Implementation of Marine Environmental Impact Assessment Mechanism for Marine Spatial Planning in Taiwan

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Abstract: To undertake a detailed and comprehensive research on the marine environmental impact assessment mechanism of marine spatial planning in Taiwan with a specific focus on the environmental impact assessment (EIA) technique. The present research adopts methodological model based on the principles of environmental impact assessment (EIA) for analysis of the Taiwan marine ecosystem. The cumulative environmental impact of human activities within the area of scope of the study is computed as the sum of the impacts of identified human activities on selected components of the ecosystem. The collection of data related to the human activities and ecosystem components variables was limited to the last five years, between 2018 and 2023, and the pre-existing data that were openly available were sourced from different sources including the Taiwan marine spatial planning (MSP) related governmental agencies, consultancies and academic research. The impactful human activities on the Taiwan marine environment include ocean bottom trawls, oil spill shipping and sand loss extraction activities as well as turbidity ocean bottom trawl, boating effects, mining activities and marine infrastructural projects and the most affected ecosystem components include the artificial and natural coastal reefs, the shoreline shallows, the deep ocean spaces and the biological components which include the plants and the animals. The most impactful human activity on the Taiwan marine environment is attributed to dumping activities within the coast zone areas which has had the most significant impact on the coastal zone ecosystem.

Keywords: Environmental Impact Assessment, Marine Spatial Planning, Use Conflicts, Ecological Impact, Coastal Zone Ecosystem, Taiwan.

1. INTRODUCTION

The conventional mechanisms for assessment of impact of marine activities has often adopted a single-component approaches which have provided unreliable results for effective marine spatial planning (MSP) among blue economies such as Taiwan. However, according to Pinkau & Schiele (2021), the recent decades have witnessed a paradigm shift towards ecosystem based approaches that encompasses holistic coverage of the cumulative effects of marine activities rather than focusing on a single aspect such as single species, sector or activity. Presently, there is a widespread claim for ocean space which has led to the depletion of marine ecosystems through human activities and pressures such as marine pollution, fishing, shipping and atmospheric emissions that directly affect the marine habitats and populations (Cheng, 2018; Declerck *et al*., 2023; Hammar *et al*., 2020). MSP which is based on cumulative assessment of the ecosystem is increasingly being adopted by blue economies as a strategic tool for addressing the increasing complexities associated with the spatial conflict claims between the different marine sectors engaging in economic activities and the environment (Hammar *et al*., 2020). The double objective of adoption of ecosystem-based MSP is protection of the environment through a cumulative assessment of the effects of the related activities and implementation of effective economic policies to boost the economic status of the region (Choi *et al*., 2021; Hammar *et al*., 2020). As a result, there has been an increased interest in the development of cumulative assessment models for projection of environmental impacts of marine activities for MSP processes and strategic marine policy decision-making.

The Environmental Impact Assessment (EIA) mechanism is being adopted by countries with marine ecosystems for a better understanding of the combined effects of human activities on the environment. While marine human activities directly affects the surrounding ecosystems, it is worth considering that the state of the ecosystems also have a direct impact on the possibilities of utilization of the marine resources and, therefore, the cumulative evaluation of both the effects of human activities and the state of surrounding ecosystem is both a necessity and crucial in supporting the long-term sustainability of the marine environment (Bergström *et al*., 2019). As an environmental assessment mechanism, the EIA is based on a geospatial index that is function of three primary components including the pressures of human activities on the environment, the components of the ecosystem and the sensitivity of each component in relation to the identified human pressures (Hammar *et al*., 2020;

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Halpern *et al*., 2019). The pressures of human activities on the marine ecosystem is expressed in form of intensity maps which show the degree of the impact of an activity on the environment while the ecosystem components is expressed in terms of value maps (Halpern *et al*., 2019). The sensitivity index, on the other hand, is determined by getting the relationship between the intensity maps and value maps to provide over time tracking of changes to the marine environment as a result of the impact of the human activities (Hammar *et al*., 2020; Halpern *et al*., 2019). When combined with MSP, the EIA can be an important environmental assessment tool for designing of baseline policies for protection of the marine environment and supporting of alternative planning decisions.

In Taiwan, the government has actively adopted MSP for management and planning of the marine environment. The Taiwan MSP governance is under the Ministry of Interior with different authorities including national and local governments which work under allotted rights and responsibilities (Lee *et al*., 2014; Liao *et al*., 2023). The Taiwan marine ecosystem is used for a wide variety of activities including transportation through ship routes and ports, fisheries and mineral resources, recreational purposes such as tourism, and coastal engineering activities such as pipelines and under-sea cables (Lee *et al*., 2014; Liao *et al*., 2023). Also, the coast zone has been used for marine protection activities in terms of wild animal sanctuaries, protection of fisheries resources, natural reserves and heritage, and protection of non-biological resources (Liao *et al*., 2023). The uses of the marine ecosystem in Taiwan is regulated under different laws and regulations which align with the objectives of MSP governance and any human activity requires the approval of competent authorities and agencies of governance (Lin *et al*., 2020). According to Yang *et al*. (2024), Taiwan coast zone areas have experienced rapid developments which has subsequently led to increased human pressures and competition over marine space allocations that has further intensified marine spatial conflicts. Despite the MSP policies implemented by the government for governance of coastal activities, the Taiwan marine environment still experiences negative impacts of human activities which highlights the urgent need for a cumulative impact assessment to assist in development of effective ecosystem MSP based policies to protect the environment while maximizing the economic potential of the region. The present study aims perform a detailed and comprehensive research on marine environmental impact assessment mechanism of MSP in Taiwan with a specific focus on the environmental impact assessment (EIA) technique which encompasses holistic coverage of the cumulative effects of marine activities rather than focusing on a single aspect.

2. METHODOLOGY

The present research adopts methodological model based on the principles of environmental impact assessment (EIA) for analysis of the Taiwan marine ecosystem. Based on the EIA technique, the cumulative environmental impact of human activities within the area of scope of the study is computed as the sum of the impacts of identified human activities on selected components of the ecosystem. First, it is worth noting that the human activities are classified based on the MSP governance principles and must have a direct quantifiable effect on the physical, chemical and biological components of the environment. Second, the ecosystem components are the habitats or populations with a quantifiable ecological value and are adapted to the marine environment and regional conditions based on natural selection process. The first step of the methodological approach entailed the collection and compilation of a list of the human activities and ecosystem components covering the Taiwan marine environment based on existing MSP publications and existing research studies that have explored and identified the variables that are related to human activities and marine ecosystem components. The compiled list of the activities and ecosystem variables was scrutinized in terms of their marine ecological relevance within the context of Taiwan. The scrutinization process eliminated the variables that had insufficient data and lacked credible spatial representation which resulted in an adjusted and relevant final compiled list. At the same time, the variables that experienced seasonal variations were excluded with the only recurring variables being included.

The collection of data related to the human activities and ecosystem components variables was limited to the last five years, between 2018 and 2023, and the pre-existing data that were openly available were sourced from different sources including the Taiwan MSP related governmental agencies, consultancies and academic research. The collected data of the

compiled variables was then reanalyzed using spatial modelling techniques to produce the final dataset for the human activities and ecosystem components for analysis. Normalization of the resulting data was done to a scale of between 0 and 100, with the lowest value showing the lowest level of exposure of the activities while the highest value showing the highest level of exposure of the activities. At this point, it is important to note that the data on human activities was not log-transformed as in other EIA-based research studies considering it might enhance the relative impact of the activities with low impacts or pressures on the environment. On the same note, the ecosystem component data that were related to coverage of habitat and ecological functions were also not log-transformed before the data were normalized. However, the ecosystem component data that were related to the abundance of species in the marine ecosystem were normalized for standardization of the logarithmic effect and then log-transformed. The log transformation of the species abundance data was considered as appropriate since the data on fish species had outliers that would have diminished the credibility of the data by not considering the impacts of specific populations.

The adopted methodological framework allowed for the spatial representation of data uncertainty to enhance the confidence of the underlying data considering the sparsity of the available marine data, particularly for ecosystem components. The uncertainty of the marine data can be enhanced by different components of the ecosystem which might directly affect the confidence of the results. To reduce the data uncertainty, the individual confidence of each of the ecosystem components was reviewed based on predefined categories of numerical data quality that were based on the data providers for every component of the ecosystem that was incorporated in the research. A sensitivity matrix was then developed to determine the sensitivity of each of the incorporated ecosystem component to the pressure of the human activities. Any pre-existing sensitivity matrices were not applied since the identified human activities and ecosystem components did not match any pre-existing EIA sensitivity matrix. The applied sensitivity matrix was developed based on expert judgement using questionnaires that were designed based on specific categories and assessment criteria. A total of only 30 experts were incorporated in the study based on the strict criteria for inclusion of participants to ensure the validity of the final results. The questionnaires were distributed to experts including MSP ecologists and professionals with expertise on ecosystem components and only the responses with a higher level of confidence were considered and the responses with low level of confidence were disregarded. The incorporated responses were used to set the sensitivity scores which were compared to the existing published sensitivity scores for necessary adjustments where deviations were identified. The criteria for defining sensitivity scores provided to the expert panel is shown in Table **1** below;

Table 1: EIA Sensitivity Analysis Score Framework. (Source: Create by this Research)

Individual Taxa (plants, invertebrates, fish, mammals, birds)	
Score	**Response/Effect**
+	A positive and acceptable impact
0.0	Either no response or a positive impact.
0.2	The impact has a low pressure.
0.4	The human impact are survivable.
0.6	The human impact have an impact on mortality.
0.8	Frequent mortality on populations
1.0	Severe mortality on marine populations
Habitats (benthic and pelagic habitats)	
Score	**Response/Effect**
+	A positive and acceptable impact
0.0	Either no response or a positive impact.
0.2	The impact has a low pressure.
0.4	The human impact are survivable.
0.6	The human impact have an impact on mortality.
0.8	Frequent mortality on populations
1.0	Severe mortality on marine populations

Considering the prospective nature of MSP, different scenarios were evaluated in relation to the impact of the human activities on the marine environment. The evaluation of the scenarios was specifically done to incorporate the MSP within the EIA methodological framework for the determination of the assessment of the environmental impact on the marine environment in Taiwan. In this regard, the first MSP scenario incorporated in the framework entailed marine spatial proposals that had been developed through stakeholder engagement while the second scenario aligned with the governmental MSP policies. With the incorporation of the relevant MSP scenarios in the

methodological framework, the scores for the cumulative impacts of the human activities on the environment were computed as the sum of the impacts of identified human activities on selected components of the ecosystem. While the applied methodological framework was detailed, there were several associated limitations. First, there are uncertainties at different levels of the model including the sparsity of marine environmental data as well as the varying nature of the models for representation of models representing ecosystem components. Second, the adopted EIA methodological framework have ecological limitations in terms of connectivity and interactions of food webs within the marine ecosystem which can imply bias. It is worth noting that the components of ecosystems incorporated in the research are constantly changing and are often based on the present state of the environment and, as such, the methodology fails to consider the historical losses that might have a direct impact on the incorporated data and related sensitivity scores. The detailed analytical framework for the study is shown in Figure **1**. Below;

3. FINDINGS

The methodological framework identified a total of 17 human activities that had a significant quantifiable impact on the identified 15 ecosystem components as indicated in Table **2**. According to the results, the most impactful human activity on the Taiwan marine environment is attributed to dumping activities which contributed to up to 50 percent of the total impacts of human activities on the marine environment. The results show that other impactful human activities on the Taiwan marine environment included the catch ocean bottom trawls which contributed to 30 percent of the total impacts as well as oil spill shipping and sand loss extraction activities which contributed to 37.5 percent and 33 percent respectively. Other impactful human activities that were identified included turbidity ocean bottom trawl, boating effects, mining activities and marine infrastructural projects. In relation to the ecosystem components, the results show that the most affected ecosystems included the Taiwan shoreline shallows which experienced approximately 63 percent of the total impacts of human activities closely followed by the marine plant life which contributed to a total of 50 percent of the total impacts of human activities within the Taiwan marine environment. Other affected marine ecosystem components included the artificial reefs, hard bottom deep and the soft bottom reef which accounted for a cumulative 89 percent of the total impacts of human activities on the environment. The complete sensitivity matrices for the impact of human activities on human environment on the Taiwan environment is shown in Table **2** below;

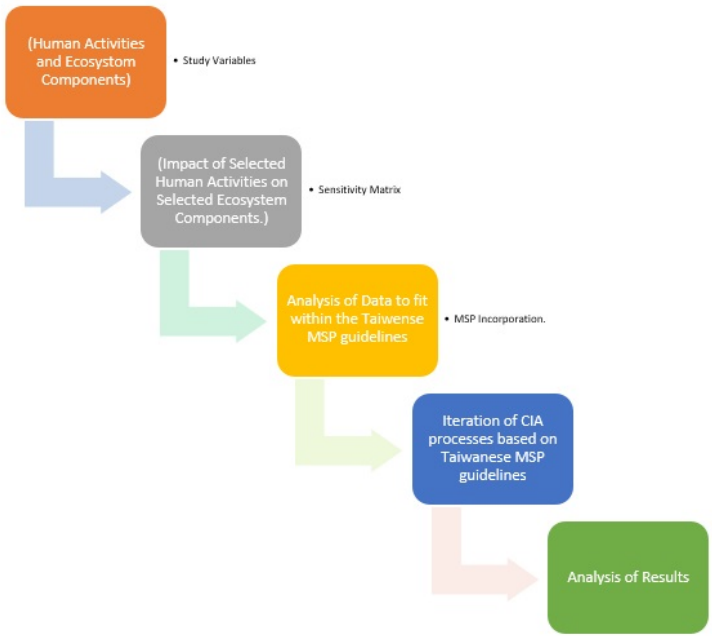

Figure 1: Methodological Framework for environmental impact assessment (EIA) of Human Activities on Taiwan Marine Environment.
(Source: Create by this Research)

Table 2: Sensitivity Matrices Scores for Human Impact on Taiwan Marine Environment. (Source: Create by this Research)

Sensitivity Matrices Scores for Taiwan Marine Environment															
SENSITIVITY Taiwanese Marine Environment.	Artificial reef	Hard bottom deep	Transport bottom deep	Rough bottom deep	Soft bottom deep	Shoreline shallows	Angiosperms (Seagrass)	Cod	Herring	Fish spawning	Rivermouth fish	Eel migration	Coastal birds	Seabird coastal wintering	Seabird offshore wintering
Catch Ocean Bottom Trawl	0.1	0.5	0.5	0.5	0.5	0.6	0	1	0.3	0.3	0	0	0	0.1	0.1
Turbidity Ocean Bottom trawl	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.1	0.2	0.2	0.4	0.2	0	0	0
Turbidity Shipping Activities.	0.4	0.4	0.4	0.4	0.4	0.4	0.6	0.2	0.2	0.2	0.4	0.2	0.1	0	0
Loss of Habitat atributed to Dumping	1	1	0.4	1	0.8	0.8	0.8	0.4	0.4	0.2	0.2	0.2	0	0	0
Habitat loss fish farm	0.4	0.4	0.4	0.4	0.8	0.4	0.6	0.2	0.2	0.1	0.2	0	0.2	0.2	0
Habitat loss coastal exploitation	0.2	0.2	0	0	0	0.8	0.8	0.4	0.4	0.3	0.4	0	0.2	0.2	0
Habitat loss infrastructure	0	0.2	0.2	0.2	0.2	0.6	0.6	0	0	0.3	0	0	0	0	0.2
Habitat loss sand extraction	1	0	0.8	0	0	1	1	0	0.2	0.5	0	0	0.2	0.2	0.2
Peak of Recorded Explosions	0.4	0.8	0.6	0.8	0.6	0.8	0.2	0	0	0	0	0	0	0	0
Oilspill shipping	0	0	0	0	0	0.4	0.2	0.2	0.4	0.1	0.4	0.4	1	1	1
Heavy metals associated with military activities	0.1	0	0.2	0	0.4	0.4	0.4	0.2	0.2	0.3	0.3	0	0.3	0.3	0.3
Heavy metals associated with mining activities	0.1	0	0.2	0	0.5	0.4	0.4	0.2	0.2	0.3	0.3	0	0.3	0.3	0.3
Synthetic toxins deposited in marine environment	0.2	0	0.2	0	0.6	0.5	0.3	0.2	0.2	0.2	0.3	0	0.3	0.3	0.3
Pollution attributed to boating effects	0.3	0.5	0.5	0.5	0.5	0.5	0.3	0.4	0.4	0.1	0.5	0	0.4	0.4	0.4
Nitrogen emission attributed to human activities	0.2	0.4	0.4	0.4	0.4	0.8	0.8	0.2	0.2	0.3	0	0.1	0.2	0.2	0.2
Phosphorous accumulation attributed to human activities	0	0.4	0.4	0.4	0.4	0.6	0.6	0	0.2	0.3	0.1	0	0.2	0.2	0.2
Anoxial accumulation attributed to human activities.	0.8	0.8	0.8	0.8	0.8	0.6	0.6	0.6	0.2	0.4	0.1	0.2	0.6	0.6	0.4

4. DISCUSSION

Marine spatial planning (MSP) has become a model strategic solution for addressing the ever increasing impacts of human impacts on marine environment among blue economies. In Taiwan, MSP has been actively adopted to optimize the economic benefits associated with human activities within the marine environment while also protecting the environment, especially the physical and chemical components which have a direct effect on the existing marine biological populations. According to Lee *et al*. (2014), the Taiwan marine ecosystem is used for a wide variety of human activities including ship routes and ports,

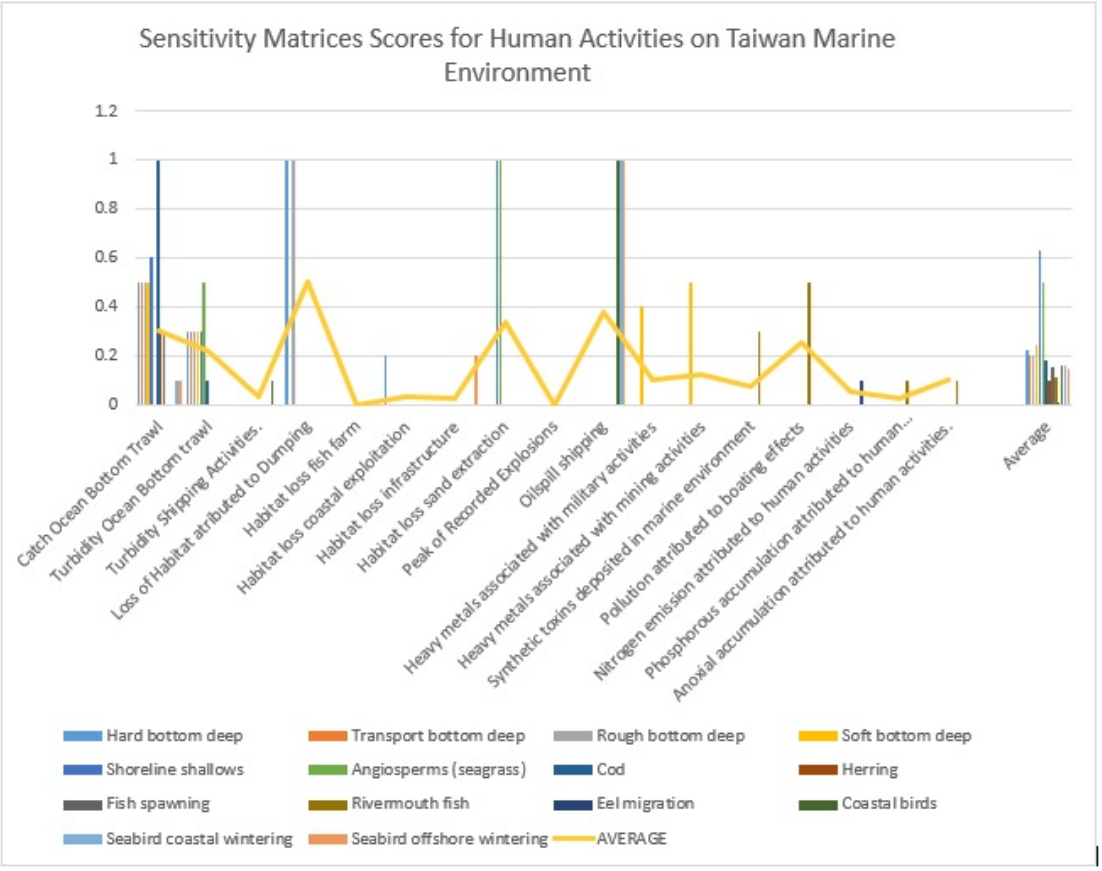

Figure 2: Sensitivity matrices scores for Human Impact on Taiwan Marine Environment.
(Source: Create by this Research)

fisheries and mineral resources, recreational purposes such as tourism, and coastal engineering activities such as pipelines and under-sea cables that directly impacts the marine biological ecosystems. Further, research studies by Liao *et al*., (2023) and Yang *et al*. *et al*. (2024) have reported rapid developments in the Taiwan marine environment which has necessitated the implementation of MSP policies by the government to address the existing and expected impact of human activities on the country's marine environment. The present study employed the EIA mechanism to determine the impact of the human activities on the Taiwan marine environment and reported that the most impactful human activity on the Taiwan marine environment is attributed to dumping activities within the coast zone which has had the most significant impact on the shoreline shallow ecosystem as compared to other marine ecosystem components. The findings align with the results of Pinkau & Schiele (20210 which reported the need for the adoption of ecosystem-based assessment mechanisms to determine the accurate impacts of human activities in marine and coast zone environments in blue economies such as Taiwan and countries within the North and the Baltic Seas.

The study findings highlight a wide variety of human activities that have a direct impact on different marine ecosystem components. According to the study findings, the impactful human activities on the Taiwan marine environment include ocean bottom trawls, oil spill shipping and sand loss extraction activities as well as turbidity ocean bottom trawl, boating effects, mining activities and marine infrastructural projects. The findings further report that the most affected ecosystem components include the artificial and natural coastal reefs, the shoreline shallows, the deep ocean spaces and the biological components which include the plants and the animals. According to the research study by Hammar *et al*. (2020) on the impacts of human activities on the marine ecosystems in the Baltic Seas, the most impactful human activities include fisheries activities, pollution, shipping and eutrophication, which align the findings of the present study that highlight trawling, oil pollution and shipping activities as major impactful activities along the Taiwan coast zone

environment. The findings by Hammar *et al*. (2020) and the present study are further supported by Bergström *et al*. (2019) which employed the environmental impact assessment (EIA) of human activities on the Baltic Seas and reported that cultivation of living resources in terms of agricultural and fisheries activities, and the physical restructuring of the marine environment are the primary human activities that have a direct impact on the overall marine environment of blue economies. Liang *et al*. (2022) further identifies the chemical aspects related to environmental impacts of human activities in marine environments including salinization of seawater, enrichment of arsenic environments, nitrate pollution and reductive dissolution of minerals such as iron (Fe^{2+}) and Manganese (Mn^{2+}), all of which have a direct impact on the chemical, physical and biological aspects of marine environments.

The research findings further indicate that the marine ecosystem components that are directly affected by human activities in Taiwan marine environment are biological systems including both plant such as seagrass and animal species such as cod, herring, fish and eel. According to the results, the most affected biological systems of the Taiwan marine environment are the seagrass followed by rivermouth fish and eels. The results are supported by other research studies including Hammar *et al*. (2020) and Bergström *et al*. (2019) which reported that biological species are the most affected ecosystem components of human activities in marine environments in blue economies within the Baltic Seas and the Arctic Ocean regions including Taiwan. Also, Tsai *et al*. (2022) reported that the conflicts between marine spatial energy from offshore wind power and the fishery rights are directly attributed to the effects of marine human activities that aim to maximize the potential of fisheries while also aiming to produce wind energy that are produced by tidal currents that emanate from the marine ecosystem. Tsai *et al*. (2022) report that the Taiwan MSP principles are based on the selection of appropriate protection measures for reduction of risks associated with possible environmental impacts related to the operation of offshore wind projects that have a direct impact on the biological aspects of the marine ecosystem. Based on the results, it can be hypothesized that there is a delicate balance between the maximization of the economic potential of marine ecosystem environments and protection of the existing biological aspects which have a direct influence on the development of the related natural ecosystems.

5. CONCLUSIONS

The increased interest in academic research on marine environment has led to a paradigm shift towards ecosystem based approaches that encompasses holistic coverage of the cumulative effects of marine activities rather than focusing on a single aspect such as single species, sector or activity. The double objective of adoption of ecosystem-based MSP is protection of the environment through a cumulative assessment of the effects of the related activities and implementation of effective economic policies to boost the economic status of the region. The marine human activities directly affects the surrounding ecosystems but also have a direct impact on the possibilities of utilization of the marine resources and, therefore, the cumulative evaluation of both the effects of human activities and the state of surrounding ecosystem is both a necessity and crucial in supporting the long-term sustainability of the marine environment. The results of the present research study indicates that that the most impactful human activity on the Taiwan marine environment is attributed to dumping activities within the coast zone which has had the most significant impact on the shoreline shallow ecosystem as compared to other marine ecosystem components. Further, the results show that the impactful human activities on the Taiwan marine environment include ocean bottom trawls, oil spill shipping and sand loss extraction activities as well as turbidity ocean bottom trawl, boating effects, mining activities and marine infrastructural projects. The study highlights the need for the adoption of ecosystem-based assessment mechanisms to determine the accurate impacts of human activities in marine and coast zone environments in blue economies including Taiwan.

CONFLICTS OF INTEREST

The author declares that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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