eISSN: 2721-5717; pISSN: 2747-2124 https://journal.unhas.ac.id/index.php/zonalaut

ZONA LAUT

JOURNAL OF OCEAN SCIENCE AND TECHNOLOGY INNOVATION

Hydro-oseanographic Influences on Artificial Reef Placement in Indonesian Coastal Areas

*Taufiqur Rachman, Siti Arifaini Suleman, dan Fitrahwati Nur
Department of Ocean Engineering, Hasanuddin University, Indonesia
*Email: trachman@unhas.ac.id

Abstract

The existence of artificial reefs in coastal areas is used to repair damaged habitats by simulating the ecological role of natural coral reefs. The selection of placement locations under the sea is done so that artificial reefs can function properly. The purpose of this study was to determine the influence of hydro-oceanographic characteristics on the placement of artificial reefs that have been carried out in several coastal areas in Indonesia. This research is expected to provide an overview of the effectiveness of artificial reef placement towards efforts to repair damage to the coastal ecosystem. Artificial reef data was obtained in coastal waters located in Java and Sulawesi Island. Review of the application of artificial reefs includes placement location, hydro-oceanographic data, and evaluation of the existing condition of artificial reefs after the sinking period. The review of the relationship between the initial data and the existing condition of artificial reefs after the sinking period at the placement site against the hydro-oceanographic characteristics of the respective coastal water location. The success of artificial reef placement as a coastal ecosystem restoration effort is strongly influenced by bathymetry contours, wave height, current speed, and sediment transport.

Keywords: Artificial Reefs, Hydro-oceanography, Coastal Ecosystem Restoration

1. INTRODUCTION

Artificial reefs are defined by the European Artificial Reef Research Network (EARRN) as structures intentionally placed on the seabed that take on some of the characteristics of natural coral reefs [1]. These artificial habitats are placed on the bottom of unproductive waters or protected areas to restore degraded ecosystems, attract a wide range of marine organisms to live and settle, and increase fisheries production. Artificial reefs are made from an array or pile of materials with different properties, such as old tyres, cement or concrete moulds, shipwrecks, old car tyres, and bamboo [2]. Artificial reef habitats can be used as an increase in biomass exploitation in the continuity and growth of an ecosystem [3]. The presence of artificial reefs is intended to simulate the ecological role of natural coral reefs and to enhance degraded habitats, transforming initially fishless waters into waters that attract schools of fish that congregate in protected areas. In the long term, these artificial reefs will be colonised by natural marine plants and corals. The construction and lowering of artificial reefs is a straightforward activity, but in order to maximise the success of artificial reef restoration efforts, the selection of underwater placement sites requires an understanding of hydro-oseanographic characteristics, including bathymetry, waves, tides, currents and sediment transport.

Most artificial reef structures are specially designed concrete modules with shapes such as coral balls, concrete tubes, concrete blocks and wrecks [4], as shown in Figure 1. However, in long-term applications, these structures can be made from a variety of materials such as old tyres, used cars, or dome or pyramid-shaped concrete structures, which can contribute to the development of natural coral reefs at the site. Artificial reefs can be created to serve as artificial habitats, refuges, feeding grounds and breeding grounds for various populations of marine life [5].

Figure 1. A variety of artificial reefs are widely used in Indonesia

In general, the selection of artificial reef sites requires several criteria, namely: hard water bottom, water depth between 10-25 m, sufficient water clarity, avoidance of strong currents, safe waters from maritime traffic and fishing activities (fish aggregating devices/FADs, floating cages, etc.), away from the harbour shipping channel and close to fishing villages or small fishing areas [6]. Artificial reefs are often placed in shallow (nearshore) waters. The placement of artificial reefs in shallow waters can be an aid to shoreline protection and erosion control. However, the placement of artificial reefs on the seabed is strongly influenced by waves and currents. Ocean waves travelling close to nearshore areas with certain morphological shapes undergo non-linear, dispersive and irregular processes that cause bottom shear stress and turbulence [7, 8, 9]. Wave motion in nearshore areas causes bottom friction effects leading to wave attenuation and sediment transport [10]. Combined with high current velocities, this creates stress on the seabed and pressure on artificial reef structures. The combination of high waves and high current velocities can create turbulence that erodes bottom sediments and causes displacement of artificial reef structures [11].
Based on the above background, this study aims to determine the influence of hydro-oseanographic characteristics on the application of artificial reefs in coastal areas of several provinces in Indonesia. This research is expected to be a consideration for the government and local governments in the placement of artificial reefs must pay attention to the hydro-oseanographic characteristics of artificial reef placement locations, so as to increase the effectiveness of the existence of artificial reefs in an effort to improve the ecosystem of coastal areas damage, help protect the coastline and control erosion.

2. RESEARCH METHODS

Data was collected through a literature review of articles related to the application of artificial reefs in the coastal waters of several Indonesian provinces located on the islands of Java and Sulawesi. The review of the application of artificial reefs includes the location of placement, hydro-oseanographic data of the waters, and evaluation of the existing condition of artificial reefs after some time of placement. The relationship between the initial data and the existing condition of artificial reefs after the sinking period at the placement site was reviewed by taking into account the hydro-oseanographic conditions of the respective coastal waters location.

3. RESULTS AND DISCUSSION

The following is an overview of the placement of artificial reefs that have been implemented in the coastal waters of several Indonesian provinces, specifically the island of Java and the island of Sulawesi.

3.1. Damas Beach, Trenggalek Regency, Province of East Java as Location 1

Artificial cube reefs were constructed in 2017 at depths ranging from 5.0-28.0m and located at coordinates 8°19'30' to 8°20'00"S and 111°41'30" to 111°42'15"E in the waters of Damas Beach, Karanggandu Village, Watulimo Subdistrict, Trenggalek Regency, facing the Indian Ocean, as shown in Figure 2. The average wave height of Damas Beach waters in the morning, afternoon and evening is 0.06m, 0.08m and 0.06m respectively, and the current speed is 0.1 - 0.4m/s. The bottom substrate type of Damas Beach was black fine sand with total suspended solids (TSS) ranging from 35-351 mg/L [12]. Concrete-based artificial cube reefs with a total of 25 units. The artificial cube reef model is a hollow concrete cube with a side length of 60cm and a thickness of 8cm, as shown in Figure 3.

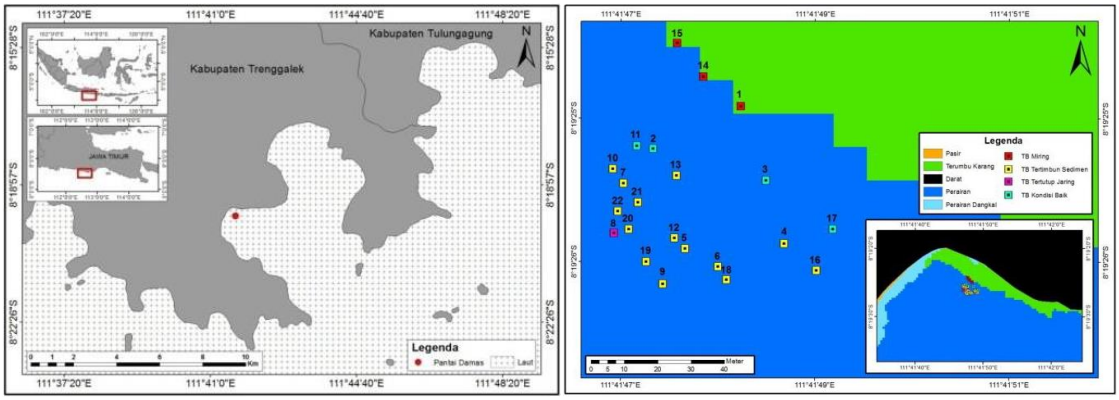

Figure 2. Map of artificial reef installation at Damas Beach [12]

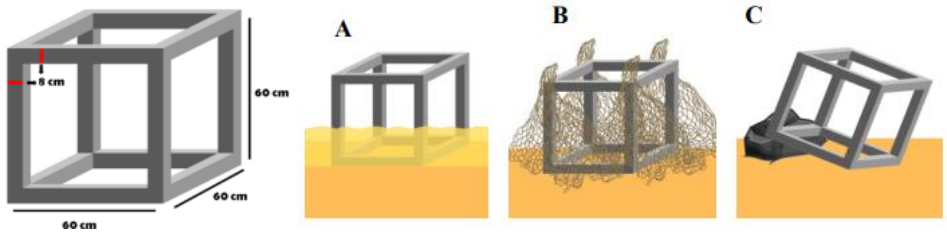

Figure 3. Dimensions and physical condition of artificial cube reefs at Damas Beach (A) Buried by sediments, (B) Covered by nets, and (C) Inclined [12]

Data on the physical characteristics of artificial cube reefs were collected after 2.5 years of sinking, in March 2020. Observations of the physical characteristics of artificial cube reefs were made visually using the underwater photo transect method and underwater digital cameras that produce underwater observation photos. The observation results showed that the physical condition of 25 artificial cube reef units in the waters of Damas Beach was as follows: 4 units in good condition, 14 units buried in sediment, 1 unit covered by net, 3 units in a tilted position (inclined) and 3 units missing. An illustration of the condition of the artificial cube reefs is shown in Figure 3 [12].

3.2. The Waters of Karang Jeruk, Tegal Regency, Province of Central Java as Location 2

This site is one of the Coral Reef Marine Protected Areas in Central Java, located in Munjungagung Village, Kramat Subdistrict, Tegal Regency, commonly known as Karang Jeruk Marine Protected Area. Karang Jeruk Waters is a fishing ground for the area around Tegal Regency. The location of Karang Jeruk Waters facing the Java Sea as shown in Figure 4(a), the position that is open to the influence of waves has a major degrading effect on the area. The management of Karang Jeruk Marine Protected Area is divided into three zones as shown in Figure 4(b), namely; core zone, buffer zone and limited use zone. The zoning is done to achieve sustainable management of fish resources and the environment by mapping damaged ecosystems to plan strategies and priorities for repair and restoration.

The location of the artificial reefs in the Karang Jeruk Waters is at 06°48'49.08"-06°48'58.80"S and 109°2.23'14.04"-109°12.41'54.54"E with a distance of 3.15 miles from the coastline [13]. The sinking of artificial reef balls in the buffer zone was carried out as an effort to preserve the coral reef ecosystem. In 2014, the reef balls were constructed as shown in Figure 5(a) and 15 units were sunk at a depth of 12 to 14 metres. The presence of artificial reefs in the Karang Jeruk Waters area has a positive impact on the water conditions as shown in Figure 5(b), as indicated by an increase in the presence of phytoplankton, juveniles and reef fish.

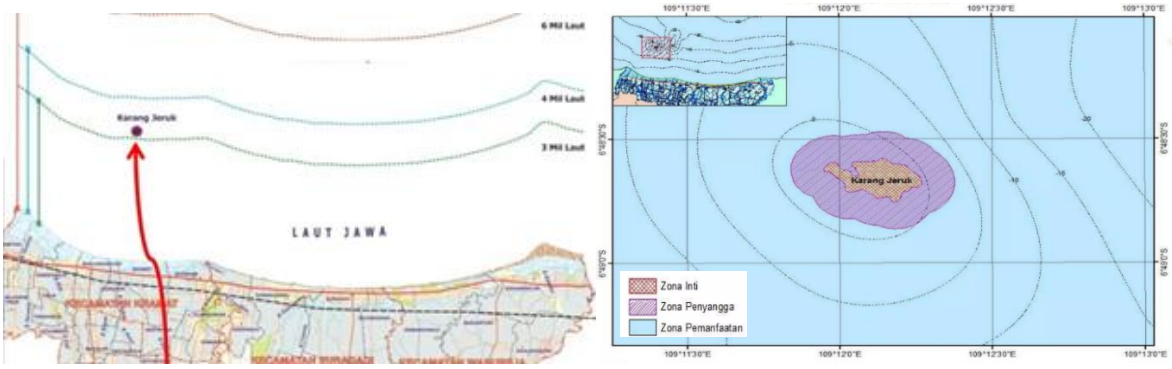

Figure 4. (a) Location of artificial reefs; (b) The zoning of the Karang Jeruk Marine Protected Area [13]

(a) Construction of reef balls; (b) Condition of reef balls after several years of use

Figure 5. Reef ball type artificial reef in Karang Jeruk waters [13]

3.3. The Waters of Malalayang Dua, Manado City, Province of North Sulawesi as Location 3

The artificial reef was placed in the waters of Malalayang Dua Sub-district, Malalayang District, Manado City, North Sulawesi Province, as shown in Figure 6. This artificial reef is the realisation of the bamboo reef rehabilitation work in 2015 [14], and was placed at a depth of 12m facing the waters of Manado Bay in the area around natural coral reefs in the waters of Malalayang Dua Sub-district. The bathymetric condition of the artificial reef site has land slope categories, namely flat and inclined. The flat category with a slope of 2.6% is found at depths between 0-7.0m, which is filled with natural coral reef flats. While the inclined category with a slope level of 13% is found at depths between 7.0-50.0m [15]. The waters of Malalayang Dua Sub-district have wave heights (H) between 0.016-1.46m and wave periods (T) between 1.304-3.2 seconds [16].

The artificial reef in the waters of Malalayang Dua Sub-district measures 200x200x50cm (LxWxH) with a substrate base frame. On each side of the substrate base frame there are parallel pieces of bamboo, and in the middle of each side of the substrate media frame there is an empty part as a hole for fish to enter and exit. On each piece of bamboo, small holes were made as a place to attach the corals to be transplanted, and on the top there is a trapezoidal bamboo frame unit [14], as shown in Figure 7.

The artificial reef site was monitored after 8 months and 15 species of demersal coral fish were found around the artificial reef. This shows that artificial reefs are good enough to be developed for coral rehabilitation in degraded areas and to become a habitat for fish in these waters [14].

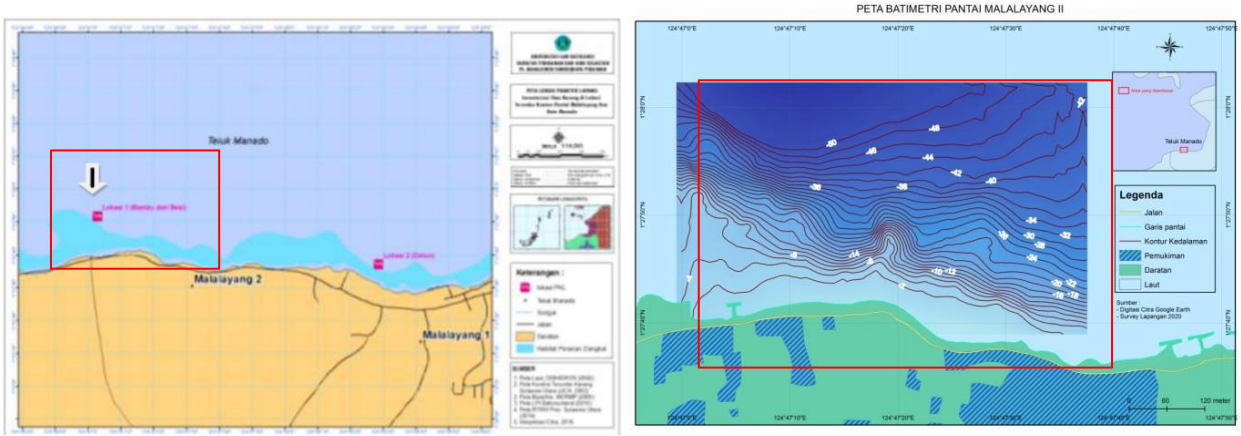

Figure 6. Map of the locations of the artificial reefs in the waters of Malalayang Dua Sub-district [14, 15]

Figure 7. Physical form of artificial reefs before and after installation in Malalayang Dua Sub-district waters [14]

The placement of artificial reefs in three provincial locations in Indonesia has been reviewed, namely Java Island precisely in Damas Beach, Trenggalek Regency, East Java Province facing the Indian Ocean and in the waters of Karang Jeruk, Tegal Regency, Central Java Province facing the Java Sea, and Sulawesi Island facing the waters of Manado Bay precisely in Malalayang Dua Waters, Manado City, North Sulawesi Province. Basically, the success of artificial reef placement can be viewed from several aspects of feasibility, such as ecological/ecosystem feasibility, technical feasibility, and economic feasibility. However, this research focuses on the technical feasibility aspect related to the artificial reef structure in relation to the hydro-oseanographic condition parameters at the artificial reef placement site.

Technical feasibility includes the placement of artificial reef structures at a certain depth, that they are strong and resistant to hydro-oseanographic conditions, i.e. bathymetry, waves, currents and sediment transport (bottom sediment and drift sediment) at the placement site, and that they practically do not interfere with shipping lanes and fishing activities. The placement of artificial reefs in a particular location can cause changes in the flow patterns on the seabed, which can affect the shape of the bathymetric contours of the site. Especially if the current speed at the artificial reef placement site is in the medium to strong speed category, which can move suspended sediments and even bottom sediments.

Site 1 showed that the current speed at the artificial reef deployment site was 0.1-0.4 m/s, which is classified as slow to moderate current speed. Current velocity is classified into five categories: very fast current (>1 m/s), fast (0.5-1 m/s), moderate (0.25-0.5 m/s), slow (0.1-0.2 m/s) and very slow (<0.1 m/s) [17]. Circulating currents play an important role in the energy transfer process. Water currents and circulation play a role in the sedimentation process. Sedimentation drifts of solid silt particles (total suspended solids) carried by surface runoff due to erosion can settle and cover the surface of artificial reefs. This condition resulted in 14 artificial reef units located in the 5-15 m depth interval, some of the artificial reef structures were covered by sediments. Even with TSS concentrations of 35-351 mg/L, it can also be inferred that 3 artificial reef units were lost due to submergence (part of the structure was completely covered) by a layer of sediment. High TSS concentrations in a water body can be used as an indicator or tendency of high sedimentation. The condition of one artificial reef unit, which was covered with net waste because it was located directly under the floating net cage owned by local fishermen. The condition of 3 sloping artificial reef units is due to the process of placing artificial reefs using only ropes from the surface, so the condition of the seabed is unknown, the substrate is flat or sloping. Placement of artificial reefs in sandy areas with moderate current speeds can cause the condition of artificial reefs to be unstable or easily shifted so that they eventually tilt.

At site 2, it is known that the current speed in Karang Jeruk Tegal waters is in the medium category, namely 0.3m/s, and this medium current speed range is suitable for coral reef life. The bathymetric condition of Karang Jeruk waters is categorised as a flat slope with a rocky/hard bottom and little sediment, and a natural coral reef flat. This results in the physical condition of artificial reefs placed in Karang Jeruk waters being in good condition and functioning.

At site 3, the artificial reef structure was placed at a depth of 12m on a hard and solid seabed so that the structure would not be affected by sedimentation. Although the artificial reef structure is considered lightweight because it is made of bamboo material and placed on a inclined seabed, the structure remains in place because it is equipped with a strong anchor to maintain the position of the artificial reef. This means that the artificial reef can function well and withstand the hydro-oseanographic conditions of the installation site in the waters of Manado Bay.

Since 2023, the installation of artificial reefs has required the submission of a Permit of Conformity of Marine Spatial Utilisation Activities (PCMSUA) to the Ministry of Marine Affairs and Fisheries. This refers to Law No. 6 of 2023 on the incorporation into law of Government Regulation No. 2 of 2022 on the creation of employment, namely Article 47(4) in Article 19, which states that "Any person who carries out the use of

marine space on a permanent basis in the territorial waters and jurisdictional areas must have the suitability of marine space utilisation activities". Furthermore, Article 113 states that the use of sea space for non-business activities carried out by government agencies and/or local governments or local communities/traditional communities requires "confirmation of sea space suitability" [18]. In addition to ensuring compliance with marine spatial plans and marine zoning plans, the issuance of the PCMSUA also takes into account the conservation of coastal ecosystems, the existence of protection and conservation areas for marine biota, the existence of protection areas for cultural sites and unique marine geomorphological features. The submission of the PCMSUA document is also accompanied by a review of the technical aspects of the hydro-osenographic conditions of the location of the waters to be used [19]. The PCMSUA is a basic requirement that must be possessed by the operators of permanent activities in the marine area in accordance with Government Regulation No. 5 of 2021 on the Implementation of Risk-Based Business Licensing [20] and Government Regulation No. 21 of 2021 on the Implementation of Spatial Planning [21]. The implementation of this PCMSUA is regulated by the Minister of Maritime Affairs and Fisheries Regulation No. 28 of 2021 on the Implementation of Marine Spatial Planning [22].

4. CONCLUSION

The influence of hydro-oseanographic characteristics on the placement of artificial reefs in coastal areas of several provinces in Indonesia has been carried out and has a significant influence on the success of artificial reef implementation at a site. Bathymetry, wave height, current velocity and sedimentation data affect the state of artificial reef placement after a certain period of time, so that the purpose and function of the presence of artificial reef structures can be assessed. The installation of artificial reefs according to Law No. 6 of 2023 requires the Permit of Conformity of Marine Spatial Utilisation Activities (PCMSUA) to be submitted to the Ministry of Marine Affairs and Fisheries. The PCMSUA document must be completed with a review of the technical aspects of the hydro-osenographic conditions of the location of the waters to be used.

REFERENCES

[1] Baine, M., 2001, Konsep Kebijakan, Strategi dan Rancang Tindak Pengelolaan Terumbu Karang, Kerjasama PKSPL-IPB dan Puslitbang LIPI. 33 hal.

[2] Direktorat Jendral Kelautan Pesisir dan Pulau–Pulau Kecil, 2005. Pedoman Pengelolaan Terumbu Buatan dan Transplantasi Karang. Departemen Kelautan dan Perikanan. 93 hal.

[3] Polovina, J. J., 1991, A Global Perspective on Artificial Reefs and Fish Aggregation Devices, IPFC, *Paper presented at the Symposium on Artificial reefs and Fish Aggregationg Device as Tools for The Management and Enhancement of Marine Fishery Resources*, Colombo, Sri Lanka. RAPA Report: 1991/11 p. 251-257.

[4] Lemoine, H. R., Paxton, A. B., Anisfeld, S. C., Rosemond, R. C., and Peterson, C. H., 2019, Selecting The Optimal Artificial Reefs to Achieve Fish Habitat Enhancement Goals, Biological Conservation, 238:108200.

[5] Setiawan, I. E., 2009, Penerapan Teknologi Terumbu Buatan di Perairan Laut Pulau Abang Batam, *Hidrosfir Indonesia*, 4(2), 1–7.

[6] Sutarto, 2000, Pengenalan tentang Rumpon dan Terumbu Karang Buatan, Balai Besar Pengembangan Penangkapan Ikan (BBPPI), Semarang.

[7] Rachman, T., Suntoyo, Sambodho, K., Armono, H. D., and Yusroni, E., 2011, Numerical Modeling of Turbulent Bottom Boundary Layer over Rough Bed under Irregular Waves, *IPTEK The Journal for Technology and Science*, 22(4).

[8] Rachman, T., and Suntoyo, 2011, A New Method for Modeling Bottom Shear Stress under Irregular Waves, *IPTEK The Journal for Technology and Science*, 22(2).

[9] Suntoyo, F. A., Fahmi, M. Y., Rachman, T., and Tanaka, H., 2016, Bottom shear stress and bed load sediment transport due to irregular wave motion, *ARPN J. of Engineering and Applied Sciences*, 11(2), 825-829.

[10] Rachman, T., and Suntoyo, 2012, Prediction of Sediment Transport Due to Irregular Wave Motion, *Jurnal Ilmu dan Teknologi Kelautan Tropis*, 4(2): 318-334. Terdapat pada laman https://doi.org/10.29244/jitkt.v4i2.7793

[11] Seaman, W. (Ed.), 2000, Artificial Reef Evaluation: with Application to Natural Marine Habitats.
[12] Sirait, A. P., Luthfi, O. M., dan Isdianto, A., 2021, Karakteristik Fisik Terumbu Buatan (Artificial Reef) Pasca Penenggalaman Tahun 2017 di Pantai Damas Trenggalek, *Journal of Marine and Coastal Science*, 10(1), 58.
[13] Zuhry, N., 2016, Upaya Pelestarian Terumbu Karang, Sosialisasi Rehabilitasi Sumberdaya Kelautan dan Perikanan, Dinas Kelautan dan Perikanan Propinsi Jawa Tengah, Tegal, 31 Maret.
[14] Kambey, A. D., Bataragoa, N. E., and Wantasen, A. S., 2017, Study on Artificial Reef Made of Bamboo "Bambooreef" in Malalayang Dua Waters, Malalayang District, Manado, *Jurnal Ilmiah Platax*, 5(1), 1. https://doi.org/10.35800/jip.5.1.2017.14967
[15] Lahay, A., Djamaluddin, R., Manengkey, H. W. K., dan Djabar, B., 2020, Pemetaan Batimetri Pantai Malalayang Dua Kota Manado, *Jurnal Pesisir dan Laut Tropis*, 8(3), Universitas Sam Ratulangi, Indonesia.
[16] Gerrits, L., Thambas, A. H., dan Jasin, M. I., 2020, Analisis Kinerja Gelombang di Pantai Malalayang II, *Jurnal Sipil Statik*, 8(1), hal. 39-44, Universitas Sam Ratulangi Manado
[17] Haliza, S. S. T., Ghitarina, G., dan Mustakim, M., 2022, Identifikasi Jenis dan Kelimpahan Sampah Laut di Pesisir Pantai Pemedas Kecamatan Samboja Kabupaten Kutai Kartanegara Kalimantan Timur, *Jurnal Tropical Aquatic Sciences*, 1(1), 69–75.
[18] Undang-Undang Republik Indonesia No 6 Tahun 2023 tentang Penetapan Peraturan Pemerintah Pengganti Undang-Undang Nomor 2 Tahun 2022 tentang Cipta Kerja menjadi Undang-Undang.
[19] Fauzan, D., Rachman, T., dan Fadly, M., 2023, Evaluasi Aspek Teknis Persetujuan Kesesuaian Kegiatan Pemanfaatan Ruang Laut (PKKPRL) sesuai Undang-Undang N0. 6 Tahun 2023, *Riset Sains dan Teknologi Kelautan*, 287-295.
[20] Peraturan Pemerintah No 5 Tahun 2021 tentang Penyelenggaran Perizinan Berusaha Berbasis Resiko.
[21] Peraturan Pemerintah No.21 Tahun 2021 tentang Penyelenggaraan Penataan Ruang.
[22] Peraturan Menteri Kelautan dan Perikanan No. 28 Tahun 2021 tentang Kesesuaian Kegiatan Pemanfatan Ruang Laut Memberikan Kepastian Hukum terhadap Pemanfaatan Ruang di Laut.