Towards Development of a Web-Based System for Analyzing Marine Ecological Carrying Capacity (MECC) for Managing Marine Resources in The Outer Island of Indonesia (Case Study: Nunukan Regency)

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Abstract. Research on the development of data integration system design and web-based system in the calculation of Marine Ecological Carrying Capacity (MECC) for managing marine and coastal resource management has been carried out. In this study, Nunukan Regency, North Kalimantan was chosen as the study area. The process of integrating data in managing marine and coastal resources in a sustainable manner using the carrying capacity concept approach is carried out by designing an information system development system in processing and displaying the results of MECC calculations. This can make it easier for decision makers to develop the utilization of blue economic potential in accordance with geographic conditions as well as efforts that can be made to increase the productivity of the blue economy in Nunukan Regency, North Kalimantan.

Key Words: Marine Ecological Carrying Capacity (MECC), Nunukan Regency, System Design, Information Systems

1. Introduction
The blue economic potential of Indonesia as an archipelago which reaches 17 thousand trillion rupiah is dominated by the marine capture fisheries sector. However, only 70% of the 12.54 million tonnes of potential marine catch in Indonesia can be realized [1]. This potential has not been able to be utilized and managed optimally because of the many obstacles that must be faced, such as limited access to information, infrastructure, and human resources (HR) capable of managing this potential. On the other hand, as a result of climate change, weather conditions in the sea become erratic (such as strong winds and extreme waves) and endanger fishermen and residents on the coast, as well as impact on weakening economic growth, especially in areas that only depend on coastal and marine resources. The concept of carrying capacity can be used as a basic principle to explore the use of coastal and marine resources in supporting a sustainable blue economy. This concept directly seeks to demonstrate the relationship between the population as a supported object (carrying object) and the environment as a support (carrier) to ensure sustainability [2]. Theoretically, population carrying capacity evolves into resource carrying capacity, environmental carrying capacity and then into ecological carrying capacity (ECC) [3].
To achieve this, a system that is capable of integrating data based on historical data, monitoring data, and predictive data is needed to see the development of sustainable use of marine and coastal resources. The results of data integration will produce information in the form of a maritime performance index wrapped in an appropriate application, so that decision makers can easily and on target in determining which development of blue economic potential is in accordance with geographic conditions and efforts that can be made to increase productivity the blue economy in the region.

Research on integrating data based on information systems used in managing marine and coastal resources is rarely conducted, especially in Nunukan District, North Kalimantan. Therefore, the challenge of integrating data into an information system to calculate Marine Ecological Carrying Capacity (MECC) is very interesting to do. Based on this explanation, the purpose of this study is to find out how to integrate data in managing marine and coastal resources in a sustainable manner using the carrying capacity concept approach.

2. Study Area
In this research, the area of Nunukan Regency, North Kalimantan was the research location. Astronomically Nunukan Regency is located at 115° 33' 00" to 118° 3' 55" East Longitude and between 3° 15' 00" to 4° 24' 55" North latitude which is the northernmost region of North Kalimantan Province [4].

![Figure 1. Location of Applied Prototype Test in Nunukan Regency, North Kalimantan](image)

3. Data Acquisition
In the Marine Ecological Carrying Capacity (MECC) calculation, the data for each parameter is obtained from various sources as follows

3.1. Significant Wave Height (SWH)
Simulated significant wave height data were obtained from the University Corporation for Atmospheric Research (USAR). USAR predicts waves using the WAVEWATCH III (WW3) wave model. WW3 is a third-generation wave simulation model developed at the Marine Modeling and Analysis Branch (MMAB) of the Environmental Modeling Center (EMC) of the National Centers for Environmental Prediction (NCEP). WW3 is based on WAVEWATCH I and WAVEWATCH II developed at Delft University of Technology and NASA’s Goddard Space Flight Center, respectively [5].

3.2. Current Sea, Sea Surface Temperature (SST), and Sea Water Level (SWL)
The HYbrid Coordinate Oceans Model (HYCOM) is a global ocean circulation model that evolved from the Miami Isopycnic-Coordinate Oceans Model (MICOM) developed by Rainer Bleck and colleagues
HYCOM provides ocean prediction data such as current velocity data, sea surface temperature (SST), and sea level (SWL) which are used as one of the parameters used in calculating carrying capacity.

3.3. Chlorophyll-a

Chlorophyll-a data is obtained from field observation data obtained from the Visible and Infrared Imager/Radiometer Suite (VIIRS) satellite sensors. VIIRS is the successor to the Moderate Resolution Imaging Spectroradiometer (MODIS) developed by the National Aeronautics and Space Administration (NASA) [7].

3.4. VIIRS Boat Detection (VBD)

Vessel monitoring data is obtained from the low light emission of fishing boats captured by VIIRS satellite imagery. The data is processed by the Earth Observation Group by developing a near real time VIIRS boat detection system that produces global mapping called VIIRS Boat Detection (VBD) [8].

3.5. Regional Statistical Data of Nunukan Regency

Regional statistical data used in the calculation of carrying capacity consisting of the number of tourists, fishery production, number of fishery households, population density, Gross Regional Domestic Product (GRDP), and human development index are obtained from reports from the Central Statistics Agency (BPS) for the Nunukan Regency.

4. System Design

In this section will explain how the design of the Marine Ecological Carrying Capacity (MECC) prediction calculation system is shown in Figure 2. The stages of forming the system design consist of three stages, namely data preparing, data processing, and data visualization.

4.1. Data Preparing

The MECC calculation to become an MPI consists of two components, namely the Carrying object component (human activities and socio-economic growth) and the Carrier resistance component (ecological resilience). Human activities include coastal and marine activities that directly suppress ecosystems (Carriers), while socio-economic growth includes elements that represent coastal populations and economies, as well as actions to protect coastal areas. Carrier resilience components consist of elements that maintain or damage the structure and function of coastal and marine ecosystems.

The data required in MECC calculations are obtained by creating an automatic download system for each data source as described in the previous section. The data will be cut automatically according to the study area so that it can represent the actual conditions in the study area.

4.2. Data Preparing

In this section the elements calculated for each component can be adjusted according to local conditions and data availability in the study area. MECC calculations are done using Python software so that calculations can be done automatically. In making the script, follow the steps in calculating MECC which consists of three stages, namely:

4.2.1. Standardizing the value of each indicator (element). In the first stage, Equation (1) and Equation (2) are used to standardize the value of each indicator (element) into the range 0-1. For indicators that are positive, the equation used is as follows:

\[ Y_{ij} = \frac{X_{ij} - X_{jmin}}{X_{jmax} - X_{jmin}} \]  

(1)

Meanwhile, for indicators that are negative, the equation used is as follows:
\[ Y_{ij} = \frac{X_{j_{\text{max}}} - X_{ij}}{X_{j_{\text{max}}} - X_{j_{\text{min}}}} \]  

(2)

where \( X_{j_{\text{max}}} \) and \( X_{j_{\text{min}}} \) are the maximum and minimum values for the \( X_j \) indicator, and \( Y_{ij} \) is the normalized value for the \( X_j \) indicator.

**Figure 2.** Design of the Marine Ecological Carrying Capacity (MECC) prediction calculation system.

4.2.2. Determining the weight of each indicator (element). The weight determination is based on the effect of each element on changes in environmental conditions in the study area, especially in coastal and marine areas. In this case, Nunukan Regency is the study area in this study.

4.2.3. Calculation of the MECC index (MPI). The principal component analysis (PCA) method is carried out to extract important information from each indicator, namely the human activity index (HI), socioeconomic growth index (SI), and ecosystem resilience index (RI). The results of the contribution of each indicator based on the PCA method are weighted for each indicator.

Based on these two stages, the values for HI, SI, and RI can be calculated by the following equation 3:
\[ I_m = \sum_{j=1}^{n} W_j Y_{ij} \]  

where \( I_m \) is HI, SI, or RI; \( W_j \) is the weight for the \( X_{ij} \) indicator; and \( Y_{ij} \) is the normalized value for \( X_j \) indicator.

**Figure 3.** Graph of human activity index (HI), socio-economic development activity index (SI), ecological resilience index (RI), MECC performance index (MPI), and object carrying index (OI)

**Figure 4.** Website-based information system for MECC monitoring

### 4.3. Data Analysis and Visualization

The calculated data (Figure 3) will be displayed in a website-based information system so that each parameter can be analyzed easily and more interactively (Figure 4). Thus, decision makers can easily
and on target in determining which development of blue economic potential is in accordance with geographic conditions as well as efforts that can be made to increase the productivity of the blue economy in Nunukan Regency, North Kalimantan.

5. Conclusions
The development of the MECC calculation system design can be used as the basis for the process of integrating data in managing sustainable marine and coastal resources using the carrying capacity concept approach. The development of a website-based information system makes it easy for decision makers to develop the utilization of blue economic potential in accordance with geographic conditions as well as efforts that can be made to increase the productivity of the blue economy in Nunukan Regency, North Kalimantan.

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References
[1] Katadata 2019 Pengusaha Perikanan Minta KKP Segera Revisi Pembatasan Ukuran Kapal Retrieved on 4 April 2019 from https://katadata.co.id/berita/2019/01/30/pengusahaan-perikanan-minta-kkp-segera-revisi-pembatasan-ukuran-kapal
[2] Ma P, Ye G, Peng X, Liu J, Qi J and Jia S 2017 Development of an index system for evaluation of ecological carrying capacity of marine ecosystems Ocean Coast. Manag. 144 pp 23–30
[3] Martire S, Castellani V and Sala S 2015 Carrying capacity assessment of forest resources: Enhancing environmental sustainability in energy production at local scale Resour. Conserv. Recycl. 94 pp 11–20
[4] Pemda Kabupaten Nunukan 2018 Perubahan RPJMD Kabupaten Nunukan Tahun 2016-2021 (Nunukan: Pemda) Retrieved from https://jdihn.go.id/files/838/PERDA%2011-2018.pdf
[5] Tolman H L 2009 User Manual and System Documentation of WAVEWATCH III TM version 3.14 pp 276–20 Retrieved from https://www.researchgate.net/publication/228750848_User_manual_and_system_documentation_of_WAVEWATCH_III_version_314
[6] Bleck R, Halliwell Jr G R, Wallcraft A J, Carroll S, Kelly K and Rushing K 2002 HYbrid Coordinate Ocean Model (HYCOM) User’s Manual: Details of the Numerical Code Retrieved from https://www.hycom.org/attachments/063_hycom_users_manual.pdf
[7] Ocean Biology Processing Group 2018 Suomi-NPP/VIIRS (NASA Goddard Space Flight Center, Ocean Ecology Laboratory) Retrieved from https://oceancolor.gsfc.nasa.gov/data/viirs-snpp/
[8] EOG VIIRS 2020 Boat Detection Retrieved on 15 October 2020 from https://eogdata.mines.edu/vbd/