choice by objective reason, such as scientific reason. The second criterion of best variable is the variables of mangrove ecosystem ESI must be measured. This means, all variables had the methods of measurement for data variables. The third criterion of best variable is the variable does not overlap with other variables. The overlaping between variables shows the tendency of the variables hav a correlation. The fourth criterion of best variable is the simple index. The simple index was formed by a small number of variable but able to present the complexity of the characteristics of the mangrove ecosystem sensitivity to oil spills.

3. The Concept of Screening Variables for Developing Mangrove Ecosystem ESI

The goal of screening variables is to get the key variables of mangrove ecosystem ESI to oil spills. The key variables must be simple, consist of small number of variables but they are able to present the complexity of the

characteristics of the mangrove ecosystem sensitivity to oil spills. The key variables must also suit to the best criteria, such as objective, measurable, not overlapping, and simple, of variables of mangrove ecosystem ESI to oil spills. Stages to select and screen variables are needed to develop the key variables. The framework for screening variables includes some steps that are based on the best criteria of the variable of mangrove ecosystem ESI to the oil spills.

To create key variables with best criteria, variables must be selected to result in objective variables, variables must be screened to remove overlapping variables, variables must be clustered and reduced to create simple variables of the index. Therefore, there are four steps to screen variables including selecting variables, screening variables, clustering variables, and reducing variables.

The method for screening must result in variables that can be scientifically justified and simple, easy to apply, and accurate for sensitivity mangrove ecosystem. The method should also be able to reduce number of variables to create simple assessment index. Moreover, to result in good key variables, screening methods, both qualitatively and quantitatively, are needed. The recommended methods are study of literature, expert survey, grouping of variables, correlation analysis, and BEST analysis. The steps for screening variables combine the qualitative (study of literature and expert judgment) and quantitative methods (correlation analysis and BEST analysis). Researches by combining qualitative and quantitative methods were done by [12] to analyze ecological vulnerability in wildlife and [11] to study group processes.

Figure 1 describes the concept of screening variables for developing mangrove ecosystem ESI to the oil spills. This figure declares the steps of screening variables and combining methods to result in key variables of mangrove ecosystem ESI to oil spills. Detail discussion of each step of variables screening is elaborated in the following section.

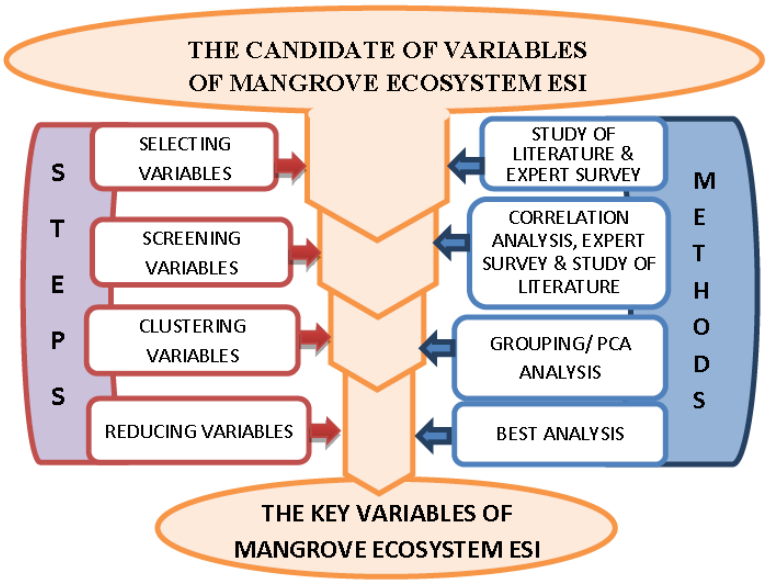

Figure 1: The concept of screening variables for developing mangrove ecosystem ESI to oil spills

4. The Steps for Screening Variables of Mangrove Ecosystem ESI

4.1 Selecting Variables

Selecting variables is an activity to collect any variables that can be categorized as variables of mangrove ESI to oil spills. Selecting variables is a step to result in true variables of mangrove ecosystem ESI to oil spills. A variable is considered as a true variable of mangrove ecosystem ESI to oil spills if it can be shown that the variable is scientifically correct to determine the mangrove ecosystem sensitivity to oil spills. In other words, the variables obtained in the step of selecting variables must be objective.

Variables of mangrove ecosystem ESI are objective if they are selected based good reasons so that they are relevant as variables of ecological sensitivity of mangrove ecosystem. The relevance can be seen from the relationship of the variables with mangrove sensitivity to oil spills. This means that the determination of variables must be supported by a strong scientific adjustment. Study of literature is a depth study method to gain a strong scientific adjustment of mangrove ecological sensitivity and oil spill effects. The object of literature study include text books, journals, and research papers [13]. The literature studies resulted in 26 variables that determine to mangrove ecosystems ESI to oil spills (Table 1).

The objectivity of variables will be stronger when they are supported by expert judgment. Expert judgment can be collected through expert surveys (direct or by email). Direct expert survey is more effective than email expert survey. Most questionnaires are returned when expert surveys are conducted directly, but only small number of them are returned in surveys done by emails. Furthermore, expert survey by email needs high number of experts.

The important factor of expert survey is expert choice. The expert is a person who has a background knowledge in the research subject [30]. Knowledge and experience of experts determine the quality of judgment. The suitable experts of this research are the experts of mangrove, environment, oil pollution, oceanography, marine biology, and coastal management. The variables of mangrove ecosystem ESI (Table 1) are supported by 10 experts from 6 countries including Indonesia (3), USA, Brazil, Australia, New Zealand, Sri Lanka, and India (2).

The literature study and exepert surveys result in the true variables of mangrove ecosystem ESI to oil spills as the methods derive all variables which are valid scientifically. The scientific validity of an index has been set as a condition for a good index by [10]. So, the 26 variables of mangrove ecosystem ESI are objective, scientific, and accurate.

4.2 Screening Variables

The variables resulted from the step of selecting variables are valid scientifically, but there may be any conflicts among variables (overlapping variables). The goal of screening variables is to remove overlapping variables. The overlapping between variables showed a tendency of variables to be correlated one to another. The correlation does imply causation [31].

Table 1: Variables of mangrove ecosystem ESI to oilspill

No	Variable	Literature
1	Tidal Type	[6] [14] [15]
2	Tidal Range	[5]
3	Wave Height	[5] [6] [16]
4	Rainfall	[17]
5	The number of rainy days	[17]
6	Type of Substrate	[18]
7	Long time waterlogging	[6]
8	Typology of mangrove	[17]
9	Kind of mangrove flora	[19]
10	The number of mangrove flora kind	[20]
11	Conditions of mangrove ecosystems	[21]
12	Age of mangrove flora	[2] [22].[23]
13	The density of mangrove trees	[4] [6]
14	The density of the mangrove saplings	[2] [22] [23]
15	The density of mangrove seedlings	[2] [22] [23]
16	Comparison of density of sapling and mangrove trees	[2] [22] 23]
17	The presence of protected mangrove flora	[24]
18	The presence of invasive flora	[25]
19	Kind of mangrove fauna	[3] [26] [19]
20	Position of mangrove fauna	[19] [27] [28]
21	Motion ability of mangrove fauna	[3] [19]
22	Age of mangrove fauna	[3]
23	The presence of a protected mangrove fauna	[24]
24	The existence of nursery habitat	[5]
25	The existence of spawning ground	[5]
26	Protection status of mangrove ecosystems	[29]

The high degree of correlation of variables would give negative effects on index. When predictor variables are correlated, the estimated index of one variable depends on the other predictor variables. This would affect the index model. The high degree of correlation among variables is not a good prediction of the response of the index model. This means that the index does not represent actual conditions.

The existence of overlapping between variables can be analyzed by using correlation methods. The correlation analysis is useful for measuring the strength of the relationship between two or more variables with a scale. The

strength of the relationship between variables is reflected by the correlation coefficient (r). The correlation coefficient of this research refers to the *Spearman's rank correlation coefficient*, because the data are non parametrics.

The *Correlation coefficient* (r) measures the strength and the direction of a linear relationship between two variables. The value of r is $-1 \leq r \leq +1$. If there is no linear correlation or a weak linear correlation, r is close to 0. A value near zero means that there is a random, nonlinear relationship between the two variables. So, strong relationship is reflected by the value of r close to -1 or 1, and weak correlation is reflected by the value of r close to 0 [32]. A positive correlation coefficient indicates the extent to which those variables increase or decrease in parallel; a negative correlation coefficient indicates the extent to which one variable increases as the other decreases.

The analysis of overlapping variables measures a correlation between variables using Spearman's rank correlation coefficient. Variables with high degree correlation will be selected, one variable will be chosen as a variable index and the others will be removed. The process to remove independent variables causing the correlation must be done carefully, because it can lead to bias specification if the removed variable is theoretically important. Therefore, the basis used for the selection of correlated variables (choosing or removing variables) is a scientific rationale based on the study of literature and expert surveys.

In this study, 5 pairs of variabels have high degree Spearmans rank correlations. The selected correlation variables by rank variables (expert survey) resulted in 4 variabels being removed. The removed variables are long waterlogging conditions of mangrove ecosystems, comparison of density of seedlings, sapling and mangrove trees, and motion ability of mangrove fauna. As the final result of this step, 22 variables of mangrove ecosystem ESI are compiled.

4.3 Clustering Variables

Clustering variables is a step done to group variables. In this step, variables are clustered into several groups. Variables can be clustered by Principal Component Analysis (PCA) or qualitatively clustered based on similar characteristics of variables. Principal Component Analysis (PCA) is a statistical method that is well used to reduce the dimension of large variables of data cluster to get a smaller group but able to retain most of the information contained in the data source [33]. In the process, Principal Component Analysis, at first, looks for an index that shows the maximum variety of observations called the first principal component. Then PCA will seek second principal components that are not correlated with the first principal component. This process continues until the primary component obtained top, where the information can be explained less. So, the principal component analysis (PCA) does not reduce but groups variables. Thus, the principal component analysis (PCA) is more precisely used to process grouping variables into the new variables. One of the advantages obtained by the use of the principal component analysis (PCA) is a new group of variables which is not correlated (no overlapping between groups of variables).

Variables also can be clustered in a group of variables with similar characteristics. The resulted groups must be

scientifically justified. Of course, the basis of clustering is a scientific rationale. Assessment of characteristics of variables can be done by the study of literature. Variables with similar characteristics can be scientifically clustered to a group of variables.

Table 2: Group of Variables of Mangrove Ecosystems ESI

No	Group of Variables	Variables
1	The environment of mangrove ecosystem	a. Tidal Type b. Tidal Range c. Long time waterlogging d. Wave Height e. Rainfall e. The number of rainy days f. Type of Substrate g. Typology of mangrove
2	Characteristics of mangrove flora	a. Kind of mangrove flora b. Age of mangrove flora c.The presence of invasive flora
3	Characteristics of mangrove vegetation	a. The density of mangrove trees b. The density of the mangrove saplings c. The density of mangrove seedlings d. Comparison of density of seedlings, sapling and mangrove trees
4	Ecological value of mangrove ecosystems	a. The number of mangrove flora species b. Conditions of mangrove ecosystems c. The existence of nursery habitat d. The presence of spawning ground
5	Characteristics of mangrove fauna and their habitat	a. Kind of mangrove fauna b. Position of mangrove fauna c. Motion ability of mangrove fauna d. Age of mangrove fauna
6	Aspects of mangrove ecosystem protection	a. The presence of protected mangrove flora b. The presence of a protected mangrove fauna c. Protection status of mangrove ecosystems

Table 2 explains grouping variables of mangrove ESI based on similar characteristics. The 26 variables of mangrove ESI (see Table 1) are grouped into 8 group of variables. The groups of variables include external environment of mangrove, internal environment of mangrove, characteristics of mangrove flora, characteristics of mangrove vegetation, characteristics of mangrove ecosystems, characteristics of mangrove fauna, ecological functions of mangrove, and aspects of mangrove ecosystem protection.

The result of step 3 (clustering variables) is the groups of variables which are in accordance with the criteria objective, measurable, and not overlapping. The groups of variables will be use as criteria to select combination of variables resulted from BEST analysis (Section 4.4).

4.4 Reducing Variables

In the screening variable step, 4 variables are removed and 22 variables of mangrove ecosystem ESI are compiled. However, the number of variables is still high, so that it needs to be reduced to generate more simple variables. Definition of simple index variables is that the index is formed by a variable but is able to present the complexity of sensitivity characteristics of the mangrove ecosystem to oil spills. The simplifying number of variables needs a process to reduce variables.

The multivariate methods that can be used to reduce the variables is BEST (Biological - Environmental Stepwise) analysis. BEST analysis is chosen to reduce variables of ecosystem mangrove ESI to oil spill because:

1. Variables of mangrove ecosystem ESI consist of biological and environmental variables and this is in accordance with the specification method of BEST analyses.

2. BEST Method will directly reduce the number of variables that are still the same as the original variable (not a new variable combination of variable origin), so it is more practical.

The BEST method is usually used to examine the relationship between biological variables similarity matrix and environmental variables. BEST analysis can also reduce the number of biological and environmental variables. The variables are representative if a matching coefficient ρ is minimal 0.95 [34].

BEST method presents several alternative combinations of variables. Several alternative combinations of the variables can be selected a variable combination with a little number of variables and coefficients ρ minimum of 0.95. The selected combination of variables is the combination that has coefficients ρ minimum of 0.95 and includes all groups of variabel characteristics, or the combination that has coefficients ρ minimum of 0.95 and does not include all group variabels, but the result of wilcoxon test is not different from that of the combination all group variables ($P<0.05$).

The reduced number of variables is the final step of screening variables. The result of this step is a simple variable index which is objective, measurable, and not overlapping. Moreover, there are some key variables of mangrove ecosystem ESI to the oil spill. In this study, the secondary data of any Indonesian mangrove surveys (24 resort in Indonesia) are analyzed by using BEST methods and the number of variables is reduced from 26

(Table 1) to 8 variables (substrate, spesies of mangrove flora, The number of mangrove species, The density of mangrove trees, The density of the mangrove saplings, the density of the mangrove sadlings, Position of mangrove fauna, and the presence of a protected mangrove fauna), Position of mangrove fauna, and they are the key variables of mangrove ecosystem ESI. It is proven that the framework of screening and reducing can produce key variables of ecological sensitivity index (ESI) of mangrove ecosystem.

5. Conclusion

Screening of variables of ecological sensitivity index (ESI) of mangrove ecosystem includes four steps based on the criteria of the best index variable (objectivity analysis, measurable analysis, overlapping analysis and simplifying analysis). The steps to screening variables to result in key variables of mangrove ecosystem ESI to oil spills include selecting variables, screening variables, clustering variables, and reducing variables. The methods that are recommended to analysis variables are literature study, expert survey, correlation analysis, grouping variables, , and BEST analysis.

Acknowledgements

The authors thank Prof. DG Bengen, Prof. C Kusmana, Dr. N Santoso (IPB, Indonesia), Dr.RA Feagin (Texas A&M University), Prof JC Wasserman (UFF, Brazil), P. Vermeiren, PhD (James Cook University, Australia), Dr. L Schwendenmann (University of Auckland, New Zealand), Prof. K Kathiresan (Annamalai University, India), Dr. S Arockiaraj (ICMAM-PD, India) and Prof LP Jayatissa (University of Ruhuna, Sri Lanka) for a good reason and answering to research questionnaire.

References

[1]. S. Soemodihardjo and Soeroyo. Dampak Pencemaran Terhadap Komunitas Mangrove. Seminar Pemantauan Pencemaran Laut, 7-9 Pebruari 1994. Pusat Penelitian dan Pengembangan Oseanologi-LIPI, Jakarta. pp: 92-98. 1994.

[2]. R. Hoff, P. Hensel, E.C. Proffitt, P. Delgado, G. Shigenaka, R. Yender. Oil Spill in Mangrove, Planning and Response Considerations. Washington (US): NOAA Ocean Service, Office of Response and Restoration. 2002. 70pp.

[3]. M. Fingas. The Basic of Oil Spill Cleanup. 2nd ed. Washington DC (US): Lewis Publishers. 2001. 230pp.

[4]. P.W.M. Souza, F.D. Goncalves, S.W.P. Rodrigues, F.R. Costa, and F.P. Miranda. Multisensor data fusion for geomorphological and environmental sensitivity index mapping in the Amazonian Mangrove Coast, Brazil. Journal of Coastal Research, SI 56 Proceedings of 10th International Coastal Symposium, Lisbon Portugal. pp:1592-1596, 2009.

[5]. E.C. Peters, N.J. Gassman, J.C. Firman, R.H. Richmond, and E.A. Power. Ecotoxicology of Tropical Marine Ecosystems. Environmental Toxicology and Chemistry, Vol. 16, No. 1, pp. 12–40, 1997.

[6]. J. Petersen, J. Michel, S. Zengel, M. White, C. Lord, C. Plank. Environmental Sensitivity Index Guidelines Version 3.0. National Oceanic and Atmospheric Administration (NOOA), U.S. Department

of Commerce. Seattle, Washington. . 2002. 192pp.

[7]. V.H. Dale, S.C. Beyeler. Challenges in the Development and Use of Ecological Indicators. Ecological Indicators 1 (2001) 3–10. 2001.

[8]. J.C. Rice and M.J. Rochet. A Framework for Selecting a Suite of Indicators for Fisheries Management. Journal of Marine Science, 62: 516-527. 2005.

[9]. J. Hilty and A.Merenlender Faunal Indicator Taxa Selection for Monitoring Ecosystem Health. Biological Conservation 92 (2000): 185-197. 2000.

[10]. A. Donnelly, M. Jones, T. O'Mahony, G. Byrne. Selecting Environmental Indicator for Use in Strategic Environmental Assessment. Environmen-tal Impact Assessment Review 27 (2007): 161–175. 2007.

[11]. S.C. Curral, T.H. Hammer, L.S. Beggett, G.M. Doniger. Combining Qualitative and Quantitative Methodologies to Study Group Processes: An Illustrative Study of a Corporate Board of Directors. Organizational Research Methods, Vol 2 No 1,: 5-36. January 1999.

[12]. H.J. De Lange, J. Lahr, J.J.C. Van Der Pol, Y. Wessels, J.H. Faber. Ecological Vulnerability in Wildlife: An Expert Judgment and Multicriteria Analysis Tool Using Ecological Traits To Assess Relative Impact of Pollutants. Environmental Toxicology and Chemistry, Vol. 28, No. 10, Pp. 2233–2240. 2009.

[13]. J.A. Onwuegbuzie, N.L. Leech, and K.M.T. Collins. Qualitative Analysis Techniques for the Review of the Literature. The Qualitative Report, 17 (56). pp:1-28. 2012.

[14]. B.Brown. Resilience Thinking Applied to the Mangroves of Indonesia. Yogyakarta (ID): IUCN & Mangrove Action Project. 2007. 52 pp.

[15]. K.A. Burns, S. Codia, C. Pratta, N.C. Duke. Weathering of Hydrocarbons in Mangrove Sediments: Testing the Effects of Using Dispersants to Treat Oil Spills. J. Organic Geochemistry 30. 1273-1286. 1999.

[16]. J.A. Oyedepo and C.O. Adeofun. Environmental Sensitivity Index Mapping of Lagos Shorelines. Global NEST Journal, Vol 13, No 3, pp 277-287, 2011.

[17]. [IPIECA] International Petroleum Industry Environmental Conservation Association. Biological Impacts of Oil Pollution: Mangroves. IPIECA Report Series Volume Four. London (UK): International Petroleum Industry Environmental Conservation Association. 1993. 20pp.

[18]. H. Ali, Poerbandono, K.Wikantika. Penentuan Indeks Kerentanan Lingkungan Pantai berbasis Geospasial dan Parameter Fisik (Studi Kasus : Tumpahan Minyak di Kepulauan Seribu, Teluk Jakarta). PIT MAPIN XVII, Bandung. 196-207. 10-12-2008.

[19]. N.C. Duke, K.A. Burn. Fate and Effects of Oil and Dispersed Oil on Mangrove Ecosystems in Australia. Australian (AU): Australian Institute of Marine Science and CRC Reef Research Centre. 1999. Pp: 233-247.

[20]. Faperikan IPB. Studi Pemetaan Indeks Kepekaan Lingkungan Wilayah Pesisir Indramayu dan Subang Jawa Barat Berkaitan dengan Dampak Kegiatan Pertamina. Bogor (ID): Kejasama Pertamina dengan Fakultas Perikanan IPB. 1995.

[21]. S.D. Garrity, S.C. Levings and K.A. Burns. The Galeta Oil Spill. Long-term Effects onthe Physical Structure of the Mangrove Fringe. Estuarine, Coastal and Shelf Science. 1994, 38:4, Florida. P: 327-348. 1994.

[22]. Q. Lin and I.A. Mendelsson. A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish and salt marshes. Marine Pollution Bulletin, 32 (2), 202–209. February 1996.

[23]. R.B. Clark. Marine Pollution. Oxford (UK): Claredon Press. 1986. 215 pp.

[24]. T. Messmer, R. Drake, and A. McElrone. Endangered and Threatened Animals of Utah. Logan (US): Berryman Institute Publication No. 17, Utah State University. 1998. 60 pp.

[25]. Ministry of Water, Land and Air Protection. Environmental Best Management Practices for Urban and Rural Land Development; Environmentally Sensitive Areas (Section Five). British Columbia: Ministry of Water, Land and Air Protection. 2004. pp:5-9.

[26]. G.A. Kolyuchkina, N.A. Belyaev, V.A. Spiridonov, U.V. Simakova. Long-term Effects of Kerch Strait Residual Oil-Spill: Hydrocarbon Concentration in Bottom Sediments and Biomarkers in Mytilus galloprovincialis (Lamarck, 1819). Turkish Journal of Fisheries and Aquatic Sciences 12: 461-469. 2012.

[27]. J.Culbertson, I.Valiela, E.Peacock,, C.Reddy, A. Carter, R.VanderKruik, Long-term effects of petroleum residues on fiddler crabs in salt marshes. Marine Pollution Bulletin 54, 955-962. 2007.

[28]. F.Melville, L.E.Anderson, and D.F. Jolley,. The Gladstone (Australia) oil spill – Impacts on intertidal areas: Baseline and six months post-spill. Marine Pollution Bulletin 58, 263-267. 2009.

[29]. [IPIECA/IMO/OGP] International Petroleum Industry Environmental Conservation Association/International Maritime Organisation/International Association of Oil and Gas Producers. Sensitivity Mapping for Oil Spill Response. London (UK): The Global Oil and Gas Industri Association for Environmental and Social Issues, International Maritime Organization, International Association of Oil & Gas Producers. 2012. 33pp.

[30]. M.A. Meyer and J.M. Booker. Eliciting and Analizing Expert Judgment: A Practical Guide. Philadelphia (US): The American Statistical Association and Society for Industrial and Applied Mathematics. 2001. 459pp.

[31]. B. Shipley. Cause and correlation in biology: a user's guide to path analysis, structural equations and causal inference. Cambridge (UK). Cambridge University Press. 2000. Pp:3.

[32]. R.G.D. Steel, J.H. Torrie. Principles and procedures of statistics a biometrical approach. New York (US): McGraw-Hill. 1980. 481pp.

[33]. A.A. Mattjik and I.M. Sumertajaya. Sidik Peubah Ganda dengan Menggunakan SAS. Bogor (ID): Departemen Statistika FMIPA IPB. 2011. 413pp.

[34]. K.R. Clarke, P.J. Somerfield, R.N. Gorley, Testing of Null hypotheses in Exploratory Community Analyses: Similitary Profiles and Biota-environment Linkage. J Exp Mar Biol Ecol 366:56-69. 2008.