# UTILIZING THE POTENTIAL RIG-TO-REEF AS A SUSTAINABLE SOLUTION FOR MARINE WASTE MANAGEMENT: CASE STUDY AND ENVIRONMENTAL ASSESSMENT OF PLATFORM "MAN"

*by* eny suparni

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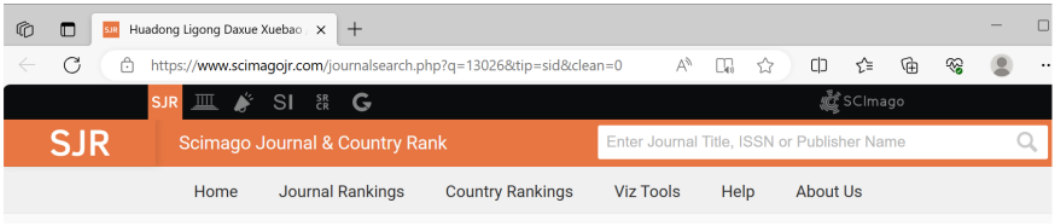


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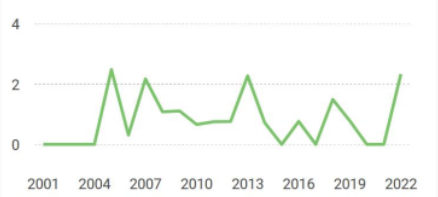


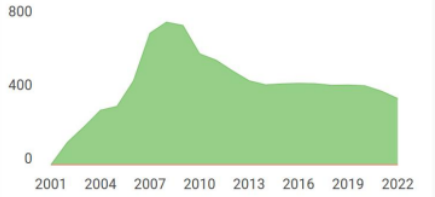


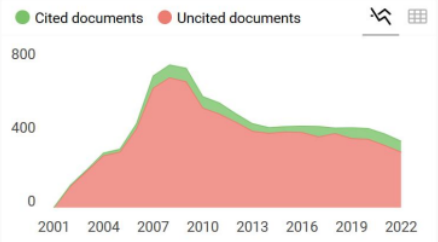



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## Abstract

Marine waste pollution has emerged as a pressing global issue, necessitating the exploration of innovative solutions for sustainable marine waste management. Offshore North West Java, with its many marine conservation areas and biodiversity, faces the risk of damage to these conservation areas from oil platforms that have been abandoned for too long. The research aims to assess the effectiveness and environmental implication of Rig-to-Reef (R2R) in addressing marine waste management challenges, specifically in the offshore North West Java region. R2R is a promising method that utilizes decommissioned offshore oil and gas platforms as artificial reefs, simultaneously providing new habitats for marine organisms and mitigating marine waste. A mixed-methods approach is adopted with literature study and incorporating quantitative field data analysis. The case study centers on decommissioning of Platform "MAN". Data is collected through examination before the implementation of R2R initiatives. This study examines the transformations that occur on the platform structures after their conversion into artificial reefs that impact the environment including the changes in biodiversity, species composition, and biomass, alongside the water quality parameters. Potential ecological benefits, such as increased fish populations, enhanced coral cover, and the establishment of new marine habitats, are assessed to gauge the positive outcomes of R2R initiatives in Offshore North West Java. Furthermore, R2R offers a cost advantage of USD 706,865 or approximately 30.4% more economical than conventional decommissioning. This makes R2R an appealing option for decommissioning offshore platforms, providing potential cost savings while still promoting marine biodiversity through the conversion of platform parts into artificial reefs. In conclusion, the potential outcomes are associated with R2R implementation, including factors such as marine waste reduction, efficiency on decommissioning expenses, and local economic growth. As the oil and gas industry embraces more environmentally friendly practices, Rig-to-Reef presents itself as a viable solution to balance ecological conservation and industrial operations. The findings from this study aim to provide valuable insights of Platform "MAN" into the feasibility, efficiency, and sustainability of R2R as a solution for marine waste management in the Offshore North West Java.

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# UTILIZING THE POTENTIAL RIG-TO-REEF AS A SUSTAINABLE SOLUTION FOR MARINE WASTE MANAGEMENT: CASE STUDY AND ENVIRONMENTAL ASSESSMENT OF PLATFORM "MAN"

**Dedy Kristanto[a*], Nanda Berkah Pratama[a*], Azhar Faari Fatahillah[a], Michael Revindra Adiperdana[a], Luky Agung Yusgiantoro[b]**

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## ABSTRACT

Marine waste pollution has emerged as a pressing global issue, necessitating the exploration of innovative solutions for sustainable marine waste management. Offshore North West Java, with its many marine conservation areas and biodiversity, faces the risk of damage to these conservation areas from oil platforms that have been abandoned for too long. The research aims to assess the effectiveness and environmental implication of Rig-to-Reef (R2R) in addressing marine waste management challenges, specifically in the offshore North West Java region. R2R is a promising method that utilizes decommissioned offshore oil and gas platforms as artificial reefs, simultaneously providing new habitats for marine organisms and mitigating marine waste. A mixed-methods approach is adopted with literature study and incorporating quantitative field data analysis. The case study centers on decommissioning of Platform "MAN". Data is collected through examination before the implementation of R2R initiatives. This study examines the transformations that occur on the platform structures after their conversion into artificial reefs that impact the environment including the changes in biodiversity, species composition, and biomass, alongside the water quality parameters. Potential ecological benefits, such as increased fish populations, enhanced coral cover, and the establishment of new marine habitats, are assessed to gauge the positive outcomes of R2R initiatives in Offshore North West Java. Furthermore, R2R offers a cost advantage of USD 706,865 or approximately 30.4% more economical than conventional decommissioning. This makes R2R an appealing option for decommissioning offshore platforms, providing potential cost savings while still promoting marine biodiversity through the conversion of platform parts into artificial reefs. In conclusion, the potential outcomes are associated with R2R implementation, including factors such as marine waste reduction, efficiency on decommissioning expenses, and local economic growth. As the oil and gas industry embraces more environmentally friendly practices, Rig-to-Reef presents itself as a viable solution to balance ecological conservation and industrial operations. The findings from this study aim to provide valuable insights of Platform "MAN" into the feasibility, efficiency, and sustainability of R2R as a solution for marine waste management in the Offshore North West Java.

**Keywords:** Rig-to-reef, Marine waste management, Cost efficiency, Ecofriendly

## INTRODUCTION

The oil and gas industry, while vital for meeting global energy demands, has inadvertently left behind a legacy of environmental challenges, prominently exemplified by the issue of marine waste arising from abandoned oil platforms. As these platforms cease operations and fall into disuse, they become potential sources of marine pollution, with the specter of oil spills and debris of its construction casting a shadow over marine ecosystems.

Oil spills, whether stemming from structural deterioration, natural events, or inadequate regulatory oversight, pose a severe threat to marine life, coastal communities, and entire ecosystems. Moreover, this concern encompasses not only the catastrophic consequences of oil spills that can harm the marine

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ecosystem but also the economic impact as well. Figure 1 shows that the oil spill from the allision of offshore construction is still the major lead to the contribution (Zafirakou, A., et al. 2018).

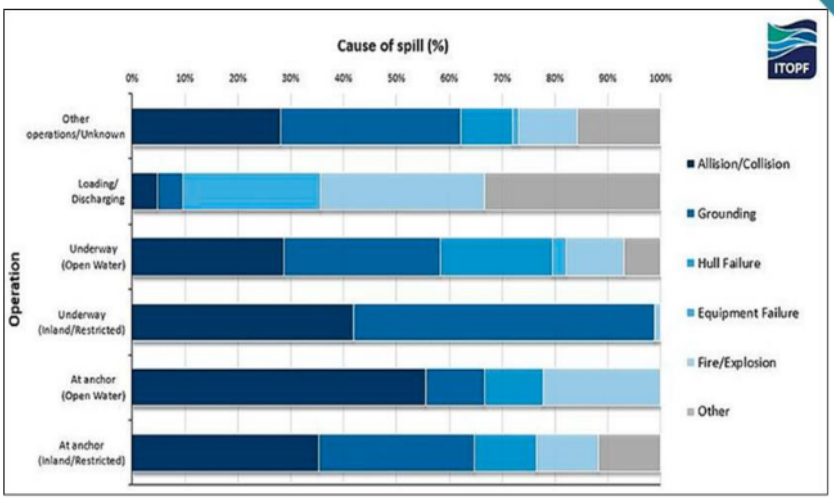


**Fig. 1.** Platform Allision Impacts of the Oil Spill in Marine (Zafirakou, A., et al. 2018)

In the case of Offshore North West Java (ONWJ), 73 leftover oil production facilities have been abandoned since 1983 (SKK Migas, 2023). Those platforms have accumulated into a sizable issue of marine garbage buildup, this urgency is well exemplified. The overall effects of this situation put the integrity of the marine environment in danger and throw doubt on keeping important marine conservation areas and the biodiversity they harbor. Figure 2 displays how many abandoned oil platforms in Indonesia. The intricate interplay between marine conservation, saving biodiversity, and the possible environmental dangers from abandoned oil platforms becomes really clear in ONWJ. This area has marine conservation zones and a lot of diverse marine life. It's facing a crucial decision on how to protect its fragile ecosystems while also dealing with the problems caused by abandoned oil platforms. A salient example is Eretan Bay, a veritable haven for marine biodiversity and also a site that houses oil production platforms (Gade, M., et al. 2016).

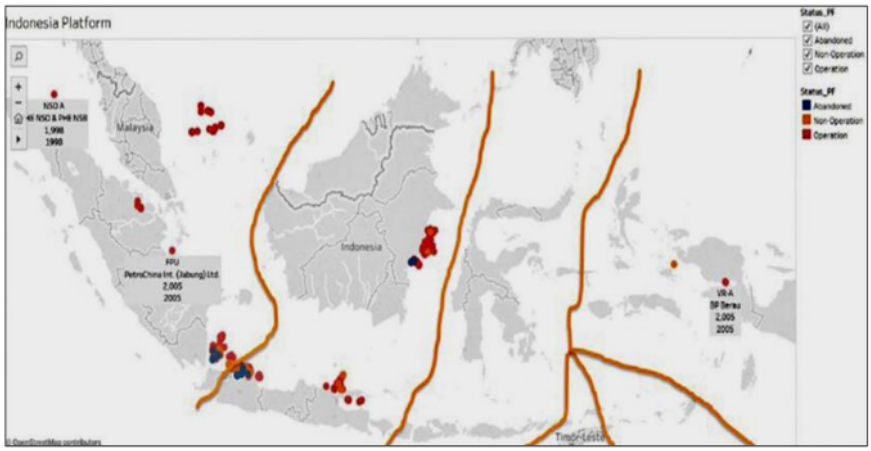


**Fig. 2.** Abandoned Oil Platforms in Indonesia (SKK Migas, 2023)

In the midst of this complex landscape, the case study of Platform "MAN" assumes significance. It represents a microcosm of the challenges and opportunities at hand. Situated within the context of Eretan

Bay, Platform "MAN" occupies a unique juncture where the preservation of marine biodiversity intertwines with the potential ramifications of abandoning oil platforms for prolonged periods.

By examining the transformation of Platform "MAN" into an artificial reef through the Rig-to-Reef (R2R) initiative, this study delves into the nuances of reconciling industrial history with ecological conservation. The examination of Platform "MAN" provides a lens through the newest government policy to safely handle the leftover oil production platforms that Contractors are required to conduct Post-Operation Activities (Regulation of The Minister of Energy and Mineral Resources Republic of Indonesia No. 15, 2018).

The R2R concept is brought up within the context of the existence of abandoned offshore platforms in the ONWJ. Given the significant marine potential of ONWJ, it is regrettable that detrimental factors are impacting the marine ecosystem due to these abandoned rigs. This program acts as a proactive measure to address issues arising from abandoned platforms, simultaneously creating new marine habitats. A notable advantage of R2R over conventional decommissioning methods is its cost-effectiveness, reducing expenses associated with conventional approaches while yielding positive environmental outcomes.

Furthermore, it is hypothesized that the establishment of these artificial reefs would support better conservation efforts in the Offshore North West Java in addition to mitigating any possible negative effects brought on by abandoned platforms. According to this hypothesis, the R2R strategy will work in concert with the current marine protected zones to protect both marine biodiversity and crucial biological processes. The R2R program emerges as a solution, highlighting the reutilization of qualified platform structures.

## OVERVIEW OF RIG-TO-REEF (R2R)

Rig-to-Reef (R2R) concept was initially introduced in Florida with the aim of relocating Exxon's offshore Louisiana structure. The conducted Rig-to-Reef program in Louisiana represents the utilization of abandoned oil platforms and serves as a manifestation of regulatory innovation. Initiated in 1985 across Louisiana and Texas, this program has provided new habitats and opportunities, serving as both recreational and fishing objectives for both human and marine organisms (Kasprzak, 1998). There are three methods of rig-to-reef i.e., tow and place, partially removed, and toppled (Bull, et al. 2019) as shows in Figure 3.

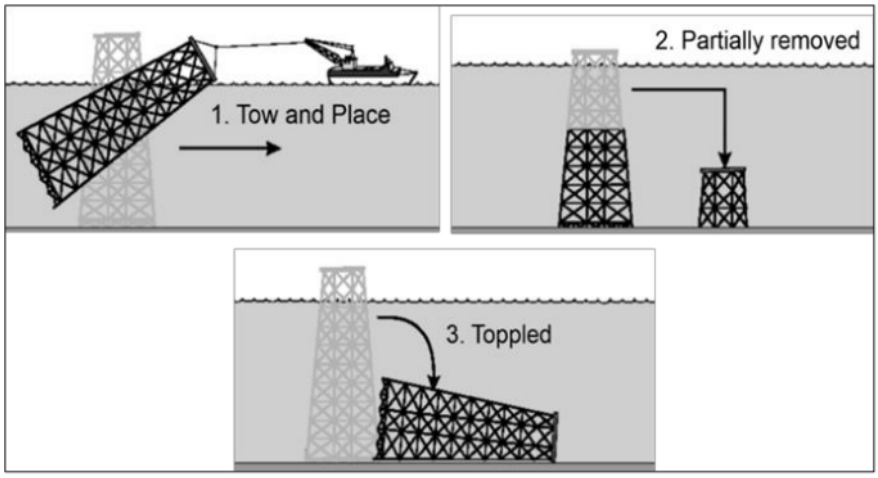


**Fig. 3.** Illustration on Different Methods of Rig-to-Reef (Bull et al., 2019)

The oil and gas platforms off the coast of California are the most productive marine habitats per unit area in the world and even the least productive platform was more productive than the Chesapeake Bay or a coral reef in Moorea (Claisse, J.T., 2014). Rig-to-Reef represents a promising approach to decommissioning, highlighting the utilization of obsolete platform structures by converting them into reefs,

rather than the costly process of bringing them back to shore for storage (Kaiser, 2006). This concept presents an effective method for fulfilling budget constraints while concurrently generating opportunities for both human and marine endeavors, and it also stands out as an efficient approach for addressing budget limitations while fostering opportunities for human activities and marine ecosystems. In the course of its application, there exist methodologies that necessitate careful consideration of the qualifications that must be fulfilled as illustrated in Figure 3.

Figure 3a, shows "Tow and Place" method is a Rig-to-Reef approach that entails the utilization of mechanical cutting techniques on the platform's bottom section. After cutting, the platform is transported via tug boat to a qualified intended area chosen for it to become an artificial reef. The designated area for securing a platform as an artificial reef is determined by factors such as the depth of the sea floor measured from the sea surface and shipping lane considerations (Bull et al., 2019).

The "Partial Removal" method is shown in Figure 3b, involves cutting a portion of the platform and separating it into upper and bottom parts. The upper portion is laid on the sea floor, while the bottom part remains standing at a certain height above the seafloor. A recent instance of this method was executed on the Baram-8 Platform in Malaysia. During the conversion process, the platform was divided into two sections, with the bottom part anchored in shallower waters and the upper part positioned 14 meters below the sea surface (Mohd et al., 2020).

Figure 3c, shows "Toppled" method employs the platform as an artificial reef right at its original location, involving an explosion and mechanical cutting of the platform's bottom parts through cutting.

Based on the mentioned implementation method, the selection of Rig to Reef deployment sites can be conducted through in-situ and ex-situ approaches. In-situ placement involves converting the platform directly to its original location, while ex-situ entails setting the Rig-to-Reef concept in a different area. The decision to designate for in-situ or ex-situ placement is based on the platform's depth qualification from the sea bed and the presence of shipping lanes in the area. In cases where a platform stands within a shipping lane, it is an obligation that the platform maintains a minimum depth of 100 ft from the sea floor to facilitate in-situ deployment. The in-situ approach can also be considered by addressing marine habitat deficiencies in the area, enabling the artificial reef to mimic a natural reef.

## DECOMMISSIONING PROJECT STAGES OF THE OIL AND GAS INDUSTRY

The interdependence of the project management phases-initiation, site selection, scoping, implementation of abandonment, and termination of the project plays an important role in effectively addressing the challenge. This comprehensive approach not only improves waste management efficiency but also preserves marine ecosystems. Detailed road map for oil production platform decommissioning is shows in Figure 4.

The "Initiation" lays the groundwork for responsible marine litter management. By setting clear waste reduction goals and aligning them with the broader project goals, stakeholders can emphasize the importance of minimizing waste generation and ensure that waste management considerations are integrated into this project.

“Selection of site” is of increasing importance in the field of marine litter management. Through careful assessment of potential sites, taking into account waste treatment methods, proximity to waste treatment facilities, and environmental sensitivities, stakeholders can ensure that waste generated during decommissioning is managed responsibly.

“Scope Definition” plays a central role in streamlining waste management efforts. By accurately outlining project waste management requirements, stakeholders ensure that adequate resources are allocated for the segregation, collection, treatment, and disposal of waste. A clear definition of scope avoids last-minute adjustments and ensures waste management strategies are comprehensive.

“Abandonment execution" directly affects the generation and disposal of marine litter. This stage requires strict adherence to environmentally responsible waste management practices, including proper sorting, packaging, and disposal of waste. Effective implementation will minimize the volume of waste generated and ensure that hazardous waste is disposed of appropriately. "Project End" marks the latest opportunity

to ensure responsible marine litter management. Stakeholders can evaluate the effectiveness of waste management strategies.

The integration of these project management phases into marine waste management underscores the commitment to environmental stewardship. By following this holistic approach, stakeholders can reduce the ecological impact of waste generated during offshore oil rig decommissioning, protect marine ecosystems, and contribute to better practices. In the context of decommissioning, storage or utilization of the abandoned platform is considered to save marine waste. Transferring the abandoned platform to shore requires extra transport costs. Therefore, stakeholders are seeking the utilization of the abandoned oil platforms.

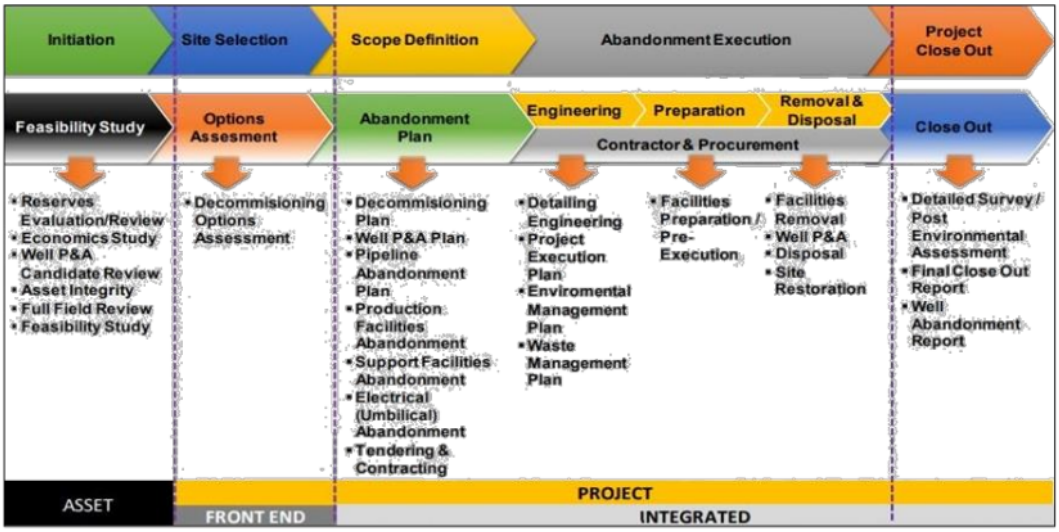


**Fig. 4.** Road Map for Oil Production Platform Decommissioning

## OVERVIEW OF THE ATTAKA RIG-TO-REEF PROGRAM

The pilot project of Attaka Platforms was completed in cooperation with the South Korean Government (PHKT, 2022). The project succeeded in November 2022. Before the project, decommissioning offshore constructions had never been done in Indonesia since the first platform was constructed nearly 50 years ago. Nugraha (2019) conducted a study of three decommissioned platforms in the Attaka block, East Kalimantan. Those platforms belonged to Chevron Indonesia Company (CICo).

The assessment included Indonesian government policy analysis, a cost-benefit analysis of the demolition, and a feasibility analysis of an offshore platform in the Attaka block. The screening criteria for decisioning the R2R program in the Attaka block are summarized in Table 2. of the study from Nugraha (2019). The optimum depth of the ocean is 60-150 ft. Due to the consideration of shipping lanes, the clearance adds 85 ft. The exact location of the platforms was not feasible to perform in-situ R2R. To guarantee that the platform's structure is solid and does not collapse or move in these places, the ideal location for R2R must have a flat, broad seabed made up of sedimentary material, such as pebbles or sand with shells, and a topographic slope of no more than 10.

Knowledge of larval dispersal trajectories is one factor to take to account when placing decommissioned platforms in sites that would maximize ecological advantages as it will boost recruitment success and help retain larvae (coral) that would otherwise be "lost" to friendly substrates (Thompson et al., 2009). Therefore, the selection of the R2R site identifies marine and benthic ecosystems in the surrounding area of Karang Segajah, Ex-Situ, which can be seen in Figure 5. The abandoned platform was barged to Bontang and dropped out at the potential locations in Karang Segajah.

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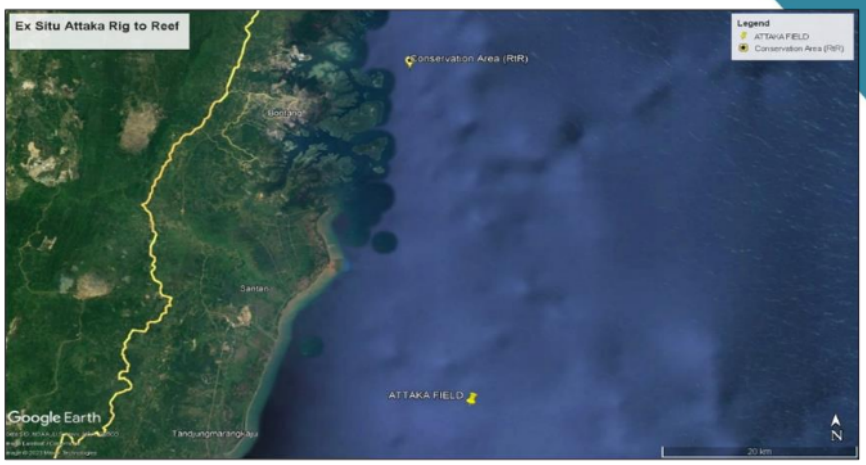


**Fig. 5.** Attaka R2R Project Location in Conservation Area

According to Nugraha et al. (2019), the benefits of R2R based on the Attaka case, were NPV value with an 11-year program duration, a discount rate of 4.02%, and a future rate of money of 5.98% was Rp. 859.64 billion. This value indicates that within 30 years of the project, a platform conversion program of former offshore oil and gas platforms to become an artificial reef ecosystem can be declared feasible.

The option has the potential of creating an environment for farming coastal fish and larvae based on the simulation that the study had. The study has calculated that the fish cage gives a high return for only 2 or 3 years, however, this alternative brings its own obstacles including placing and retrieving the cages from within the structure, overall safety considerations, high capital investment as well as the operational and maintenance cost.

## CASE STUDY OF OFFSHORE NORTH WEST JAVA

Indonesian territorial waters cover about three million square kilometers. Thereby being larger than the Mediterranean Sea, and are home to more than 3,000 species of fish and more than 500 species of corals (Gade, M., et al., 2016). Offshore North West Java has an area of 1,655,121 hectares (Geospatial Information Centre through Detik.com. 2021). According to the Division for Sustainable Development Department of Economic and Social Affairs United Nations (2017) with goal number 14 Sustainable Development Goals on conservation and sustainable use of marine, oceanic, and maritime resources for sustainable development, at least 10% of the coastal and marine areas are marine protected area-based management. Furthermore, major ship traffic routes, connecting the economic centers on the South China Sea (and beyond) with Europe, Africa, Australia, or the Persian Gulf, run through Indonesian waters.

Figure 6 shows that there is a Marine Protected Areas (MPA) in Eretan Bay. It is an area consisting of various marine habitats. The density of reef fishes variated from 5.967±1.767 ind/ha to 20.433±10.355 ind/ha with 85 species and 18 families and the density of benthos variated from 2.000±1.000 ind/ha to 14.667±14.964 with 29 species and 23 families (Nuriadi et al., 2012). There is an Eretan Wetan fishing port in Indramayu Regency which accommodates fishery products in Eretan Bay (Presidential Regulation No. 3 of 2022 Article 19 Point 3). Summarizes the coral condition in this Marine Protected Area (MPA) when the first observation initiatives are shows in Table 1.

ONWJ is not only an area for various marine conservation, but also for oil and gas industry platforms. Gade, M., et al. (2016) examined the marine waste problem from oil and gas activity. Figure 7 shows oil spills show up on SAR imagery as dark patches.

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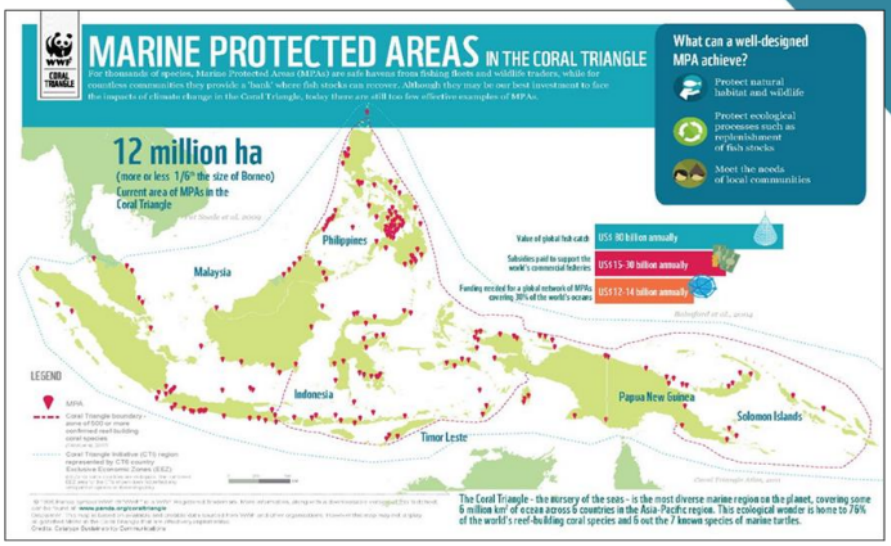


**Fig. 6.** Marine Protected Area (MPA) Distribution in Indonesia (Gade, M., et al. 2016)

**Table 1.** Coral Cover of MPA on ONWJ

| Depth, ft | Coverage, % | | Abiotic | Algae | Other Biota |
|---|---|---|---|---|---|
| | Life | Dead | | | |
| **10** | 52.42 | 12.70 | 32.18 | 2.55 | - |
| **32** | 23.09 | 39.96 | 35.90 | - | 1.05 |

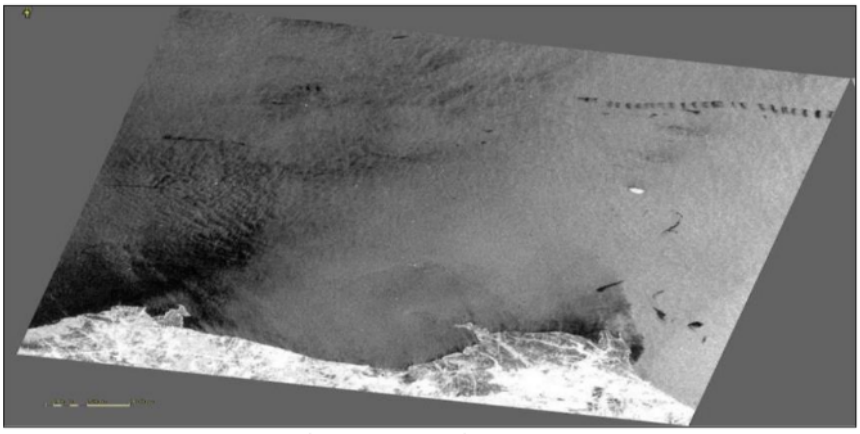

**Fig. 7.** SAR Imagery of the Eretan Bay.
The Upper Right Part of the Image is an MPA (Gade, M., et al. 2016)

Platform "MAN" is the closest platform location near the MPA (06°0558.23"S - 108°08'33.28"E), as shows in Figure 8. As this study mentioned previously, the allision of offshore structure led to a major impact of oil spills. This abandoned platform has been left since 1983 and significantly contributes to the marine waste.

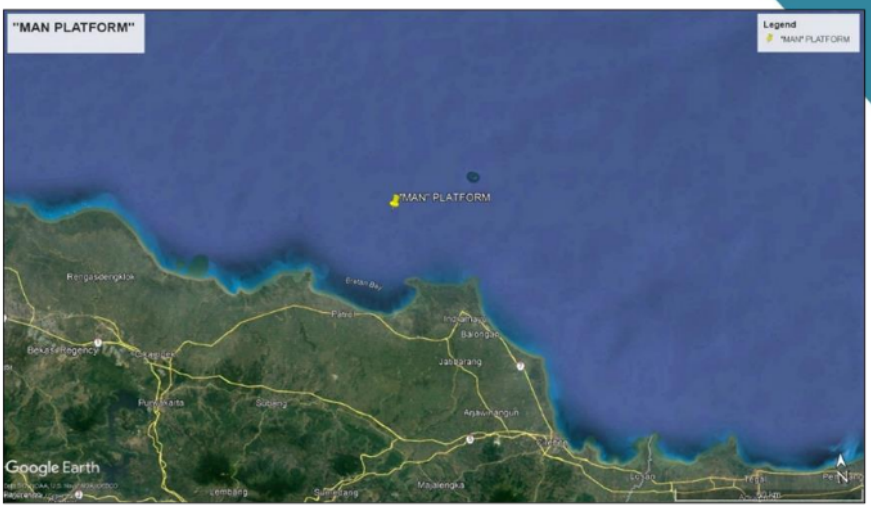


**Fig. 8.** Platform "MAN" Location

### 5.1. Regulatory Landscape

The complex interplay of these regulatory tools has important implications not only for the responsible practice of offshore oil rig incidents but also for the broader areas of governance. marine waste management and marine sustainability. As the oil and gas industry grapples with environmental concerns, the culmination of these regulations forms a solid framework that goes beyond safety to encompass ecological survival and orderly execution. As depicted in Figure 9, those regulations serve as a beacon of guidance for responsible waste disposal practices during and after the oil rig is decommissioned.

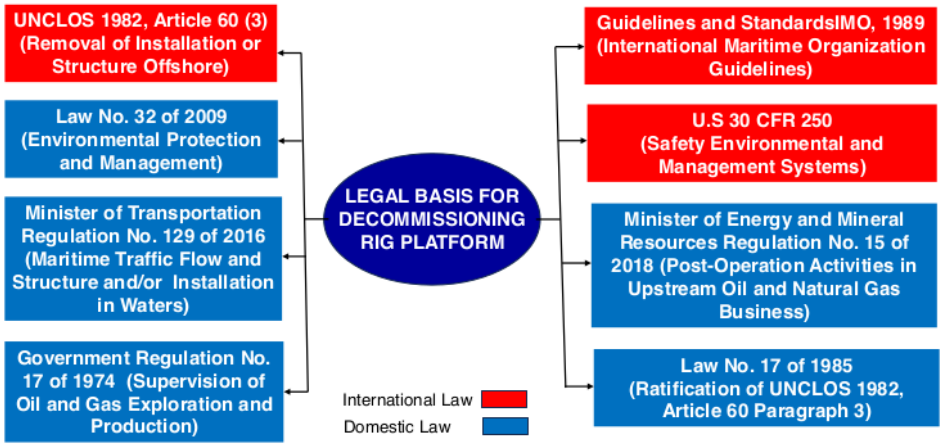


**Fig. 9.** The Navigation of Decommissioning Policies

The basic principle established by the United Nations Convention on the Law of the Sea (1982) emphasizes the need for the appropriate dismantling of structures. Law No. 32 (2009), as the foundation of environmental protection, is inherently tied to the goals of sustainable waste management and sustainability of the sea.

The overall framework provided by the Minister of Transport Regulation No. 129 (2016) ensures that the safe destruction of marine structures takes into account waste management considerations. Government Regulation No. 17 (1974) emphasizing careful planning, safety measures, and environmental protection during decommissioning repeats the requirement for responsible waste management. In addition,

guidelines and standards issued by the International Maritime Organization (1989), which emphasize environmental and safety responsibilities, are directly linked to marine litter management goals. The application of these standards to reduce the ecological risks associated with waste. Minister of Energy and Mineral Resources Regulation No. 15 (2018), which focuses on mitigation and habitat restoration, broadens its relevance to marine sustainability by advocating for effective waste management measures to minimize environmental ramifications.

Finally, the ratification of Law No. 17 (1985) reflects a country's commitment to responsible operations and compliance with international mandates, tied to principles of marine sustainability. By adopting these regulatory frameworks dismantling offshore oil platforms becomes a catalyst for sustainable practices and marine waste management that ensures that marine sustainability is an integral aspect of responsible offshore business.

### 5.2. Platform "MAN" Decommissioning Project Demonstration

The demonstration involves a systematic process of repurposing Platform "MAN" structures as shown in Figure 10, employing environmentally friendly techniques to prepare them for their new role as marine habitats. The previous "MAN" platform was a temporary processing platform during the first development phase in 1980 (Arya, G., 2021). The platform has not been operated since 1983. By strategically placing the platform not far from the Eretan Bay MPA, the project not only contributes to conserving marine biodiversity but also aligns with the broader conservation goals of the region.

**Fig. 10.** Platform "MAN" Imagery Condition in ONWJ

Platform "MAN" is feasible to be decommissioned similarly to Platform Attaka. However, it will be decommissioned in-situ. Table 2 shows Platform "MAN" parameters. The values of each parameter are feasible to be decommissioned by the R2R program. The height of the platform is qualified to be separated into parts. The deck area is flat-designated structures. The deck areas maximize coral growth and marine habitat. This structure has 3 (three) main legs that have been corroded as can be seen in Figure 10.

**Table 2.** Platform "MAN" Parameters Description

| Parameters, Unit | Value |
|---|---|
| Platform Height, ft | 140.00 |
| Water Depth, ft | 112.50 |
| Dead Load, lb(s) | 540133.82 |
| Live Load, lb(s) | 1,913,940.62 |
| Legs | 3 |
| OD Conductor, in | 36.00 |
| Deck Area, ft$^2$ | 1,312.34 |

The platform will be cut into three main sections, the jacket and two deck sections. This sectioning is due to the relatively shallow seas in these waters, so a minimum clearance of 85 ft from the subsea is required (LDWF, 2014). The structure must be cleaned of hydrocarbon contamination due to the regulation of SKK Migas in PTK-041 of 2018. Therefore, the structure had to be cut parallel to the mud line, and the main

deck separated from the lower deck. Crane lifting was required for the cleaning of the structure on the transport vessel. The lowering of the three structures to the seabed must be done using a crane slowly so as not to damage the condition of the structures and the maritime environment around the R2R site. Figure 11, illustrates the possible artificial reef condition where Platform "MAN" is on the seabed as toppled condition as a Rig-to-Reef construction option.

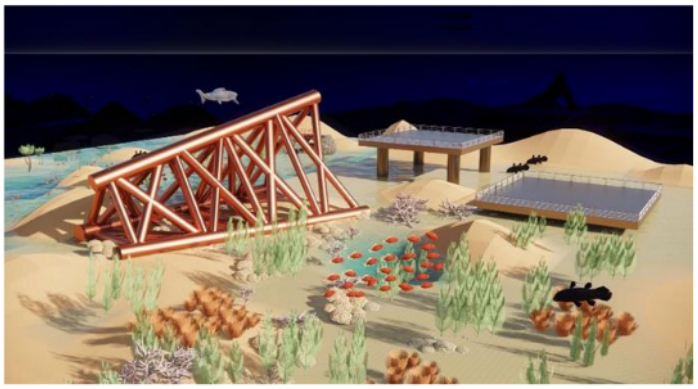

**Fig. 11.** Platform "MAN" Sketchup Imagery Condition in ONWJ Seabed

**Table 3.** Cost Comparison of Platform "MAN" Decommissioning Option from Case Study of ONWJ

| | Activity | Cost | |
|---|---|---|---|
| | | Conventional Decommissioning | Rig-to-Reef |
| 1 | Rig dismantling | | |
| a | Manpower | $25.313,43 | $25.313,43 |
| b | Equipment | $1.107.593,34 | $1.107.593,34 |
| c | Services | $486.443,75 | $486.443,75 |
| Sub Total (1) | | $ 1.619.350,53 | $1.619.350,53 |
| 2 | Transportation to land | | |
| a | Manpower | $1.860,70 | |
| b | Equipment | $58.800,00 | No Cost |
| c | Services | $145.029,41 | |
| Sub Total (2) | | $205.690,11 | $0 |
| 3 | Storage on the land | | |
| a | Manpower | $60.590,00 | |
| b | Equipment | $283.260,31 | No Cost |
| c | Services | $26.280,00 | |
| Sub Total (3) | | $370.130,31 | $0 |
| Total (1+2+3) | | $2.195.180,95 | $1.619.350,53 |

When comparing the costs of the two methods of structural dismantling as shown in Table 3, Rig-to-Reef stands out in terms of affordability. It is important to note that the cost of the Rig-to-Reef covers only the dismantling of the structure and does not include transportation and storage on land. This cost disparity stems from Rig-to-Reef's clever idea of turning decommissioned structures into artificial reefs, saving money on land storage. In short USD706,865 or approximately 30.4% more economical.

### 5.3. Rig-to-Reef as an Oil Spill Mitigation Program

Oil spills are a major concern due to their adverse effects on marine and human life. Apprehensions arising from oil spills are a consequence of the detrimental impacts accompanying such incidents, including the loss of habitat for marine organisms, contamination of marine fauna, and the inhibition of sunlight penetration into the sea surface (Asif et al., 2022). Abandoned platforms significantly contribute to leaking oil into the environment, cause of oil spills.

The alarming frequency of oil spills in ONWJ has underscored the need for innovative interventions and avoiding the MPA damage. The R2R concept emerges as a solution and serves as a mitigation program against oil spills. It constitutes a form of decommissioning, transforming abandoned rigs into artificial reefs, thereby eradicating the potential for these rigs to oil spill risks. Presented in Figure 7 previously, is an instance of an oil spill in Eretan Bay, highlighting the ocean's susceptibility to oil spills. The R2R initiative conducted in the ONWJ region serves as an approach to prevent oil spills, similar to those in Eretan Bay, which are detrimental to various stakeholders encompassing fisheries, economy, and human well-being.

### 5.4. Analysis after the Rig-to-Reef Program

Platform “MAN” would very clearly be useful to be decommissioned in-situ. The support of an artificial reef near the MPA is not only mitigating the oil spill that possibly ruined the MPA’s ecosystem but also creating new marine habitats. 85 species and 18 families lived in MPA in NWJO (Nuriadi et al. 2012) could be increasing due to the implementation of R2R. The implementation of R2R initiatives in Eretan Bay has marked a significant turning point for local fisheries, particularly within the confines of the MPA. It can be seen in Figure 6 and Figure 7 that Platform “MAN” is close to the MPA for about 10 miles. According to projections, the North Sea's current oil and gas platforms, along with the subsea equipment and fishing exclusion zones that go along with it, offer habitat for 1% or less of the total of some species in economic importance (Bull et al., 2019).

The oxidation process of Fe and Zn is not a big issue as several platform jackets on Offshore South East Sumatera (OSES) already have corals growing on the jacket before it got decommissioned and states that decommissioning a jacket that already has corals makes the R2R program feasible as it presented at Offshore Construction IAFMI Conference (2023). By integrating the pressure forces applied to the cylinder's surface, the resulting hydrodynamic forces are determined. Sumer and Fredsoe (2006) studied that when fluid passes through a cylinder, pressure changes are brought on by the cylinder's form, turbulence, and shear in the incoming flow. The hydrodynamic study can be altered to Platform “MAN” and it simplified that R2R is feasible in shallow marine because the structure will be on the seabed with the required minimum clearance. The presence of the artificial reef structure can alter water circulation patterns in the vicinity. This can lead to changes in nutrient transport, oxygen levels, and water temperature, which can have implications for the growth and distribution of marine organisms, including fish (Vjekoslav et al., 2022).

The MPA, once a haven for conservation efforts, now emerges as a potential source of economic growth. The increased abundance and diversity of fish species have the potential to augment the catches of local fishermen, ultimately leading to economic benefits for coastal communities. Platform “MAN” decommissioning also enhances the activity of Eretan Bay Fish Landing Places (FLP) in Indramayu. FLP is the place for auctioning and selling fish from the catches of Indramayu fishermen (Indramayu Regency Marine and Fisheries Service, 2018). Some of the catches from FLPs are sent to Jakarta and sold around Indramayu itself.

This transformation showcases the delicate interplay between ecological conservation and economic prosperity, offering a harmonious model where R2R initiatives contribute to the restoration of marine ecosystems while simultaneously bolstering the livelihoods of those dependent on the sea's bounty. Proximity to fish landing places allows researchers and conservationists to monitor the ecological impacts of the R2R program effectively. Scientists can study the fish species composition, growth patterns, and migration trends around the artificial reefs.

Artificial reef in shallow waters does result in additional socioeconomic advantages from recreational usage. Studies on fish drawn near platforms have not shown any negative impacts on growth or physical condition, and they also imply that platform connection may speed up growth rates in fish of commercial

relevance. The R2R program could support members of the Blue Economy, like divers and fishers, by increasing accessibility to reef habitat Furthermore, platforms offer hard surfaces for sessile species to attach to, habitat for fish and motile invertebrates, and orientation and feeding areas for bigger fish, turtles, and marine mammals (Lowry et al., 2007).

## CONCLUSIONS

In conclusion, the Rig-to-Reef strategy embodies a comprehensive approach grounded in pivotal considerations:

1. Adherence to the Environmental Regulations: R2R not only complies with regulations but is also in line with marine waste management and environmental mandates. Converting structures into artificial reefs aligns with governmental guidelines, showcasing a preemptive commitment to responsible decommissioning and marine conservation.
2. Marine Waste Management, Environmental Impact, and Global Success Stories: R2R innovatively addresses marine waste by transforming decommissioned structures into thriving artificial reefs. Its implementation across diverse global locations not only mitigates ecological risks tied to waste disposal but also actively revitalizes marine ecosystems.
3. Cost Efficiency: The cost contrast between Conventional Decommissioning ($2,326,215.87) and R2R ($1,619,350.53) highlights the financial benefits of R2R. It is important to note that decommissioning costs make up a significant portion of the cost of Abandonment and Site Restoration (ASR), often up to 80%. R2R's ability to reduce these costs contributes to efficient and long-term economic sustainability.
4. Platform “MAN” decommissioning will provide the presence of commercial fish species also enhance macroeconomy growth around Indramayu waters. The Blue Economy, which includes activities related to the sustainable use of ocean resources, can benefit from Rig-to-Reef implementation.
5. The Rig-to-Reef approach harmonizes regulatory alignment within a dynamic framework, marine waste management, and financial prudence. Reinforced by global accomplishments, R2R not only adheres to regulations but also proactively nurtures marine ecosystems, underscoring its potential sustainable practice.

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## DECLARATION OF COMPETING INTEREST

The authors have no conflict of interest to declare.

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# UTILIZING THE POTENTIAL RIG-TO-REEF AS A SUSTAINABLE SOLUTION FOR MARINE WASTE MANAGEMENT: CASE STUDY AND ENVIRONMENTAL ASSESSMENT OF PLATFORM “MAN”

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