Online ISSN: 2588-3526

Journal of Wildlife and Biodiversity

Volume 5 (1): 63-80 (2021) (http://www.wildlife-biodiversity.com/)

Research Article

Geospatial Analyzing of Straits Shipping Paths for Integration of Air Quality and Marine Wildlife Conservation

Mehrdad Hadipour[1*], Morteza Naderi[2], Mazlin Mokhtar[3], Lee Khai Ern[3]

[1] Department of Environment, Faculty of Biological Science, Kharazmi University, Iran

[2] Department of Environmental Sciences, Faculty of Agriculture and Natural Sciences, Arak University, Arak 38156-8-8349, Iran

[3] Institute for Environment and Development (LESTARI), National University Malaysia (UKM), Bangi, 43600 Selangor, Malaysia

*Email: mhadipour50@yahoo.com

Received: 5 Septembert 2020 / Revised: 3 November 2020 / Accepted: 14 November 2020 / Published online: 14 November 2020. Ministry of Sciences, Research and Technology, Arak University, Iran.

How to cite: Hadipour M, Naderi M, Mokhtar M, Khai L. (2021). Geospatial Analyzing of Straits Shipping Paths for Integration of Air Quality and Marine Wildlife Conservation, 5(1), 63-80. https://doi.org/10.22120/jwb.2020.135939.1184

Abstract

This paper develops a GIS-based model to determine suitable locations for shipping paths within Malacca Strait by investigating the best air quality. The mathematical and geospatial approach is used to identify a reasonable relationship between air quality and Dugong's habitat location. Various factors with different levels of influence and degrees of importance were established as criteria. The chosen region of study, Malacca Strait, the world's second-busiest commercial shipping channel, undertakes several statistical and mathematical analyses of vessel transportation that focus on air quality concerning the main marine animal of Strait (Dugong), using the geographic information system (GIS) as a visualization platform. The distance from the maritime paths to the dugong home range is modeled based on NOx's factor as the primary air pollutant of shipping emissions from moving vessels in the sea. The results took into consideration the main negative environmental elements in shipping paths. The minimum calculated distance serves as a constraint to indicate where the dugongs' habitats cannot be located. The result is that too many parts of the probability of suitable Dugong habitat in the study area do not have a proper position that does not put it in conflict with shipping polluted zones. This research has successfully managed and developed a scientifically based method for understanding the relationship between wide life habitat and marine transportation by analyzing successful and non-successful present and future shipping.

Keywords: GIS-based modeling; Malacca Strait; Dugong

Introduction

Straits as the maritime transportation corridors are among the essential types within the context of environmental issues. Because the contribution of Straits maritime transport to air pollution is too crucial for the sustainability of the debate in the transport sector (Miola & Ciuffo, 2011), an effective environmental strategy for straights humans and marine biodiversity is necessary. This policy strategy can regulate air emissions where straights are located.

Many researchers have considered the environmental impacts of air pollution created by vessels to be one of the most significant environmental elements. Saxe and Larsen (2004) applied an operational meteorological air quality model (OML) to calculate air pollutants' dispersion emitted by vessels in 3 ports. Emissions impacts of NO_x and particulate matter on human health have been investigated in this research. Matthias et al. (2010) used a regional chemistry transport model to investigate the annual pollution emissions impact of ships in the North Sea's coastal areas. They found that ships' emissions significantly increase air pollution due to secondary inorganic aerosols in the study area.

Miola and Ciuffo (2011) evaluated the geographic characterization of pollutants emissions utilizing the classification of primary methodologies based on the approach used (bottom-up or top-down). These studies also lack a strong focus on the Strait environment. The main environmental impacts of vessel air pollution in the straight are focused on marine biodiversity. The model is developed so that the main element is the optimum distance of the shipping path from the seaside to prevent air pollution-related air pollution-related to shipping in proximity to the habitat.

The chosen region of study, Malacca Strait, the world's second-busiest commercial shipping channel, runs through Thailand's territorial waters. To minimize threats to dugongs and seagrass in this region, Thailand, Indonesia, Singapore and Malaysia should work together regarding its management. The Malacca Strait has the following characteristics that align with the developed model and environmental factors. Today, Malacca Strait (with approximately 600 vessels using it each day) is the world's second-busiest commercial seaway (MDM, 2015).

Fifty years ago, this Strait was abundant in seagrass, which probably supported a substantial Dugong population (Solvay et al., 2008). The Dugong is primarily a marine mammal that inhabits typically shallow waters, remaining at depths of around 10 m, although Dugongs occasionally dive to depths of 39 m to feed. Conservation Union (Marsh & Sobtzick, 2015) has listed the World Dugong species as vulnerable to extinction globally. Their primary source of nourishment and optimal habitats are Seagrass beds consisting of phanerogamous seagrasses. Dugongs are also observed in deeper water where the continental shelf is broad, sheltered, and neritic. Different activities use different habitats; for example, their potential areas suitable for calving are tidal sandbanks and estuaries (relatively shallow).

Dugongs are primary consumers and the only entirely herbivorous marine mammals. They consume seagrass, particularly of the families Potamogetonaceae and Hydrocharitaceae in the genera Halophila and Halodule. They also have a low metabolism. When seagrass is scarce, dugongs also eat marine algae. They are speculated to supplement their diet with invertebrates such as polychaete worms, shellfish, and sea squirts, which live in seagrasses. They require a territory with 0.4 ha of seagrass (Lawler et al., 2002, Marsh et al., 2002).

Maritime transportation is too essential for several purposes of militaries, commercial and industrial organizations. This importance has resulted in restricted access to commercial seaways and ports. Despite access importance to commercial marine areas and ports, there has not been sufficient research focus on this issue, and there is only indirect studies by a few researchers during the marine or coastal researches. As the number of vessels in maritime transportation increases, their environmental impacts also increase. As mentioned earlier about the Malacca strait, average of 30 shipping accidents occur each year on this Strait. These accidents kill or injure Slow-moving Dugongs and force their feeding areas. Pollution from passing ships destroys seagrass beds, and Dugongs are often found trapped or dead in fishers' nets (Solvay et al., 2008).

This paper tries to develop a GIS-based model to analyze suitable locations for shipping paths within Malacca Strait by investigating the best air quality for comprehensive life habitat conservation. Mathematical and geospatial approaches are used to identify a reasonable relationship between air quality and the location of the Dugong's habitat.

Material and methods

Species Conservation Programs

There is no management plan for dugong populations in Malaysia (Marsh, 2002). Marsh (2002) emphasizes that for the conservation of the species, Malaysian authorities should work in cooperation with Thai, Indonesian and Singaporean rules to protect dugongs, especially in the Strait of Malacca. Briscoe et al. (2014) showed that distance from the coast is the highest contributing variable to the probability of Dugong's presence in Sabah, Malaysia. They resulted that there are several areas of high risk where Dugong uses the habitat. In habitat modeling by MaxEnt model, Briscoe et al. (2014) used geophysical parameters, including coastal distance, depth, insolation, and topographic openness. Defining the overlap between critical habitats and fisheries threats has been one of the most essential marine conservation research (Lefebvre et al. 2000). While dugongs frequently occur in shallow coastal waters, they have also been observed in deeper waters further offshore, where the continental shelf is vast and remains relatively shallow and protected (Adulyanukosol et al., 2007). Although they are seagrass specialists, dugongs have been shown to prefer some seagrass beds and avoid others, presumably making foraging decisions at a range of spatial scales (Anderson, 1997). For this reason, understanding the spatial dynamics of foraging habitat is essential for predicting patterns of use by selectively feeding dugongs and for the effective management of seagrass resources.

Dugongs breeding cycle

Dugongs (*Dugong dugon*) are a long-lived species with a low reproductive rate. Their limited reproductive potential has been identified as a significant contributing factor to the vulnerability of populations (Heinsohn et al., 2004). Furthering our knowledge on Dugong reproductive biology throughout their tropical–subtropical range has been highlighted as a priority for effective management and conservation of dugong populations (Marsh, 2002). However, some investigators believe that this species breed year-round, but other studies proved that fecal testosterone in mature males has been significantly higher in September-November, especially in equatorial habitats like Malaysia (Burgess et al., 2012). Therefore, this period can be considered as the special Dugongs breeding season.

Research Approach

This research undertakes several mathematical and statistical analyses of vessel transportation that focus on air quality related to the main marine animal of Strait (Dugong), using a visualization platform (GIS). The distance from the maritime paths to the dugong home range is calculated based on shipping emissions (Escourroug, 1996) from moving vessels in the Strait.

The research method includes four main steps. At first, a new model is developed concerning air pollution threshold, shipping, and the Dugong home range. Next, the model is applied with generalized values for the components of the shipping system and weather conditions to fit the region of the study. To implement the third step, the elements of a transportation network database are used to design a suitable maritime transportation path. Finally, spatial analyses of maps are performed to determine the adaptability of marine routes with considerations for dugong home range and air pollution. These steps, which are useful for modeling suitable maritime paths, will be explained as follows. Various factors with different influence levels and importance degrees were established as criteria as shown in figure1.

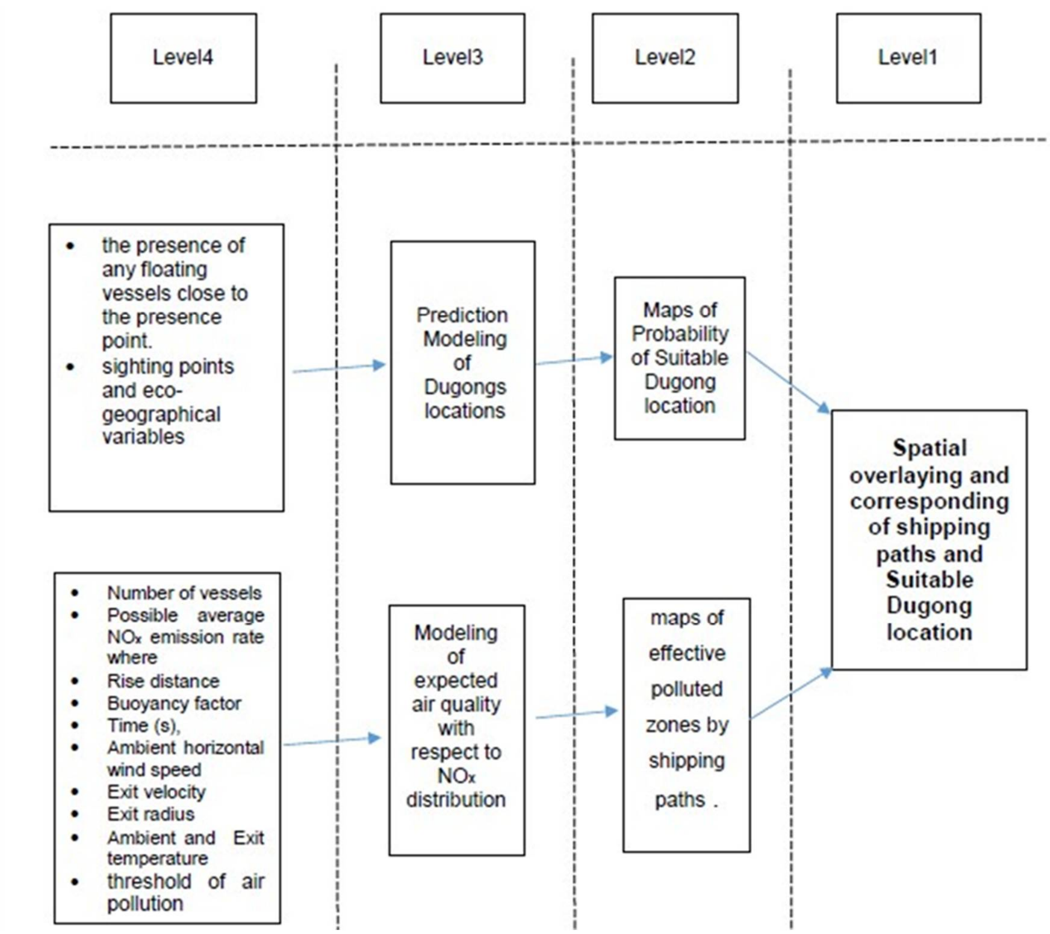

Figure 1: Various factors and different influence levels in the research

As shown in figure 1, the most output of this research is analyzing and corresponding of hs and Suitable Dugong locations The role of factors (levels 1, 2, and 3) will be clarified in the methodology, and the main output (level 4) will be clarified and discussed in the results and conclusion.

Habitat modeling

The Maximum Entropy modeling approach was used to predict the areas with high presence potential based on the maximum entropy algorithm. This modeling approach performs better than other presence-only modeling approaches such as Ecological niche Factor Analysis (ENFA) and DOMAIN. Meanwhile, this modeling method acts better than GLM/GAMs modeling methods by its generative approach, especially when the location data are incomplete (Hernandez et al. 2006, Gastón & García-Viñas, 2011). Both continuous and categorical variables can be used in this modeling approach (Baldwin 2009). The maximum entropy algorithm that is based on machine learning response estimates the most uniform distribution (maximum entropy) of sampling points compared to background locations given the constraints derived from the data (Rudrapati &Arun, 2019; Phillips et al., 2004). This deterministic algorithm can be covered to the maximum entropy probability distribution (Phillips et al., 2009). So the resulting outputs represent how much better the model fits the location data than a uniform distribution (Phillips et al., 2004, 2009, Elith et al., 2011). To better use the small sample size of the species, we use the replication function in MaxEnt to randomly sample occurrences for training runs and use the remaining circumstances to test the model. Specifically, we performed ten replications using the cross-validation procedure in MaxEnt 3.3.3. Using all of the data for model performing and validation, cross-validation is preferable compared to using a single training/test split in the dataset, thus making better use of small datasets (Hernandez et al., 2006).

Representation of Models Ability

We used receiving operator characteristic (ROC) curve to represent models ability to predict species locations and absences by plotting sensitivity (true positive) against 1– specificity (false positive) (Caetano & Silva Jota, 2016; Phillips et al., 2006) and derived AUC statistic was used as a threshold-independent measure of the overall fit of the model. An optimal model, one that predicted each occurrence of a species and for which each prediction was accurate, would have an AUC of 1.0, while a model that predicted species occurrences at random would have an AUC of 0.5 (Phillips et al., 2006).

Variables

Two sets of data were used in the modeling process, including dugongs' sighting points and eco-geographical variables including distance to the nearest coastal line, water mean depth, the presence of any floating vessels close to the presence point. Dugong sightings were collected as in line transects using ferries and boats. Totally 114 dugong sightings points were recorded during the study period. Sightings data also were accessed based on fisher interviews and community monitoring programs conducted by other regional projects (Marsh et al., 2010) and the MarineResearch Foundation. High-resolution seagrass distributions have been mapped in Australia (e.g. the Great Barrier Reef) (Grech & Coles, 2010) and the Mediterranean Sea (Pasqualini et al., 2005); however, current seagrass data sets are incongruent and spatially restrictive for Malaysia. Depth, coastal proximity, and solar accessibility and intensity are all factors in seagrass growth and productivity, including two dominant seagrass species favored by dugongs: *Halodule uninervis* and *Halophila ovalis* (De Iongh et al., 2007). Several proxy parameters that are known to be favorable for seagrass growth, and thus dugong foraging including depth (m), distance from the coast, seafloor slope, solar radiation, were used to assess the plant species distribution mapping. Arc-second global bathymetry data were accessed from the Oceans' General Bathymetric Chart (GEBCO, 2014). To maximize variation related to slope aspect, total solar radiation was calculated for the late afternoon during the winter solstice (Austin, 2002). The coast's distance was calculated in ArcGIS (version.10.1) as the Euclidean distance from an individual raster cell center to the coast.

Shipping Air Pollution Modeling

Modeling expected air quality regarding NO_x distribution is done using the basic theory of the primary standard of pollutants in eight hours (WHO, 2000). The threshold of air pollution for Dugong health in Malaysia is considered 10 mg /m^3.

The modeling method's basic theory is the maximum ground level concentration of NO_x, considering the spread of a plume in vertical and horizontal directions. In this basic theory, a plume is assumed to occur by simple diffusion along the mean wind direction. Like other pollutants, NOx accumulation is done based on stability time, independently or in conjunction with atmospheric temperature, wind speed, curb length, atmospheric pressure, and area. The curb length of NO_x, as an indicator of a suitable distance from Dugongs home range, is a function of the plume rise of NO_x, average atmospheric pressure and temperature, average estimated stack diameter, average stack exiting velocity, average wind speed, and type of marine vehicle) Matthias et al., 2010). This function is restructured for the Melacca Strait to plan shipping Paths.

The basis of the mathematical trajectory is the combination of several relative formulas and models to calibrate a new model concerning the problem. The mathematical trajectory steps are summarized in this section, assuming that the optimum Euclidean distance (D_{min}) from vessels is defined based on good air quality. The elements to be constructed in the model are listed as the indicator of good air quality for Dugong, the role of marine transportation in the production of air pollution, and the acceptable distance between vessels and the wildlife habitats to meet the goal of good air quality. The modeling aims to determine the main variables of these elements.

Element Description

Several pollutants are emitted by vessels, but statistics on air pollution emissions attributed to maritime transportation show that the main contribution is NO_x (Escourroug, 1996). In this paper, NO_x is considered the air pollution indicator of maritime transportation. Practical information (MDM, 2015) shows that the average passing time of vessels through Malacca strait length is approximately 6 hours; thus, 6 hours is considered the model's passing time. Based on this consideration, the concentration level of air pollution for animals of seaside areas' health (30 mg/m^3 for 6 hours) is an indicator of acceptable air quality for Dugong (WHO, 2005).

With respect to the above explanation, the minimum safe distance between the shipping route and the Dugong habitat to avoid the emitted air pollution of marine vehicles (D_{min}) is the distance in which the total NO_x emission rate of vessels is reduced to 30 mg/m^3, the known acceptable concentration level of NO_x for health (WHO, 2005). This safe distance depends on a plume in the vertical and horizontal directions and is assumed to occur by simple diffusion along the direction of the mean wind, and takes into account the total NO_x emission rate of vehicles as expressed in Equation (1), developed by Turner (1995):

$$C_x = \frac{Q}{\pi\sigma_y\sigma_z U} e^{-1/2}\left(\frac{H}{\sigma_z}\right) e^{-1/2}\left(\frac{Y}{\sigma_y}\right)^{-1} \quad (1)$$

Cx= Ground level concentration at some distance x downwind (g/m3),

Q= Average emission rate (g/sec),

σy= Standard deviation of wind direction in the horizontal (m),

σz= Standard deviation of wind direction in the vertical (m),

U= Mean wind speed (m/sec),

e= Natural log (equal to 2.71828),

H= Effective stack height (m), and

Y= Off-centerline distance (m).

To calculate this distance, the following information is required: total NO_x emission rate of vehicles, rise distance of emitted NO_x, mean wind speed, and standard deviation of vertical and horizontal wind direction.

NO_x pollution is highly sensitive. To calculate the total NO_x emission rate of vessels, it is best to consider the total number of vessels passed through straight, as expressed in Equation 2:

$$Q = \sum_i (v_i \times q_i), \quad (2)$$

where

Q = Total NO_x emission rate of vessels passed through straight,

v_i = Number of vessels of type *i* passed through straight, and

q_i = Possible average NO_x emission rate for one vessel of type *i* during passing time.

The vessel type and passing time are considered for computing q_i. To calculate the rise distance of emitted NO_x bypassed straight vessels (Δh), these equations, developed by Wayson (2000), can be used:

$$\Delta h = 1.6\left(\frac{F_0 t^2}{U}\right)^{1/3}, \quad (3)$$

$$F_0 = g v_s r_s^{\,2}\left[1-\left(\frac{T_a}{T_s}\right)\right], \qquad (4)$$

where

Δh = Rise distance (m),

F0 = Buoyancy factor (m^4/s^3),

t = Time (s),

U = Ambient horizontal wind speed (m/s),

g = Gravitational constant = 9.81 m/s^2,

vs = Exit velocity (m/s),

rs = Exit radius (m),

Ta = Ambient temperature (K) and

Ts = Exit temperature (K).

The parameters of Equations 2, 3, and 4 can easily be obtained through annual reports of the region of study and actual measurements concerning vessel type (bulk), standards, and guidelines. Time is stability time of NOx equal to 15 minutes or 900s (Gulam et al., 2013). The average Passed straight vessels number in this time is about 40 vessels

Vertical and horizontal dispersion (σy and σz) can be found in the attributes in Table 1.

Finalization of the Model

By applying the amount of Cx = 0.03g/m^3 (primary standard of NO_x pollutant in 6 hours), Equation (1) can be rewritten as follows:

$$(\delta_z)^3\delta_y = 6.8\left(\frac{Q\times \Delta h^2}{U}\right) \qquad (5)$$

Δh and Q are obtained by Equations 2 and 3, but where is D_{min}? In Equation 6, σy and σz are replaced by a mathematical function of D_{min}:

$$(\delta_z)^3\delta_y = F(D_{\min}) \qquad (6)$$

Therefore, based on Equation 6 and 5,

$$F(D_{\min}) = 6.8\left(\frac{Q\times \Delta h^2}{U}\right) \qquad (7)$$

Weather Stability Classes are expressed in 6 situation (A,B,C,D,E and F) based on 3 main parameters: Incoming solar radiation, thinly overcast, and wind speed (Table 1)

Therefore, it is necessary to develop $F(D_{min})$. Because most vessels are passed through Strait during the day (MDM, 2015), the factor of thinly overcast skies as a weather indicator for the night (Table 1) is ignored.

Table 1: Key to Weather Stability Classes

Wind Speed (m/s)	Day: Incoming Solar Radiation			Night: Thinly Overcast	
	Strong	**Moderate**	**Slight**	**More than 50 % Cloud**	**Less than 50 % Cloud**
Less than 2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
More than 6	C	D	D	D	D

Source: Turner, 1995

Solar radiation and average wind speed in the study area play prominent roles in this process. Based on historical data (Annual Climate Assessment Reports, 2014) and table 1, the study area is similar to the situation (C). Thus, this situation (C) was used to develop $F(D_{min})$. Crowl and Louvar (2002) developed the following equations for the situation (C):

$$\delta_y = 0.22D(1+0.0004) , \quad (8)$$

$$\delta_z = 0.20D \quad (9)$$

Because the numerical values of 0.0004 D_{min} given in Equations 8 and 9 are extremely small, they can be eliminated. Based on Equation 6,

$$F(D_{min}) = 0.22(D_{min})[0.2(D_{min})]^3 \quad (12)$$

Then,

$$F(D_{min}) = 0.0021(D_{min})^4 . \quad (13)$$

Then, based on Equations 8 and 14,

$$\left(\frac{6.8\Delta h^2 Q}{U}\right) = 0.0021(D_{min})^4 \quad (14)$$

The final model can be rewritten as follows:

$$D_{\min} = 7.54 \frac{\Delta h^{1/2} Q^{1/4}}{U^{1/4}} \quad (15)$$

Evaluation of the Model

During the sensitivity analysis process, the effects of three main variables (Δh, Q, and U) on calculated and field D_{min} were compared to test the accuracy and ability of the model. It was done to determine which of these three variables are critical and significantly affect the model outputs. The mathematical relationship of model parameters shows the non-acceptable level of accuracy in most of the samples. more concentration of errors in higher values of Q. It means more sensitivity of the model is relative to Q and its parameters. Also, Q's parameter is flexible and controllable, which can be changed to achieve more accuracy through NOx's stability period. The peak value of NOx concentration (5 minutes) decreasing emitted NOx is done very fast. So, the maximum stability period of NOx (15 minutes) is not a good indicator of transport air pollution. It is better to make an average time between the peak value and maximum stability time (10 minutes). The result shows the minimum errors in the application of the grid size equal to 25 m and stability time equal to 10 minutes (Fig. 2).

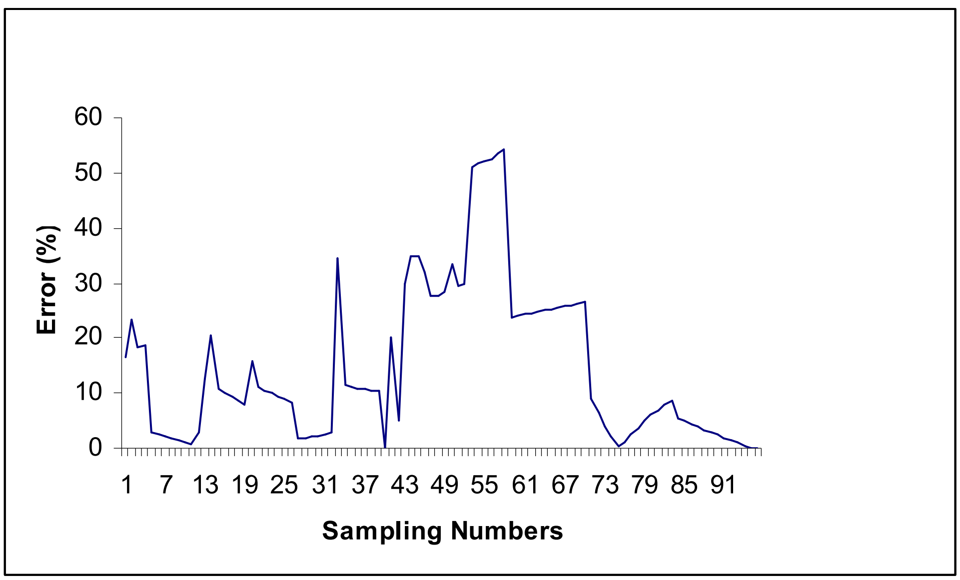

Figure 2: Mathematical Errors of Field D_{min} after Calibration of Stability Time

Validation is done to evaluate model accuracy. It assesses whether the model is working as intended. The model validation is done by comparing its predictions with field data. If the differences between field prediction and field data are small, then the proposed model is accurate. Concerning basic knowledge of sensitivity analysis, this process (validation) is done by applying values of parameters of calculated D_{min} and field D_{min} and analyzing them two parameters' mathematical relationship

Testing of the Model is to create a practical test (derived from an implementation) to verify the model. For example, if the calculated minimum safe distance for one station was more than the actual distance, the sensors monitored some pollution in this station. Also, if the calculated distance was less than the field distance, there should not be any pollution. Also, testing results, which have been done, show 82.9 % of the cases coincided in the observations confirming the model's ability and usefulness (Fig. 3).

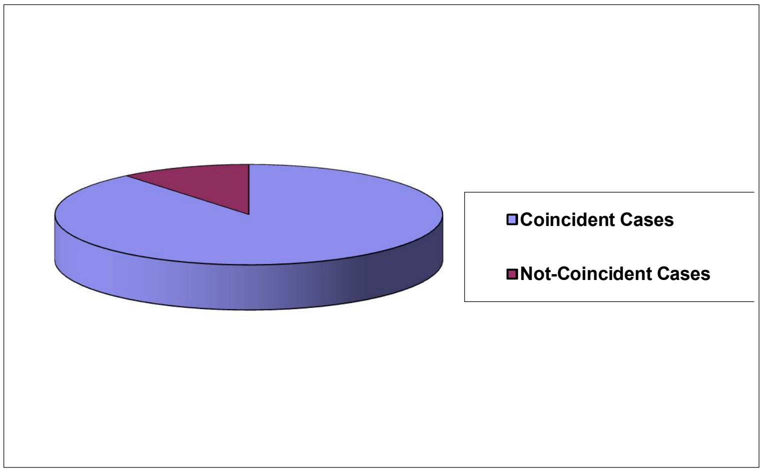

Figure 3: Results of Model Testing

Contribution of the Model for Malacca Strait

After performing a sensitivity analysis, calibration, testing, and validation of the model in the study area, the model was applied with the generalized values for the components of the shipping system and weather condition and was found to fit the study area. Since more than 95% of passed vessel types in the study area include bulk type (MDM, 2015), our calculation is done by considering this type and fuel consumption (Williams et al., 2006), equal to about 80 tons per day.

Concerning the average rate of NO_X in marine fuel consumption and summarizing the number of passing vessels, the main data constants used are the following:

a) T_s (General average exiting gas temperature from exhaust) = 395K,

b) T_a (Average annual atmospheric temperature for study area) = 293K,

c) P (Average annual atmospheric pressure for study area) =1000 mB,

d) t (duration time for calculation) = 600s

After applying these generalized values in the model, the D_{min} was calculated for shipping paths equal to 1655m.

Determination of Probability of Suitable Dugong Habitat Conditions

Figure 1 shows the modeled probability of suitable habitat conditions based on dugong presence data. The MaxEnt model predicted the most suitable dugong habitat in the Malacca Strait. We obtained 114 sites for the Dugongs to develop a distribution model. The average result derived from 10 replication runs by the model is presented in figure 4. The species' potential distribution map indicated that 23.36% of the whole study area occurred in areas with the highest suitability value (0.6 to 1). When the binary output is preferred (e.g., habitat *vs.* non-habitat), the threshold value to reclassify continuous suitability map to suitable/unsuitable becomes critical, and further research is required to establish rules for choosing optimal thresholds to distinguish suitable areas from unsuitable ones. Threshold independent tests of the model indicated that the model performed well in predicting *D. dugong* distribution. The mean AUC value for the cross-validated model was 0.854, which was considered to offer 'excellent discrimination' given our interpretation of AUC values. We also found that the standard deviation of AUC values was low (0.012), indicating some level of uniformity amongst replications. Relative contributions of the environmental variables to the MaxEnt model revealed that variables included distance to the coastal line (88.2%), sea bed slope (7%), and the presence of any moving vessel (4.8%). The averaged area under the curve (AUC) value derived from the 10 replicated MaxEnt models was 0.88 (± 0.04), indicating that the model performed well

.

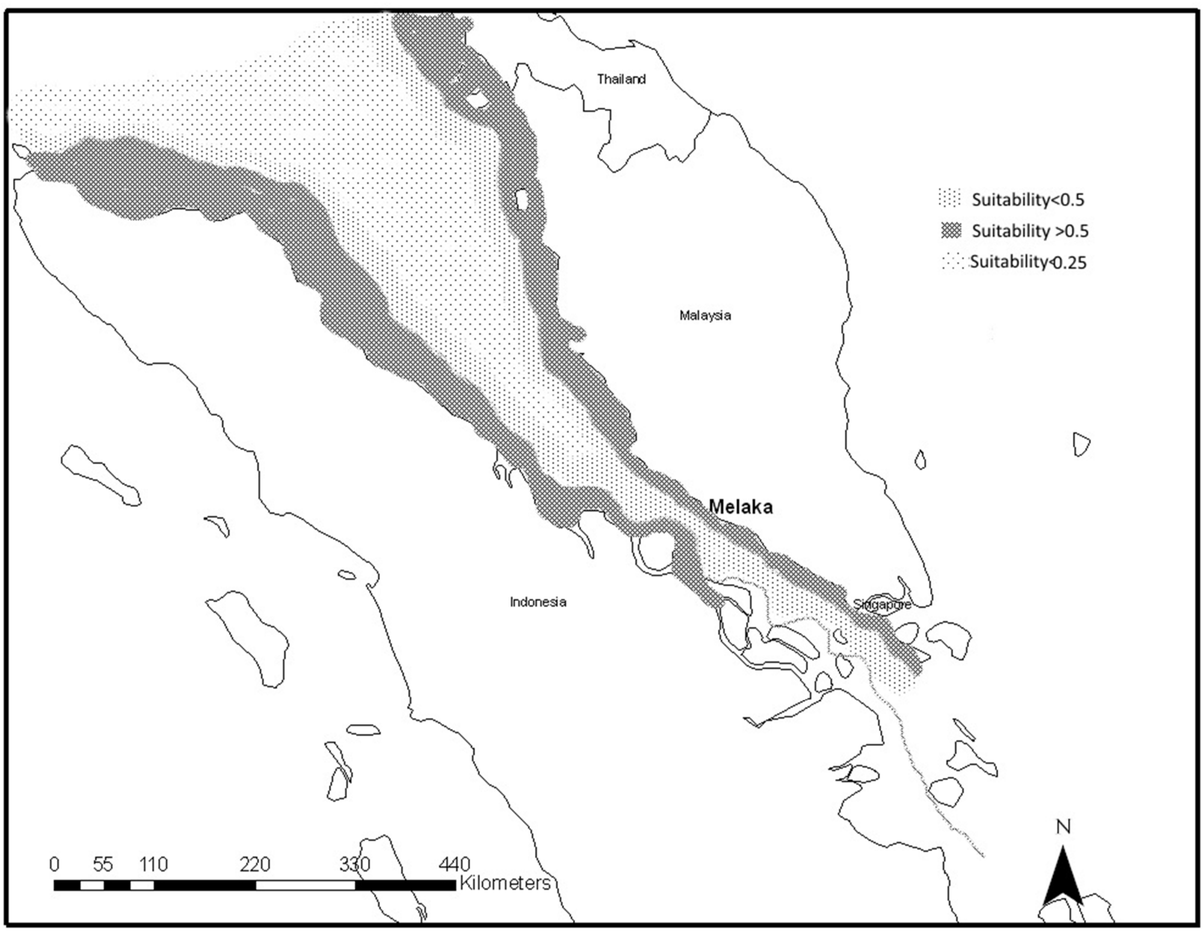

Figure 4: Probability of Dugong Suitable Habitat Conditions

Spatial overlaying maps for the determination of adaptability

In this research, the pollution evaluation of Dugong Habitat was performed by determining polluted areas of the seaside. Areas with low air quality were obtained by overlay analysis and selecting effective polluted zones by Probability of Suitable Dugong Habitat. The categorization of polluted areas was based on emitted pollution using buffering and dissolving the "spatial analysis toolbox" in ArcGIS 9.1. These powerful tools can perform various spatial operations on all types of vector data. The process was performed by overlaying Probability of Suitable Dugong Habitat maps using the following procedures:

- Creating maps of effective polluted zones by shipping paths.
- Overlaying maps of Probability of Suitable Dugong Habitat and polluted zones.

Results

The results took into consideration the main negative environmental elements in shipping paths. Based on environmental guidelines, there is no air pollution danger for dugongs' health. These guidelines ensure that the seaside is located a safe distance away from shipping paths. The minimum calculated distance serves as a constraint to indicate where the dugongs' habitats cannot be located. The result is that too many parts of the probability of suitable Dugong habitat in the study area do not have a proper position that does not put it in conflict with shipping polluted zones (Fig. 5).

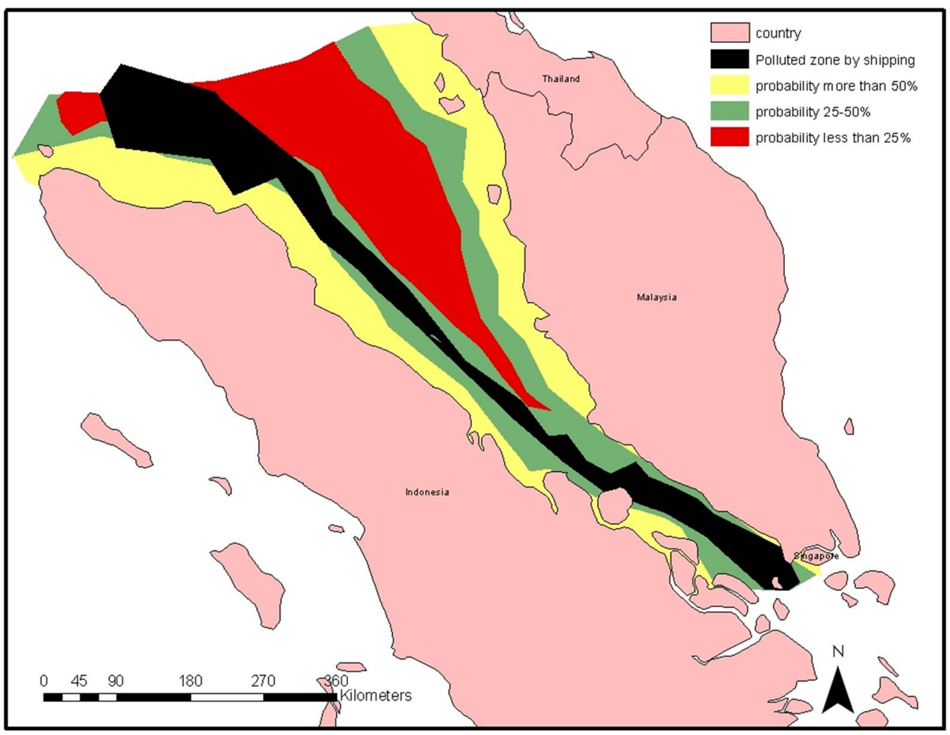

Figure 5: Position of Probability of Dugong Habitat in Conflict with Shipping Polluted Zones

The results (Figure 4) show 3 dangerous situations levels for shipping pollution by controlling implementation and isolation of Dugong Habitat in the study area:

1- **Very dangerous**: interaction of shipping pollution area with high (more than 50%) Probability of Suitable Dugong Habitat
2- **Dangerous**: interaction of shipping pollution area with moderate (25 - 50%) Probability of Suitable Dugong Habitat
3- **No dangerous**: interaction of shipping pollution area with low (less than 25%) Probability

of Suitable Dugong Habitat

With regard to the above categories, the shipping path of the Strait can be divided into three geographical parts (Figure 6 and Table 2):

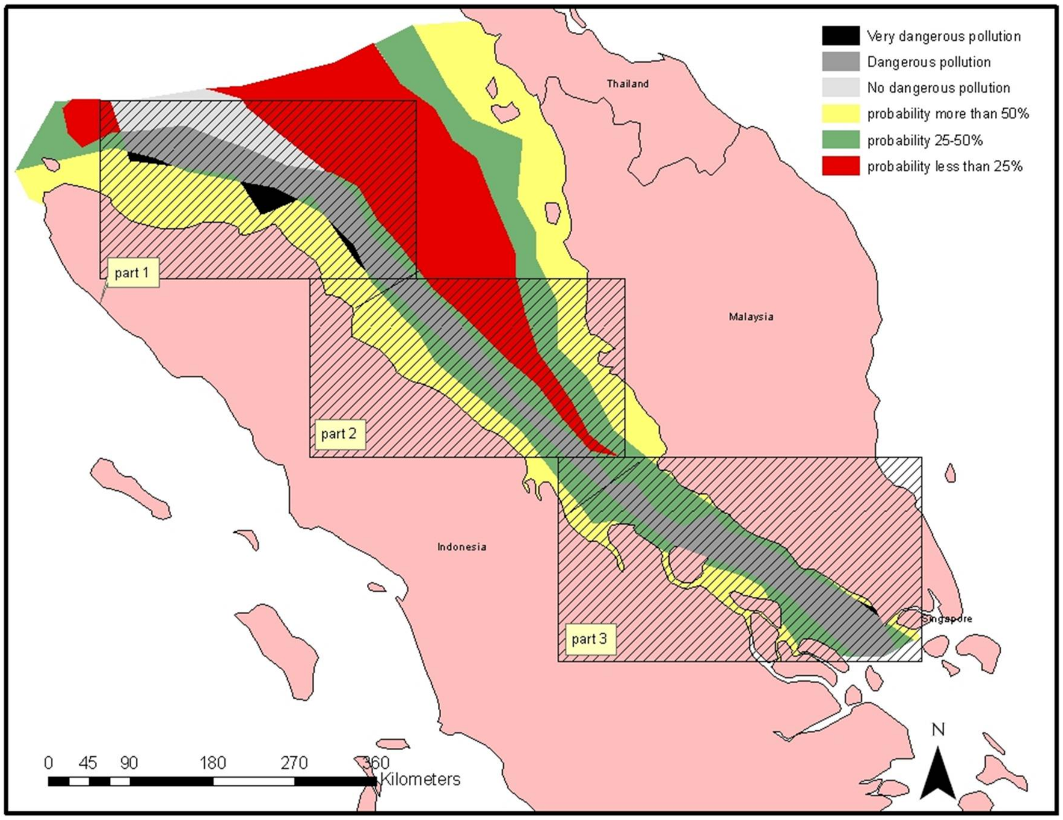

Figure 6: Categorizing of Shipping Pollution for Dugong Habitat Controlling Implementation

Table2: Situation of Polluted Zones and Probability of Suitable Dugong Habitat in 3 Shipping Path Parts

Part	**1**	**2**	**3**
Including Polluted zone	Very dangerous dangerous No dangerous	dangerous	Very dangerous dangerous
Including Probability of Suitable Dugong Habitat	Low Moderate High	Low Moderate High	Moderate High

Since the more suitable shipping path should be located in lower Probability of Suitable Dugong Habitat, with respect to the criteria and considerations of shipping path designation, there are similar types of spatial conditions. Low Probability of Suitable Dugong Habitat have higher preferences for designation, and high Probability of Suitable Dugong Habitat require improvement and re-designation. There are several options to improve the currently unsuitable shipping paths, which can be investigated through the following scenarios:

- Removing all unsuitable shipping paths and designing new shipping paths in Low Probability of Suitable Dugong Habitat,
- Changing vessel types and number to provide smaller strait shipping paths

- Shifting some unsuitable shipping paths to low and moderate probability of suitable Dugong habitat,

With respect to economic and technical possibilities, the first scenario cannot be accepted for study area, furthermore, in part 3 of strait shipping paths, there is no low probability of suitable Dugong habitat.

The second scenario can be discussed. Changing vessel types with respect to the economic importance of Malacca strait for petrol bulk carrier transits is impossible, but the numbers and traffic of vessels can be changed via controlling by taxes. Different daily taxes can help distribute vessel traffic during more and varied times (days or nights).

Shifting unsuitably shipping paths to low and moderate probability of suitable Dugong habitat is the most reasonable scenario. Concerning economic and technical limitations and also mentioned the breeding cycle of Dugong, this scenario can give us several spatial and seasonal options. With regard to the categorized shipping pollution for Dugong habitat, further preferences should be considered based on ecological, economic, and technical limitations. The following suggestions may help to improve shipping paths:

- Removing very dangerous zone (Figure3) via shifting parts 1 and 2 of the path to the low probability of suitable Dugong habitat at especial Dugongs breeding season (September-November).
- Shifting parts 1 and 2 of the path to moderate probability of suitable Dugong habitat at all year except especial Dugongs breeding season (September-November).
- More limitation in vessel numbers and transportation time via taxes and port police and maritime police, particularly in part 3 of the path.

Conclusion

This research has successfully managed and developed a scientifically based method for understanding the relationship between wildlife habitat and marine transportation by analyzing successful and non-successful present and future shipping. As discussed in the results, successful shipping will be achieved when the shipping path is located in a lower probability of suitable Dugong habitats. It means polluted areas by shipping paths should not have spatial interaction with a high probability of suitable Dugong habitats. This issue has been analyzed by zoning and exploring shipping paths concerning Dugongs' habitats. The research strategy can support maritime planners with a range of options. However, with selecting the best or most suitable routes, an experimental approach can be developed. The primary purpose of this experimental approach will be to choose the shipping path from among the alternatives. Implementation of the method and scenario analysis suggests that some areas are more suitable than others for shipping path if the performance (Dugong's health and air quality) and criteria (shipping paths and the probability of suitable Dugong habitats) are considered carefully. The suitability of the shipping path largely depends on the goals of the marine transportation, but the importance of the two main performances (Dugong's health and air quality) cannot be ignored in any marine transportation project.

By developing and implementing the mentioned methods in the study area, it is possible to illustrate the implementation of a spatial strategy in maritime transportation planning to explain the linkage between wildlife protection and air quality for the better design of shipping paths. This approach can help planners to determine potential locations for shipping paths. The method presented in this study is not intended for the exact site selection of polluted areas and shipping paths. This method includes a generalized spatial tool. This spatial tool can help decision-makers to design better shipping path. This tool can also assist maritime planners by providing a list of alternatives and their advantages and disadvantages within marine transportation policies and projects. In this way, planners can offer a maximum amount of marine transportation at the lowest economic and environmental investment cost.

Acknowledgment

We wish to acknowledge the Institute for Environment and Development (Grant no : XX-15-2012, Upscaling of MSMA Stormwater Ecohydrology at Catchment Level in Sg. Langat), UKM, Malaysia, to provide resources and collaborative efforts.

References

Adulyanukosol, K., Thongsukdee, S., Hara, T., Arai, N., Tsuchiya, M. (2007). Observations of Dugong reproductive behaviour in Trang Province, Thailand: further evidence of intraspecific variation in dugong behavior. Marine Biology. 151(5), 1887-1891. DOI: 10.1007/s00227-007-0619-y

Anderson, P. (1997) Shark Bay dugongs in summer, I: Lek mating. Behaviour. 134(5/6), 433-462. DOI: https://www.jstor.org/stable/4535450

Annual Climate Assessment Reports (2014) Singapore Metrological Service, 5-16

Austin, M.P. (2002) Spatial prediction of species distribution: an interface between ecological theory and statistical modeling. Ecol. Model. 157, 101–118.DOI: https://doi.org/10.1016/S0304-3800(02)00205-3

Baldwin, R.A (2009) Use of Maximum Entropy Modeling in Wildlife Research. Entropy. 11, 854–866. DOI: https://doi.org/10.3390/e11040854

Briscoe, D., Hiatt, S., Lewison, R., Hines, E. (2014) Modeling habitat and bycatch risk for dugongs in Sabah, Malaysia ENDANGERED SPECIES RESEARCH. 24, 237–247. DOI: 10.3354/esr00600

Burgess, E. A., Lanyon, J.M., and Keeley, T. (2012) Testosterone and tusks: maturation and seasonal reproductive patterns of live, free-ranging male dugongs (*Dugong dugon*) in a subtropical population. Reproduction, 143, pp 683–697 .doi: 10.1530/REP-11-0434. Epub 2012 Mar 5.

Caetano, W.D., da Silva Jota, P. (2016) Load Static Models for Conservation Voltage Reduction in the Presence of Harmonics. Energy and Power Engineering. 8(2), 62-75. DOI: 10.4236/epe.2016.82006.

Crowl, A. D., and Louvar, J. F. (2002) Chemical Process Safety. Prentice Hall PTR, USA. 186-236

De Iongh, H., Kiswara, W. Kustiawan,W., Loth, P. (2007) A review of research on the interactions between dugongs (Dugong dugon Muller 1776) and intertidal seagrass beds in Indonesia. Hydrobiologia. 591, 73-83. DOI 10.7717/peerj.2194

Elith, J., Phillips, S.J., Hastie, T., Dudík, M., Chee, Y.E., Yates, C.J. (2011) A statistical explanation of MaxEnt for ecologists. Diver. Distrib. 17,43–57.DOI: https://doi.org/10.1111/j.1472-4642.2010.00725.x

Escourroug (1996) Transport, contraintes climatiques et pollution. Sedes.

Gastón, A., García-Viñas, J.I. (2011) Modeling species distributions with penalized logistic regressions: A comparison with maximum entropy models. Ecol. Model. 222, 2037–2041. DOI: 10.1016/j.ecolmodel.2011.04.015

GEBCO (General Bathymetric Chart of the Oceans) (2014) https://www.gebco.net

Grech, A. & G.Coles (2010) An ecosystem-scale predictive model of coastal seagrass distribution. AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS. 20, 437–444. https://doi.org/10.1002/aqc.1107

Gulam, M., Alka, A., Sanjula, B., And Javed, A. (2013) Box-Behnken supported validation of stability-indicating high performance thin-layer chromatography (HPTLC) method: An application in degradation kinetic profiling of ropinirole. Saudi Pharmaceutical Journal. 21(1), 93-102. DOI: https://doi.org/10.1016/j.jsps.2011.11.006

Hernandez, P.A., Graham, C.H., Master, L.L., Albert, D.L. (2006) The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography. 29, 773–785. DOI: https://doi.org/10.1111/j.0906-7590.2006.04700.x

Ilangakoon, A., Tun, T. (2007) Rediscovering the Dugong in Myanmar and capacity building for research and conservation. The Raffles Bulletin of Zoology. 55(1), 195-199. DOI: https://www.researchgate.net/publication/228661505

Lawler, I., Marsh, H. McDonald, B. and Stokes, T. (2002) Dugongs in the Great Barrier Reef: Current state of knowledge. Cooperative Research Centre for the Great Barrier Reef World Heritage Area .CRC Reef Research Centre Report.

Lefebvre, L., Reid, J. Kenworthy, W. Powell, J. (2000) Characterizing manatee habitat use and seagrass grazing in Florida and Puerto Rico:implications for conservation and management. Pac Conserv Biol 5, 289−298. DOI: 10.3354/meps11986

Marsh, H. and Sobtzick, S. (2015) Dugong dugon. The IUCN Red List of Threatened Species 2015.

Marsh, H. (2002) Dugong: Status Report and Action Plans for Countries and Territories. UNEP

Marsh, H., Heinsohn, G. Marsh, L. (2010) Breeding cycle, life history, and population dynamics of the Dugong, Dugong dugon (Sirenia: Dugongidae). Australian Journal of Zoology, 32(6), 767-788. DOI: 10.1071/ZO9840767

Matthias. V, Bewersdorff, I. Aulinger, A. and Quante, M. (2010) The contribution of ship emissions to air pollution in the North Sea regions. Environmental pollution. 158, 2241-2250. https://doi.org/10.1016/j.envpol.2010.02.013

MDM (Marine Department of Malaysia) (2015) Official website, List of statistic, available in http://www.marine.gov.my

Miola, A. and Ciuffo, M. (2011) Estimating air emissions from ship: Meta-analysis of modelling approaches and available data sources. 5, 2242-2251. DOI: 10.1016/j.atmosenv.2011.01.046

Pasqualini, V., Pergent-Martini, C., Fernandez,C., Ferrat, L., Tomaszewski, J. and Pergent, G. (2005) Wetland monitoring: aquatic plant changes in two Corsican coastal lagoons (Western Mediterranean Sea), AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS.16(1) , 43-60. https://hal.archives-ouvertes.fr/hal-01769109

Phillips, S.J., Dudík, M., Schapire, R.E. (2009) MaxEnt software for species habitat modeling, version 3.3.1. Available online

Phillips, S.J., Dudík, M., Schapire, R.E. (2004) A maximum entropy approach to species distribution modeling (In: Proceeding of 21st International Conference on Machine Learning) . ACM Press: New York, NY, USA. 655–662.

Rudrapati, R. and Patil, A. (2019). Optimization of Cutting Conditions for Surface Roughness in VMC 5-Axis. Materials Science Forum. 969, 631-636. DOI: 10.4028/www.scientific.net/MSF.

Saxe, H. and Larsen, T. (2004) Air Pollution from Ships in three Danish ports. Atmospheric Environment. 38, 4057-4067. DOI: https://doi.org/10.1016/j.atmosenv.2004.03.055

Solvay, G., Hans-Dieter, E. and Anna-Katharina, H. (2008) The Straits of Malacca: knowledge and diversity. Lit; London: Global [distributor], Berlin, 23-113

Turner, D. B. (1995) Atmospheric Dispersion Estimates, an Introduction to Dispersion Modeling. Lewis Publisher, USA.

Wayson, R. (2000) Predicting Air Quality near Roadways through the Application of a Gaussian Puff Model to Moving Sources. Proceeding of 93rd Annual Conference and Exhibition of the Air and Waste Management Association, USA.

WHO (2005) Air Quality Guidelines. Regional Office for Europe, Copenhagen, Denmark, 15-17

Williams, E. J., Lerner, B. M., Murphy, P. C. Herndon, S. C. (2006) Emissions of NO_x, SO_2, CO, and HCHO from commercial marine shipping during Texas Air Quality Study (TexAQS), Journal of Geographic Research, 114(21), 1984–2012.
https://doi.org/10.1029/2009JD012094