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A Systematic Review on the Ecological Efficiency of Artificial Reefs for Lobster Fisheries in Malaysia

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ABSTRACT

Artificial reefs represent human-made constructs designed to emulate natural reefs, offering diverse habitats for marine species. Among other benefits, these reefs influence lobster appraisal and breeding, with artificial reefs (ARs) being crucial variables. Therefore, the objective of this study is to review the research on lobsters in Malaysia, specifically focusing on the ecological efficiency aspects as shown by existing academic resources. The entire study used systematic literature review (SLR). This systematic investigation used WoS and Scopus with PRISMA criteria. Employing carefully selected keywords, a total of 17 pertinent papers were identified. Due to a lack of research in Malaysia, this study includes papers from other countries. The findings have been categorized into two main sections: general findings and discussions centered on research questions and themes. These thematic discussions revolve around two primary themes, encompassing fisheries and marine biodiversity. This research evaluation shows that artificial reefs have a significant impact on the assessment of lobster value from several viewpoints. All the publications show that Malaysia has a gap in this field of study. Malaysia was represented in only one of 17 reviewed publications. Lobster valuation research with artificial reefs is rare. Given the rarity of such investigations, a complete examination helps identify shortcomings. These studies focus on artificial reefs' significance, needs, valuation, and function. The essential role lobsters perform is rarely assessed. This study could inspire future research on lobsters, artificial reefs, and their economic values.

1. INTRODUCTION

Over the past three decades, the fishing industry in Malaysia has experienced rapid and dynamic growth, making it one of the fastest-growing industries in the country. Malaysia's surrounding waters are abundant with marine fisheries, leading to high fish consumption rates within the nation. Estimates indicate that each person consumes over 50 kilograms of fish per year, accounting for approximately 60% of the country's total animal protein intake [1]. In 2016, the marine fisheries industry contributed 1.4% to Malaysia's Gross Domestic Product (GDP). The fishing sector plays a crucial role in Malaysia's development as it not only boosts the GDP but also provides a significant amount of protein, supports the export of Malaysian goods, generates employment opportunities, and indirectly impacts other related industries such as boat manufacturing, sardine processing plants, and fishing equipment production [2].

However, our oceans are struggling to cope with the increasing demand for fish and the expanding global population, as we are fishing at an unsustainable rate. Fishery managers in Malaysia officially acknowledge that the fishery resources in the inshore waters have been overexploited, leading to biological overfishing. Excessive trawl fishing is a clear indicator of overfishing [3]. The collapse of local small-scale coastal fisheries has prompted commercial fishing to expand into the open oceans, causing a significant decline in wild fish populations [4].

Moreover, artisanal fisherman are the sole individuals allowed to fish inshore within five miles. Trawlers have damaged coastal marine habitats despite the ban. Thus, Malaysian small-scale artisanal fishers have suffered economically. The Department of Fisheries Malaysia (DOFM) and Fisheries Development Authority of Malaysia (FDAM) are concerned about overfishing in Malaysian waterways.

1.1 The development of artificial reefs in Malaysia

DOFM based in Penang, initiated research and development (R&D) efforts on the design and construction of artificial reefs (AR) in Malaysia in 1975. The efforts on AR in Malaysia were to improve fisheries production by enhancing the habitat using

artificial reefs. The aim was to improve fisheries resources, increase fisheries population and production, and promote resource conservation [5]. Meanwhile, the FDAM established AR in the meantime to boost the economic benefits to artisanal fishermen from catch in the vicinity of AR zones. Over the past thirty years, the government of Malaysia has implemented a significant program towards AR development. The government has contributed significantly to the development of a wide variety of AR structures and designs [6].

Increasing catches is one of the goals of using AR in maritime environments so that artisanal fishing communities can prosper economically. However, in general, the AR program was developed to address ecological aspects rather than social and economic considerations. Further, the anticipation was that the clustering of fish and lobster in AR areas would streamline harvesting for fishers. This would be accomplished by diminishing travel distances, thereby lowering fishing expenses.

1.2 The evolution of marine fishery activities in Malaysia

The evolution of marine fishery activities in Malaysia began with traditional inshore fishing and has now expanded to include a combination of traditional and commercial deep-sea fishing subsectors. The majority of marine fish landing comes from the commercial and deep-sea fishing subsectors in the inshore region. Fishing activities take place year-round in Malaysia; however, severe winds hamper fishing in November and January. Outboard-powered boats are used by most Malaysian artisanal fisherman. Inboard boats with 25-horsepower engines are prevalent. Small fiberglass boats, called "sampans," are common in artisanal fishing. Malaysian fishermen use hand lines, long lines, traps, gill nets, and drift nets [6]. Each gear type targets specific fish and lobster species with distinct shapes and sizes. Figure 1 shows the lobster landing in Malaysia from 2010 to 2022 by DOFM [7].

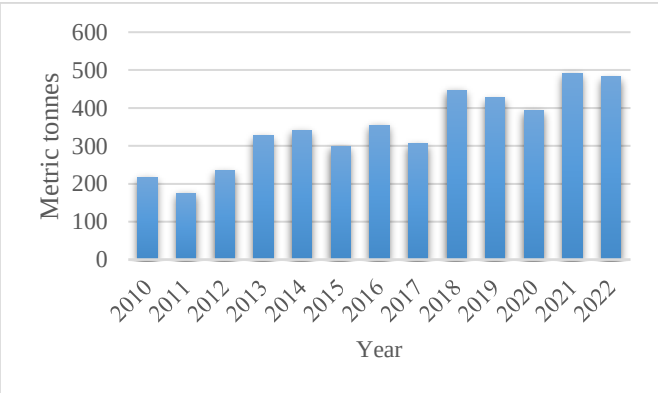

Figure 1. Landing of lobsters in Malaysia, 2010 – 2022
Source: Department of Fisheries Malaysia [7]

To address these issues, the DOFM and the FDAM actively engage in the artificial reef program. The aim is to safeguard inshore fishery habitats from trawlers, enhance fisheries resources, and uplift the economic well-being of artisanal fishing communities. This research presented here focuses on analyzing the economic benefits that artisanal fishers in Malaysia derive from artificial reefs. Thus, the following research was formed in the current systematic review: (1) how to determine the ecological efficiency of artificial reefs for lobsters in the study area? And (2) how much is the economic contribution (in general) of lobster on artificial reef based on the artificial reef development program in Malaysia?

2. MATERIALS AND METHODS

The current investigation used PRISMA-based systematic literature reviews (SLRs). This section covers PRISMA, resources, inclusion and exclusion criteria, systematic review procedure, and data abstraction and analysis, the five main sub-sections of current research.

2.1 Preferred reporting items for systematic reviews or meta-analyses (PRISMA)

The PRISMA Statement, which guides systematic reviews and meta-analyses, was followed in this study. It followed the Cochrane Collaboration's definition of a systematic review: a well-defined research topic, systematic and explicit techniques for discovering and choosing relevant research, critical assessment of included studies, and data collecting and analysis. Statistical approaches for summarizing results vary [8, 9]. PRISMA also allows a thorough search of the scientific literature database within a set date, enabling accurate research on artificial reef effectiveness and lobster economic significance.

The PRISMA methodology encompasses several key steps, including the criteria for determining eligibility, the sources of information, strategies for conducting searches, processes for selecting studies, procedures for collecting data, the specific data items relevant to the research questions, the measures of effect for each outcome, methods for synthesizing data such as tables, figures, and statistical analysis, as well as the approach employed for assessing the certainty of findings, particularly in relation to estimating ecological efficiency.

2.2 Resources

Scopus and Web of Science (WoS) were used for this study's reviews. Comprehensive databases cover over 256 disciplines, including environmental studies. Scopus indexes 1,360 environmental science journals, while WoS indexes 108. The selection of Scopus and WoS follows [10] proposal for similar searches. These databases include comprehensive search options, large coverage (over 5,000 publishers), article quality control, and a multidisciplinary focus with pertinent studies [10].

2.3 The systematic review process for selecting the articles

The study employed systematic search strategies based on a selection of keywords derived from the research question. To ensure thorough and systematic searching, three distinct stages were conducted: identification, screening, and eligibility. These sequential processes were implemented to ensure a rigorous and comprehensive search approach.

2.3.1 Identification

The systematic review process consisted of three primary phases to select relevant publications for the present review. Firstly, keywords were identified, and then a search was conducted for related and similar terms using various resources such as thesauri, dictionaries, encyclopedias, and previous studies. Subsequently, search strings were developed

for the Scopus and WoS databases in May 2023 (Table 1) based on the identified keywords.

Table 1. Results of identification process

Section	Main Keywords	Enriched Keywords
RQ1: How to determine the ecological efficiency of artificial reefs for lobsters in the study area?	1. Efficiency 2. Artificial Reefs 3. Lobsters	**Efficiency**- Effectiveness, Productivity, Performance, Competence **Artificial Reefs**- Man-Made Reefs, Created Reefs, Constructed Reefs. **Lobsters**- Shellfish
RQ2: How much is the economic contribution of lobster on artificial reef based on the artificial reef development program in Malaysia?	1. Economic Values 2. Artificial Reefs 3. Lobsters 4. Malaysia	**Economic Values**- Economic Valuation, Economic evaluation **Artificial Reefs**- Man-Made Reefs, Created Reefs, Constructed Reefs **Lobsters**- Shellfish

Table 2. Search string used in selected databases

Database	String
WoS	**TS=** (("Efficiency" OR "Effectiveness" OR "Productivity" OR "Performance" OR "Competence") AND ("Artificial Reefs" OR "Man-Made Reefs" OR "Created Reefs" OR "Constructed Reefs ") AND ("Lobsters" OR "Shellfish"))
	TS= ((*"Economic Valuation" OR "Economic Value" OR "Economic evaluation" OR "WTP") AND ("Artificial Reef" OR "Man-Made Reef" OR "Created Reef" OR "Constructed Reef") AND ("lobster" OR "Shellfish" OR "lobsters") AND ("Artificial Reefs" OR "Man-Made Reefs" OR "Created Reefs" OR "Constructed Reefs"))*
	TS= (("Economic Valuation" OR "Economic Value" OR "Economic evaluation" OR "WTP") AND ("Artificial Reef" OR "Man-Made Reef" OR "Created Reef" OR "Constructed Reef") AND ("Marine Resources" OR "Marine Species" OR "Aquatic species" OR "Ocean resources" OR "Ocean Species" OR "Ocean"))
	TS= (("Economic Valuation" OR "Economic Value" OR "Economic evaluation" OR "WTP") AND ("Artificial Reef" OR "Man-Made Reef" OR "Created Reef" OR "Constructed Reef") AND ("Artificial Reefs" OR "Man-Made Reefs" OR "Created Reefs" OR "Constructed Reefs"))
Scopus	**TITLE-ABS-KEY** (("Efficiency" OR "Effectiveness" OR "Productivity" OR "Performance" OR "Competence") AND ("Artificial Reefs" OR "Man-Made Reefs" OR "Created Reefs" OR "Constructed Reefs ") AND ("Lobsters" OR "Shellfish"))
	TITLE-ABS-KEY (*"Economic Valuation" OR "Economic Value" OR "Economic evaluation" OR "WTP") AND ("Artificial Reef" OR "Man-Made Reef" OR "Created Reef" OR "Constructed Reef") AND ("lobster" OR "Shellfish" OR "lobsters") AND ("Artificial Reefs" OR "Man-Made Reefs" OR "Created Reefs" OR "Constructed Reefs"))*
	TITLE-ABS-KEY (("Economic Valuation" OR "Economic Value" OR "Economic evaluation" OR "WTP") AND ("Artificial Reef" OR "Man-Made Reef" OR "Created Reef" OR "Constructed Reef") AND ("Marine Resources" OR "Marine Species" OR "Aquatic species" OR "Ocean resources" OR "Ocean Species" OR "Ocean"))
	TITLE-ABS-KEY (("Economic Valuation" OR "Economic Value" OR "Economic evaluation" OR "WTP") AND ("Artificial Reef" OR "Man-Made Reef" OR "Created Reef" OR "Constructed Reef") AND ("Artificial Reefs" OR "Man-Made Reefs" OR "Created Reefs" OR "Constructed Reefs"))

The search was carried out on prominent databases using advanced techniques like Boolean operators, phrase searching, truncation, wildcards, and field codes. These techniques were applied individually or combined to form comprehensive search strings based on the main and additional keywords (Table 2). Additionally, manual search strategies such as handpicking, snowballing, and contacting authors directly via email were employed. Significantly, the present research successfully obtained a total of 177 articles from both databases, marking the retrieval of 177 articles in the initial stage of the systematic review process.

2.3.2 Screening

The initial stage of the screening process involved removing papers that met the exclusion criteria. The screening process involved automatically applying selection criteria based on the sorting functions provided by the databases. The same criteria were applied to all databases, with the manual exclusion of articles in cases where sorting functions were not available. According to Shaffril et al. [11], the researchers can employ their own inclusion and exclusion criteria for their study, as outlined in Table 3, which provides the inclusion and exclusion criteria for this study.

Table 3. The inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Timeline	no specific year	NA
Publication type/ Document type	no specific document type	NA
Subject Area	Malaysia	Other than Malaysia
Language	English and Malay language	Other than English

The initial screening process involved filtering the search results based on publication year, aiming to comprehensively identify the frequency of relevant studies published in previous years up to the present, aligned with our research objective. For this study, there was no constraint on the search year, allowing for a comprehensive historical view. Subsequently, the second screening criterion centered on document type. The research team deliberately concentrated on all forms of research documents, seeking to discern which specific document types predominantly addressed the research topic. Moreover, to ensure a cohesive review objective, studies carried out within Malaysia were deliberately selected. However, due to the limited availability of papers concerning this specific topic within Malaysia, additional papers from other regions were incorporated. This strategic decision aimed to elucidate the existing gap in the study of artificial reefs within the Malaysian context. In instances where no articles

specifically relevant to the objective within Malaysia were identified, general papers were included to bolster the broader understanding. Lastly, it's essential to underscore that this review exclusively targeted articles published in English and Malay language. This linguistic selection enables the inclusion of a wider range of studies while ensuring accessibility for a broader audience. This multi-lingual approach amplifies the reach and impact of the research findings within both local and international communities.

However, in the screening phase, no papers were excluded, as the goal was to thoroughly assess the eligibility of each paper during the eligibility assessment process. This rigorous evaluation ensures a comprehensive understanding of each paper's potential contribution to the research objectives.

2.3.3 Eligibility

Eligibility testing is the third step of screening to check that all articles fit the criteria [12, 13]. This third stage had 177 articles. Six duplicate papers were deleted from databases. The remaining papers' titles, abstracts, and primary contents were carefully scrutinized to see if they matched the inclusion criteria and could answer the study's research questions. The analysis rejected 160 publications because they did not examine the economic worth of lobster in Malaysia through artificial reefs. Some studies addressed marine themes like fish, while this one focuses on lobster artificial reefs. It's interesting that many publications focus on scuba diving and tourism rather than marine species. After screening, 17 papers were selected for further examination. Figure 2 shows the systematic review procedure that selected these papers.

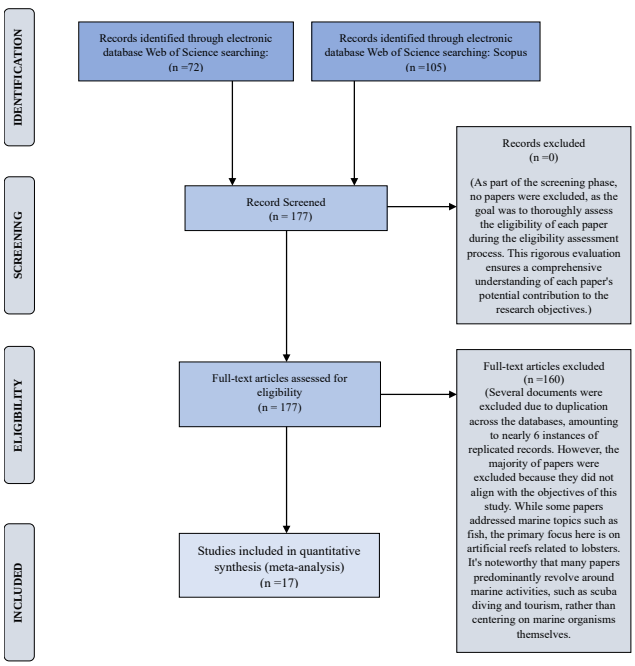

Figure 2. PRISMA flow diagram

2.3.4 Data abstraction and analysis

During this phase, a comprehensive analysis of the 17 chosen articles is undertaken to extract pertinent statements or data addressing the research inquiries. Subsequently, the authors adopted a thematic approach to establish cohesive clusters of concepts or ideas that could heighten the interrelatedness and significance of the data. The process of data extraction and synthesis incorporated thematic analysis, encompassing the identification of themes present in the literature, their subsequent arrangement into distinct clusters, and their ultimate integration into analytical themes [14-16].

3. RESULTS

Prior to delving into the discussion, let us first examine the overall findings derived from these 17 publications. This initial examination aims to emphasize the noteworthy contributions made in previous research. During this evaluation, our focus will be on the publication year, geographical distribution of studies, and document types.

3.1 General finding results

3.1.1 Published year

Figure 3 illustrates the publication count spanning from 1989 to 2020. Notably, the publications concerning the selected keywords related to artificial reefs do not appear consistently throughout every year. However, starting from the year 2000, there is a discernible trend of more frequent occurrences, though often limited to just one paper annually. This observation strongly suggests a decline in current-year research activity in this specific field. It is evident that fewer researchers are currently engaging with this topic, as indicated by the minimal output of recent studies.

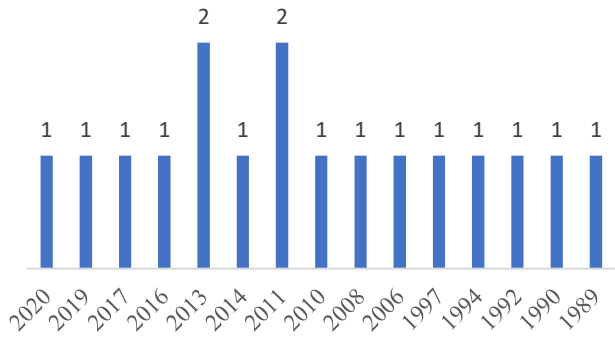

Figure 3. Distribution of articles by year of publication

3.1.2 Geographical location of studies

Emphasizing the geographical context of the research within these 17 papers is of utmost importance. By doing so, we can pinpoint the regions where the selected keywords have been predominantly investigated. The figure provided offers insights into the scarcity of studies focusing on the chosen keywords, particularly in Malaysia. Remarkably, only one study delves into the efficiency of artificial reefs in Malaysia. To bridge this gap, we turn our attention to studies conducted in other countries, shedding light on the economic value of lobsters in their respective regions through the prism of artificial reefs.

Upon thorough analysis of the 17 papers, a pattern emerges (Figure 4). Notably, two papers originated from the United Kingdom, and Portugal, indicating a strong research presence in these countries. In contrast, a single paper tackled the subject in India, Korea, Türkiye, China, Thailand, and the

Caribbean. Intriguingly, five papers omit specific location details, leaving their research areas undisclosed. This comprehensive exploration reveals distinct research concentrations, emphasizing the need for a broader global perspective on the economic impacts of artificial reefs on lobster populations especially in Malaysia.

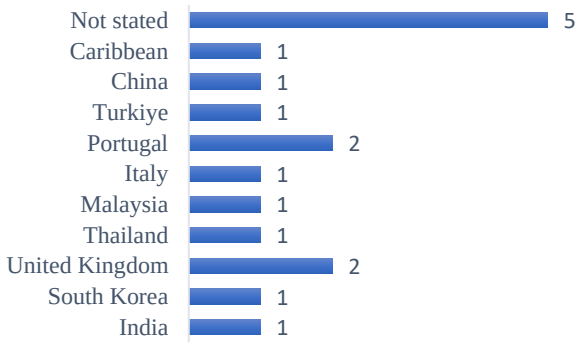

Figure 4. Number of studies per region

Two studies were conducted in Portugal and the United Kingdom, respectively. Each country exhibits a higher number of studies in comparison to other nations due to the relatively recent emergence of artificial reef research in both Portugal in 1990 and the United Kingdom in 1989.

3.1.3 Document type

Among the 17 pertinent documents, the concentration extends across three primary document categories: research articles, conference papers, and review papers sourced from both databases. A comprehensive assessment of these 17 documents underscores that the majority of papers fall under the category of research articles. This pattern elucidates a notable trend: artificial reef-related subjects are predominantly disseminated through the medium of research articles, in contrast to the representation observed in conference papers or review papers. Specifically, among the 17 documents, an impressive 13 are research article-based, while 3 stem from conference papers, and 1 originates from a review paper. The distribution of articles based on document type is vividly depicted in Figure 5.

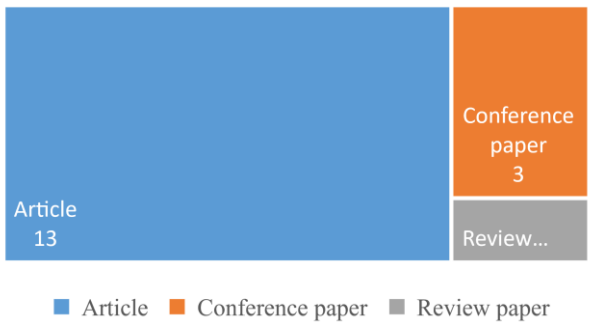

Figure 5. Distribution of articles by document types

4. MAIN FINDINGS

In this section, the focus of the discussion centers on addressing the research questions through targeted discussions and exploring the themes and subthemes identified in the analysis. Table 4 shows the result of article based on the research questions.

Table 4. The result of article based on research questions

Research Question	Reference
RQ1	Spanier et al. [17]; Kim [18]; Pickering and Whitmarsh [19]; Barshaw and Spanier [20]; Collins et al. [21]; Caddy and Stamatopoulos [22]; Spanier [23]; Mohamad Kasim et al. [24]; Ramos et al. [25]; Giansante et al. [26]
RQ2	Islam et al. [6]; Kirkbride-Smith et al. [27]; Polak and Shashar [28]; Acarli and Kale [29]; Sun et al. [30]; Kantavichai et al. [31]; Whitmarsh et al. [32]

4.1 The ecological efficiency of artificial reefs for lobsters

A growing number of people are interested in using artificial reefs as a viable remedy to lessen these environmental issues as a result of the collapse of natural coral reefs and the accompanying loss of important maritime habitats. With artificial reefs, protected areas are kept protected from the intrusion of damaging gears like trawls while simultaneously providing fresh habitat for fish and other wildlife [16]. For effective marine resource management and conservation activities, it is crucial to comprehend how well they support fish communities. In this RQ1, we focus on the effectiveness of artificial reefs as habitats for lobsters, assessing their effects on lobster abundance, species diversity, and community dynamics. Specifically, 10 articles in total were discussed in relation to this research question. By evaluating these artificial reefs structures' performance, we hope to provide insight on their potential as instruments for ecological restoration and the long-term management of maritime ecosystems.

Due to habitat destruction and degradation, along with the desire to boost local lobster populations for exploitation, researchers have started exploring ways to offer more shelter options in areas with limited habitats. Spanier et al. [17] quantifying effectiveness of artificial reefs for lobster through fisheries enhancement, management, and conservation. This book shows that artificial reefs designed for commercially valuable lobster species and their life stages have attracted lobsters, helped them recruit into the benthic environment, and made up for lost habitat over the past 50 years. To succeed, artificial reefs must be erected in suitable habitats and seasons and meet the ecological and behavioral criteria of the targeted species. The efficiency of these man-made habitats in promoting lobster population development over the long term, nevertheless, is still uncertain. Therefore, Spanier et al. [17] recommended carrying out large-scale, long-term research that compare lobster populations with and without artificial reefs in order to acquire deeper insights. The studies should ideally be conducted within Marine Protected Areas (MPAs) in order to take into consideration potential harvesting impacts by humans.

Kim [18] researched Korean artificial reefs for fish and shellfish. Korea has been studying artificial reef effectiveness since 1975. Six sites are examined annually for dominant fish species, catch weight per reef, reef condition, and structure shape. To evaluate the performance of fish and shellfish artificial reefs, the survey comprises dominating species,

capture weight per reef, reef condition, and structure shape. ROVs, underwater VTRs, side scan sonar, and gillnets evaluate. Reviewing Pickering and Whitmarsh's [19] "attraction versus production" discussion emphasizes the importance of design on reef effectiveness. Artificial reefs can boost lobster productivity if they are constructed to match the habitat needs of particular species and age groups, according to the scientists. They also argue that few studies assess how well different reef structures or designs perform for different species, but that many have proven that different species prefer different reef designs and that reef structure affects catch volume.

Barshaw and Spanier [20] examined lobster capture to assess artificial reef performance. In the study, Mediterranean slipper lobsters were tied within and outside an artificial reef to assess predator protection. Death rates were lower on the reef (7%) than in the open area (77%), according to their study. This indicates that the artificial reef effectively protected the lobsters from predators. The study also shed light on how lobsters defend themselves by hiding from predators and sticking to the substrate, among other strategies.

Collins et al. [21], focused is on the creation of a trial artificial reef using various combinations of waste materials. The study involves tracking the levels of heavy metals in the reef blocks, comparing the epibiota found on the blocks to the surrounding seabed, and identifying commercially harvested species, including lobsters. The outcomes of their experiment indicate that artificial reefs could support and increase lobster populations. This is due to the possibility that adding new reef areas for the experiment could result in an increase in the natural lobster population where there is currently a habitat shortage. The study also revealed that the reef had quick biological colonization by a variety of species, demonstrating the appropriateness of the artificial reef as a habitat.

Caddy and Stamatopoulos [22] provide a theoretical approach to analyze artificial surface habitat limits for lobster population enhancement. The method compares growth and mortality rates to natural substrate crevice frequency. This research advises identifying the ideal hole frequency at size before building an artificial reef by projecting growth and death rates onto the artificial surface and estimating crevice frequency at size. A "niche sampler" experimental field method can estimate occupancy at size in existing habitats to help build and install artificial lobster reefs. Spanier [23] suggests assessing lobster artificial reefs. These include sheltering high-value species on the reef, enriching reefs with nutrient-rich materials to attract commercially valuable fish, rearing commercial species in cages on the reef to boost productivity, and using acoustic signals and artificial enrichment to lure commercial species to underwater traps. These methods improve fisheries and fish yield by Mediterranean slipper lobsters in low-productive marine habitats.

4.2 The economic contribution of lobster on artificial reef based on the artificial reef development program

In this research question section, there are 7 main articles are used to analysis. The articles are not based in Malaysia study where the main gap of the research is the lack of study in Malaysia. The lobster's habitat and ecosystem are always around the reefs. The artificial reef is designed for the lobsters to increase the habitat. Here the valuation of lobsters based on the ARs designs and importance towards the lobster's livestock. Economic valuation is a huge method to identify the valuation of a certain object. Economic valuation can conduct to analysis the efficiency of the object.

To assess the economic contribution of lobster on artificial reefs, various methods can be employed. These methods include the contingent valuation method (CVM), habitat surveys, community and socioeconomic surveys, and visual census of artificial reefs (AR). Every method has robust justifications. CVM is employed to gauge the willingness to pay and consumer surplus. The habitat survey was conducted to ascertain the economic impact of the environment. During the process of performing a community and socioeconomic survey, the main objective is to identify the economic contributions made to the community. The visual census is conducted to detect alterations in the AR over a period of time.

Contingent valuation surveys people's values of goods, services, and facilities [27]. Environmental research sometimes uses contingent valuation to value amenities non-marketly. Hypothetical scenarios are used to assess WTP and non-market value use [28]. Figure 6 shows this research question's economic value technique.

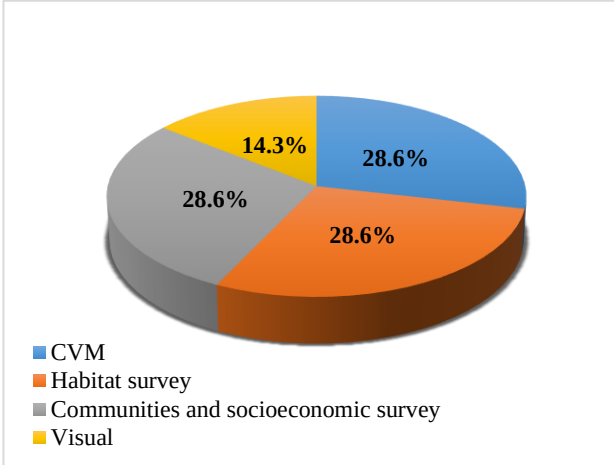

Figure 6. The economic valuation techniques of the study

The research based on the valuation of lobsters towards the artificial reef. The European lobster is an important species due to its great economic value and consumption as human food. The findings showed that artificial reefs might improve the area's species composition [29]. *Inachus dorsettensis* (28.64%) and *Carcinus aestuarii* (25.91%) species account for 55% of all individuals observed near the artificial reefs. As a result, while these artificial reefs are species-specific for lobsters, they also serve a vital ecological function for other species. The study focuses on the artificial reef design should be sustainable towards the biodiversity where it helps to evaluate the economic values of lobsters. To ensure the sustainability of lobster stocks in the natural environment, the construction and study of species-specific artificial reef models is necessary [29].

Compared to biological AR evaluations, economic AR evaluations are new, according to Sun et al. [30]. Economic evaluations consider efficiency and social impact. If resource access is not regulated, an AR that aggregates fish may harm a fishery's economic performance. ARs' economic performance can be assessed using consumer and producer surplus methods. The investigation found mixed results: artificial reefs did not increase fish and invertebrate catches or revenues. An artificial reef boosted capture and value per unit

effort by 40% relative to control areas by accounting for species variations and focusing on common fish [30].

This study compares respondents' usage ratings of natural and artificial reefs in a Barbados marine protected area [27]. Bermuda estimated the annual economic value of their coral reefs at US$722 million, with tourism contributing US$406 million. The paper examines artificial reefs and economic valuation. The contingent valuation approach of willingness to pay (WTP) can estimate visitor contributions. Surveys and payment card contingent valuation are used to estimate the maximum WTP. Single- and double-bounded dichotomous choice and open-ended inquiry are other common non-market item demand evaluation methods. The average WTP for natural and artificial reef use was US$18.33 and US$17.58, respectively. This information may help set a daily marine reserve user fee for the island.

Polak and Shashar [28], using the contingent valuation technique (CVM), examined divers' willingness to pay for fish and coral quality changes across an artificial reef. Contingent valuation method is an actual act of analysis the economic valuation. This study focuses on artificial reef and the importance of biodiversity aspects. Furthermore, most characteristics of biodiversity are valued positively by individuals [28]. However, being artificially created structures, ARs provide researchers with an excellent environment in which to conduct planned and controlled investigations. Here, the economic evaluation is basically based on the artificial reef where how it effects towards the fishes by having CVM towards the divers.

The field of research on lobsters and artificial reefs is still in its nascent stage in Malaysia. The only study conducted in Malaysia primarily examined the fisher's community and assessed the effectiveness of AR by quantifying its impact on the fisher's income. The Department of Fisheries Malaysia (DOFM) implemented a new initiative in 2022 to establish refugia protected areas for spiny lobster in Johor, Malaysia, and for tiger shrimp in Miri, Sarawak. Various factors can be examined, particularly those pertaining to ecological efficiency and the assessment of economic contributions in Malaysia.

This study holds relevance and significance in its contribution to the fields of fisheries and marine biodiversity. It aims to enhance our understanding of various aspects, including the socioeconomic profiles of fishers and communities, coastal activities, economic valuation, marine biodiversity, the significance of artificial reefs for habitat purposes, lobster breeding, and species valuation.

5. THEME AND SUBTHEME BASED FINDING

The discussion in this section focuses on a topic and its subthemes. The analysis resulted in two themes and six sub-themes in total for this theme and subtheme-based discussion.

5.1 Theme 1: Fisheries

All the research articles are contributing towards the fisheries as in multiple aspect. Fisheries are organized based on the types of fish attracted by reefs, which include small fish, lobsters, and other shellfish [22]. Many artificial reefs have been developed worldwide to improve fisheries [21]. High recruitment mortality severely limits the reef's coordinated fisheries management [19].

Experiments on the behavior and ecology of slipper lobsters have previously been hampered by the lobsters' vast spread and deep-water distribution, as well as the difficulty in locating a stable population [20]. AR designs focus on marine species. Acoustic signals and partly artificial enrichment could lure commercial species to underwater traps to improve fishing in such habitats. In all oceans, *Palinuridae*, *Nephropidae*, and *Scyllaridae* adult lobsters are valuable fishing resources [17].

Thailand's fisheries agency improves ARs. In 1978, Thailand's Department of Fisheries began installing AR in coastal provinces in the Gulf of Thailand and Andaman Sea [31]. ARs have been built 5 km from the coast in Lang Suan District, Chumphon Province, since 2011 to improve small-scale fishing and prevent illicit inshore trawling.

DOFM used AR to protect inshore fishery habitats from trawls to improve fisheries resources in Malaysia, whereas FDAM used AR to help artisanal fishermen raise fishing income [6]. In Tamil Nadu, India, ARs are also used in fisheries to attract dispersed fishes and produce new fish biomass, create fishing opportunities, reduce user conflicts, save time and fuel, reduce fishing effort, make fish location more predictable, increase public access and safety by deploying in nearshore sites, and reduce fishing effort [24].

Whereas in Italy, it highlights the benefit of artificial reefs as a solution to the problem of low income, non-commercial fisheries, as well as the problem of overexploitation of halieutic resources. Man-made constructions in Portugal can also change marine habitats and fisheries. These "artificial reefs" are used for food production, mariculture, tourism, and resource conservation [32]. Commercial and recreational fisheries were the only activities detected in the artificial reef and surrounding regions [25].

Fisheries is basically related with fisheries management. Artificial reefs have been utilized for a variety of purposes, including habitat restoration, fish stock augmentation, and fisheries management [29]. Hence, in China a long-term ecosystem analysis of the primary fishing areas for Shandong-based fisheries revealed that the overall capture rate decreased from 420 kg/h to 8 kg/h between 1959 and 2008 [30]. AR's principal purpose is to increase fisheries production. Fisheries and ARs are related where the largest number of reefs are found near the coasts of underdeveloped countries, where people rely largely on reef ecosystems for a living [27].

It also attracts the fishing tourism category, especially the recreational fishing activity. Direct and indirect usage values include fishing tourist, recreation, coastal preservation, and fisheries nursery grounds [28]. The fisheries aspect can discuss in various matter. As the main theme of the research, there are two subthemes are split which are (1) socioeconomic profile and (2) economic valuation. All the articles are discussed briefly about the subtheme diversely.

5.1.1 Sub theme 1: Socioeconomic profile

The entire socioeconomic profile can be divided towards the fishers, communities and coastal activities. Table 5 below shows the studies that contributes towards the element. Basically, the socioeconomic profile is based on the fishers, vessels, fishing activities, coastal communities and many other aspects. Over the next six years, Korea intends to invest more than US$2 billion in these initiatives. When these projects are completed, coastal fisheries production is estimated to exceed 3 million tons per year, which is one million tons greater than it is now [18].

Table 5. The efficiency of artificial reefs towards the lobsters

Elements	Articles
Design of Artificial Reefs	Spanier et al. [17], Pickering and Whitmarsh [19], Barshaw and Spanier [20], Caddy and Stamatopoulos [22]
Survival of Lobster	Kim [18], Collins et al. [21], Spanier [23]

Because the major AR design determines harvest levels from such endeavors, it also affects the socioeconomic viability of deployment, especially for species-specific projects. Enforcing reef property rights may decrease or eliminate economic damage, but the legislative and policy changes needed may be difficult [19].

There is study also about random aspect of the fishers and the type of catches. Whereas, Collins et al. [21], relates how the socioeconomic profile as fishers affects the artificial reefs continuously. The artificial reefs have always been disturbed by the big vessels such as trawlers and seiners. Where this author concern about the fishers towards the ARs [22]. Fishers are always visible towards the opportunity. Knowing lobsters are drawn to these unexpected constructed reefs, fishermen have set traps and lobster pots there to collect more. According to some, these reefs' fundamental significance is their ability to concentrate fishing activities, allowing Japanese fishing villages' small fishing vessels to survive [17].

While these benefits exist, Thailand's Department of Fisheries includes AR initiatives in the national socioeconomic development plan to improve small-scale fishermen's incomes and quality of life. Artificial reefs reduced fishery revenue for 24% of households. While those with no change and those with a fishing income increase were both 38% [31].

Small-scale fisherman in Terengganu, Malaysia, have always used ARs to catch more. The results suggest that artificial reefs may not help Terengganu's artisanal fisherman catch and earn more [6]. In India, the Joint Directors and other staff of the Tamil Nadu Fisheries Department sanctioned the consultancy project, assisted in the fabrication and deployment of artificial reefs, and studied the socioeconomic impact of the reefs on coastal fishery and fishers [24].

Hence, in Italy the fishers especially the small-scale fisher has high concern towards the socioeconomic performance. Both artificial reefs and control sites were monitored for lobster valuation around the reefs with the help of small-scale fishermen [26]. Since these impacts may be evaluated in monetary terms, AR programs' socioeconomic efficacy can be assessed based on overall economic efficiency or group benefits (raising fishermen's income) [32]. The concern is based on the fishers and income. The case study in Portugal focuses on the communities where it has the benefits of socioeconomic. These have resulted in socioeconomic benefits for traditional fishing village families. The reef's influence in order to determine the net socioeconomic advantages garnered by local populations [25].

There are research concerns on the coastal activities where the ARs and lobsters may play an important role. Artificial reef development takes place to improve diving tourism, sport fishing, and angling [29]. The recreational fishers mostly allowed in the ARs developed area because it may not affect the habitat entirely. The emphasis is on recreational and artisanal fishermen. Recreational fishermen can catch in AR habitat regions where artisanal are not permitted to access [30].

The scuba diving and snorkeling businesses depend on coral reefs, and reef tourism brings millions of dollars to coastal towns [27]. Coastal divers are the sole focus of the investigation. Artificial reef design affects structure. Socioeconomic interaction study should help explain this AR tendency. Transplanting corals in natural coral reefs and ARs and designing ARs to increase fish population may improve reef aesthetics [28]. According to the study, socioeconomic profile is crucial to analysis.

5.1.2 Sub theme 2: Economic valuation

The economic valuation based on the ARs and also the marine species are the major concern. The evaluation in various ways helps to boost the research entirely but there are many studies with no exact method in valuation conducted. Since 1975, Korea has been researching the efficiency of artificial reefs, and six sites are monitored each year. The catch volume per reef was 2-13 times more in artificial reefs than in natural reefs, according to the findings. Over the next six years, Korea intends to invest more than US$2 billion in these initiatives to improve coastal fisheries productivity [18].

After attempts to increase productivity and environmental carrying capacity, reef-based fisheries may lose much of their commercial value if exploitative initiatives are allowed to flourish freely for profit [19]. A study found that the economic evaluation failed to identify the AR and lobster predation, with 42 lobsters rescued and survived [20].

Commercial harvesting of economically significant species like lobsters is recommended by Caddy and Stamatopoulos [22]. Lobsters usually have von Bertalanffy K values above 0.5. Spanier [23] noted high-priced species use the reef just for protection during part of the day or season and feed over a larger area are the source. Catching lobsters is the main objective. Although several lobster species have been successfully raised in captivity, economic hurdles prevent commercial aquaculture. However, aquaculture can replenish fisheries and natural populations [17].

Fishing is becoming more profitable. Kantavichai et al. [31] said 6% fisheries income growth is good for the economy. The warning was included. To prevent resource overexploitation, a clear exploitation strategy and management plan should be established for long-term advantages. In Besut, Terengganu, inboard fisherman is profiting from AR habitat fishing. Inboard-powered fisherman caught 17% more (US$831) than outboard-powered fishers (US$686). Inboard-powered Besut fishermen made 39% more [6].

The Tamil Nadu, India study uses cost effectiveness analysis to evaluate economic evaluation, according to Mohamad Kasim et al. [24]. Cost-effectiveness analysis can assess artificial reef project economics, activities, and benefits. This approach calculates how much of the expected deployment cost was realized during reef deployment. According to the Italian research paper, each catch was recorded to estimate fishery productivity after artificial reefs were installed: species identification specimen count [26].

Quantifying reef effects (e.g., catch weight) and using market prices to value output makes monetary valuation simple. It is generally known that commercial fisheries can overexploit artificial reefs, despite their significant economic benefits. Direct and indirect values are employed to value the study economically [32]. The catch per unit is another approach to appraise this reef system [25]. The economic performance (measured as value per unit of effort) shows a significant "reef effect," with larger catches expected.

Moreover, the study that conducted at Sea of Marmara [29] mentioned that around the artificial reefs, 988 individuals from 20 distinct species were counted. These species comprise ten *actinopterygii*, six crustaceans, three *echinodermata*, and one mollusk, six of which have economic value. Sun et al. [30] mentioned that Shandong China economic evaluations include assessing socioeconomic impact and efficiency. If access to a resource is not restricted, an AR that is effective at aggregating fish may jeopardize the overall economic performance of a fishery. It was emphasized that non-restricted harvesting is the reason that ARs failed to deliver economic benefits to artisanal fisherman.

Based on economic evaluation, WTP is included. Kirkbride-Smith et al. [27] found that coral reef tourism generates US$406 million of their average US$722 million annual economic value. WTP research show that divers will pay more for conservation programs that promote biodiversity on artificial coral reefs and larger fish on natural reefs. The CVM also produces outstanding production that leads to economic evaluation. Using contingent value, Polak and Shashar [28] examined divers' willingness to pay for fish and coral quality changes over an artificial reef. The majority of biodiversity is valued. Economic valuation is crucial since it improves AR and lobster analysis. Due to the minimal number of research investigations, lobster evaluation is lacking. This is one of the most important research factors.

5.2 Marine biodiversity

In order to maintain marine ecosystem habitat, destructive fishing gears such as trawl nets and push nets are also prohibited in this zone [31]. Artificial reefs are constructions established on the sea floor to generate and act as a new habitat type for marine organisms or to protect and develop existing habitat [29]. Coral implantation is projected to increase fish and invertebrate richness while also providing a new habitat for common and, in some cases, unusual marine creatures [28].

The marine species are basically the important theme are categorized due to the marine biodiversity. The ARs and lobsters are the part of marine species, habitats and many more. Kim [18] mentioned that Korea, which is bordered by water on three sides, has used marine items in its cuisine since ancient times. Koreans appreciate seaweeds such as kelp, shellfish such as abalone and top shell, and fish. In fact, marine items account for around 45% of Korea's protein supply.

However, coastal zone output has recently fallen due to overfishing, pollution in coastal areas, intense aquaculture, and land reclamation. Whereas, marine structures, whether man-made or natural, have been shown to attract and concentrate fish, hence improving stock levels [19]. The ARs are also major focus in the marine biodiversity theme. Here, the marine fauna and algae samples are utilized on the surface of blocks for routine metal analysis and to assess the relative growth of organisms [21].

Theoretically, marine biodiversity involves investigating artificial surface habitat constraints for population augmentation of crevice-dwelling or territorial organisms like reef fish or lobsters, taking into account known growth and mortality rates [22]. Protected areas are crucial to marine biodiversity. Spanier et al. [17] noted that marine protected zones (MPAs) have become popular for protecting marine organism populations. Lobsters can be managed with MPAs and artificial reefs. Marine reserves can protect reproductive populations and endangered or overfished populations. Spanier [23] said complicated artificial reefs created coastal waters, lowering breeding productivity.

Overexploitation factors always target marine biodiversity. Islam et al. [6], who have long targeted marine fisheries overexploitation in numerous nations, have gained policymakers' attention. Studies mention MPAs. An innovative artificial reef deployment program linked to restricted-entry marine protected zones (MPAs) to mitigate overfishing [32].

ARs encourage recreational fishing, restrict access to marine protected areas, and restore and sustain coastal fisheries [30]. Mohamad Kasim et al. [24] say artificial reefs can be marine protected areas. Nearshore fish are constantly available. Artificial modules have repopulated ichthyic fauna, protected marine biodiversity, and increased high-value marine species [26].

Meanwhile, Ramos [25] concluded that artificial reefs have been deployed in a number of locations across the world to support commercial or recreational fishing activities, or simply to conserve fish and marine ecosystems. Marine species and marine protected areas (MPAs) have proven to be successful methods of protecting reef ecosystems from human interference while yet enabling recreational use of resources such as scuba diving and snorkeling [27]. The marine biodiversity is the main second theme of the study. Here, the subthemes are split into 2 such as (1) importance of artificial reefs and (2) species valuation. The subthemes are explained precisely in the below sections.

5.2.1 Sub theme 1: Importance of artificial reefs

The importance of artificial reefs is a major analysis of the entire study where it has the own purpose of functions. Table 6 shows the element of the importance of the ARs are sorted out. The habitat here refers to the habitat of fishes, lobsters and any marine species around the ARs. The fish and lobsters breeding purpose here refers to the increase of population of the species after the ARs installation. Hence, the coastal activities are categories as fishing, diving, scuba and many more.

Table 6. The categories of socioeconomic profile

Elements	Articles
Fishers	Islam et al. [6]; Spanier et al. [17]; Kim [18]; Pickering and Whitmarsh [19]; Barshaw and Spanier [20]; Collins et al. [21]; Caddy and Stamatopoulos [22]; Spanier [23]; Kantavichai et al. [31]; Mohamad Kasim et al. [24]; Whitmarsh et al. [32]; Giansante et al. [26]
Communities	Kirkbride-Smith et al. [27]; Ramos et al. [25]
Coastal Activities	Polak and Shashar [25]; Acarli and Kale [29]; Sun et al. [30]

Since the 1970s, numerous coastal locations have artificial reefs to boost fisheries [18]. The national government finances reef projects up to 80%, while local governments pay the rest. Pickering and Whitmarsh [19] found that artificial reefs increase benthic invertebrate biomass. They also add cover by making the artificial reef look natural. Artificial reef design, location, planning, and evaluation are becoming a priority for research.

Barshaw and Spanier [20] addresses these issues, as artificial reefs were constructed and installed at a depth of 18.5

meters off the coast of Haifa. Long-term studies on the ecology and behavior of S. latus were undertaken using these artificial reefs, allowing researchers to track seasonal movement patterns and shelter preferences of this little-studied species. The artificial reefs help to expand the population of the species, but it has the own disadvantage too. Collins et al. [21] mentioned that one of the biggest concerns about artificial reefs is that they attract members of the existing natural population while not increasing overall numbers, hence increasing exploitation.

Thus, artificial reefs must be designed to maximize lobster and other marine species breeding. To design and test artificial structures with perforations of a size and frequency appropriate to the life cycles of mobile crevice fauna (such as reef fish or lobsters), one can design the surface based on theoretical concepts or evaluate an arbitrarily selected sequence of designs to find the best productivity or standing stock [22]. Enriching man-made structures with nutrients attracts valuable fish like large groupers [23]. Therefore, artificial reefs aim to increase target species' long-term abundance and productivity [17].

Artificial reefs have several marine environment benefits. Over the past 30 years, Thailand has increasingly used ARs, submerged objects that simulate natural reefs, to increase biological resources [31]. Artificial reefs (AR) on the sea floor can manage fishing, increase fish stock productivity, and reduce habitat damage [30]. Artificial reefs may increase biodiversity by diversifying habitats [26]. The Terengganu, Malaysia, study indicated that artificial reefs (AR) are becoming more popular for coastal fisheries and fishermen's revenue [6]. Artificial reefs may boost resource development and the economy. High-quality fish from artificial reefs allowed fisherman to earn more per unit effort [24]. Artificial reefs, like any fishing technique that increases catchability coefficient, boost economic rent from fisheries, but unless effort is limited, the rent may be wasted [32]. Thus, it has been used as an artificial reef to increase marine resources cheaply. Artificial reefs have altered commercial fishing [25].

ARs are traditionally characterized as submerged, man-made structures that have an impact on the local ecological community [28]. The artificial reef focuses on the sustainability of lobsters too. Acarli and Kale [29], ensure the sustainability of lobster stocks in the natural environment, species-specific artificial reef models are necessary. The importance of coral reefs to coastal populations in terms of marine enjoyment, shoreline protection, and fisheries output [27]. The importance of artificial reefs is equally needed to analyze due to the contribution of articles are lack as mentioned earlier. The study based on the ARs, and lobsters are rare in Malaysia entirely. Table 7 shows the aim and importance of artificial reefs based on reviewed articles.

Table 7. The aim or importance of artificial reefs

Elements	Articles
Habitat Purpose	Kim [18]; Pickering and Whitmarsh [19]; Barshaw and Spanier [20]; Sun et al. [30]; Kantavichai et al. [31]; Giansante et al. [26]
Fish or Lobster Breeding	Spanier et al. [17]; Collins et al. [21]; Caddy and Stamatopoulos [22]; Spanier [23]
Coastal Activities enhancement	Islam et al. [6]; Kirkbride-Smith et al. [27]; Polak and Shashar [28]; Mohamad Kasim et al. [24]; Whitmarsh et al. [32]; (Ramos et al. [25]

5.2.2 Sub theme 2: Species valuation

The species valuation conducted in this area primarily encompasses lobster, various types of shellfish, and fish that inhabit the vicinity of the artificial reefs. The scarcity of studies undertaken on lobsters has resulted in a dearth of comprehensive study, with most of the existing papers merely providing a general overview of the species. In our study, we included both ecological and economic assessments to measure the value of the species. Here, a significant research vacuum exists in the paucity of studies on the correlation between lobsters and artificial reefs, both in Malaysia and globally. Table 8 displays the elements that were classified for the analysis.

Table 8. The main species valuation of the entire studies

Elements	Articles
Lobsters	Islam et al. [6]; Spanier et al. [17]; Pickering and Whitmarsh [19]; Barshaw and Spanier [20]; Collins et al. [21]; Spanier [23]; Acarli and Kale [29]
Shellfish	Kim [18]; Caddy and Stamatopoulos [22]; Sun et al. [30]; Kantavichai et al. [31]
Fishes	Kirkbride-Smith et al. [27]; Polak and Shashar [28]; Mohamad Kasim et al. [24]; Whitmarsh et al. [32]; Ramos et al. [25]; Giansante et al. [26]

Reef programs in Korea promote shellfish, seaweed, and finfish [18]. Shellfish and seaweed structures are erected in 20-meter water. About 104 of the 800 fish species in Korean coastal waters were captured in reefs. Pickering and Whitmarsh [19] found that artificial reefs have lower lobster occupancy than productive lobster grounds. In 1993, little lobsters (27 mm CL) were captured on the reef, indicating recruitment, however larval lobsters may not stay to complete the life cycle.

The cycle of lobster mortality is also linked, with reef lobsters dying at 7% compared to 77% in the open environment, proving that sheltering is beneficial [20]. Off the shore, Mediterranean slipper lobster habitats may be rare. Collins et al. [21] concur lobster populations are rising. Eight commercially important species—lobsters, edible crabs, spider crabs, swimming crabs, whelks, oysters, red mullet, and cuttlefish—show the structure's fisheries potential.

The lobsters on Poole Bay are from existing reefs, but adding new sites would allow the native population to grow in habitat-poor places. Research [22] shown that artificial reefs value lobsters by breed. There are many ways to boost shellfish output in low-productive maritime environments. A popular example is the Mediterranean slipper lobster [23]. The 2007 lobster valuation was 226,805 metric tons, with clawed lobsters accounting for 158,933 tons, 70%, spiny lobsters for 63,972 tons, 28%, and slipper lobsters for 3,900 tons, 2% [17].

Moreover, small-scale fishers catch shellfish near the artificial reef region, which results in a good profit [31]. The small-scale fishers usually will gain high profit due to the catches are near to the coastal area. The Department of Fisheries Malaysia built concrete cubes, cuboids, soft bottoms, lobsters, and tetrapod [6]. These robust shelters were built to protect inshore fishing from trawls.

Mohamad Kasim et al. [24] noted that artificial reefs attract a variety of species and are plucked indiscriminately, which could lead to overfishing quickly. This area's fish prefer shellfish. Reefs are favorable for ARs, which colonize quickly

and feed other fish and shellfish [26]. Additionally, reefs attract marine life. When a reef takes fish from their native home, vessels operating in such areas may catch less [30]. Thus, artificial reef deployment concentrates fish species, improving catch per unit of effort (CPUE) and resource accessibility for nearby fishing populations [25].

The European lobster (*Homarus gammarus Linnaeus, 1758*) is important because of its economic value and human consumption, according to Acarli and Kale [29]. Thus, artificial reefs resemble natural ecosystems, allowing young shellfish and fish to grow normally with or without some exogenous feed [30].

According to Kirkbride-Smith et al. [27], AR conservation initiatives include fish species growth and biomass. 95% of AR tourists saw fish, the most generally recalled species. The author noted that fish and coral values, diversity, and richness have yet to be tested, and their respective contributions have yet to be defined. Adding shellfish and corals to ARs may make them better reef surrogates. ARs' worth depends on the fish's intent.

6. CONCLUSIONS

Coral reefs are among the most important ecosystems on the planet. They resemble tropical rainforests in that they can survive in nutrient-poor conditions while still supporting wealthy communities and exhibiting high levels of species diversity and total productivity. However, according to a survey by the World Resources Institute, up to 56% of the world's reefs are currently in danger. Already, 24% of the world's reefs have suffered significant harm or have been completely destroyed. Numerous reefs that have been observed over the past 15 years show a consistent decrease in the amount of live coral cover. Up to 70% may be irreversibly lost, according to some scientists, by 2020. Artificial reef has thus been proposed as a viable technique for reef rehabilitation and restoration. Malaysia don't exception for this since DOFM initiated R&D efforts on the design and construction of ARs in Malaysia in 1975.

However, upon reviewing all the articles, it becomes evident that there exists a substantial gap in this field of study in Malaysia. Among the total of 17 reviewed articles, only one paper was centered in Malaysia. The research exploring lobster valuation in conjunction with artificial reefs is exceptionally scarce. Given the rarity of such investigations, a comprehensive review becomes highly valuable in highlighting the prevailing gaps. The overarching research questions of these studies predominantly delve into the significance, requirements, valuation, and function of artificial reefs. However, the evaluation of the critical role lobsters play remains notably infrequent.

In terms of the reviewed studies, the 17 articles hail from at least 9 different countries, representing a diverse geographical spread. Within this collection, the papers encompass a mix of articles, conference papers, and review papers. The research is organized around two main research questions: evaluating the efficiency of artificial reefs for lobsters, and appraising the economic value of lobsters in artificial reefs. These inquiries are further classified into two primary themes: (1) fisheries and (2) marine biodiversity, each with specific subthemes such as socioeconomic profile, economic valuation, importance of artificial reefs, and species valuation. All 17 articles are meticulously reviewed in light of these factors.

This comprehensive evaluation underscores the existing research gaps and validates the necessity of this review. The insights gained through this analysis serve to augment the understanding of both lobsters and artificial reefs, fostering potential avenues for further exploration. This project allows future lobster and artificial reef researchers to contribute to the field. Thus, this study and its gaps are crucial to future research.

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