Bioculture
Bioculture Journal
Bioculture 2(2): 91-105
ISSN 3025-3632

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

The role of humans in the sustainability of marine ecosystems: A case study on the conservation of parrotfish and its ecological impact

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Received Date: December 16, 2024 Revised Date: January 31, 2025 Accepted Date: January 31, 2025

ABSTRACT

Background: Life is supported by the ecology and natural resources that exist on earth. Continents and oceans are the two main natural resources that host life and ecosystems around the world. 75% of the Earth's surface is covered by ocean waters that are rich in marine life. Although the oceans are vast, this does not mean that they are limitless. Population growth and development have led to an increase in the demand for marine resources. Increased demand and over-utilization of marine resources have led to strong pressures that have led to a decline in marine ecosystem services. Karimunjawa is famous for the natural beauty of its underwater coral reefs. **Methods**: This study employs a qualitative approach using literature and secondary data to examine the impact of parrotfish populations on coral reef sustainability. **Findings**: Based on current conditions, excessive catching of parrotfish has a negative impact on the sustainability of coral reefs in Karimunjawa National Park. It is necessary for local communities to understand the importance of the role of parrot fish for the sustainability of marine ecosystems. Parrotfish spend 90% of their time eating algae attached to coral reefs. Damage to the coral reef ecosystem causes coastal erosion in Karimunjawa National Park. Therefore, the role of the community in managing parrotfish resources is very necessary so as not to threaten the population for the sustainability of the marine ecosystem. **Conclusion**: The results of this research illustrate the role of humans, namely the community and tourists who come to Karimunjawa to carry out activities to preserve damaged coral reefs and create new coral reef areas. **Novelty/Originality of this article**: There are also government policies that must be considered and implemented properly for the sustainability of coral reef ecosystems and the conservation of parrotfish in Karimunjawa.

KEYWORDS: parrotfish; coral reef fish; coral reef; marine; Karimunjawa; sustainability.

1. Introduction

Life is supported by ecology and natural resources on earth. Continents and oceans are two main natural resources, which are places of life and ecosystems throughout the world. 75% of the earth's surface is covered by ocean waters, which contain a wealth of marine biota. The main source of food, energy and mineral resources is in the sea. The oceans also control the global climate. Land is dominated by plant biomass, while animal biomass dominates in ocean waters. Water-based living environments are called aquatic ecosystems (Balasubramanian, 2011). The sea does not only have fish and food resources for human consumption. There are islands that contain endless biodiversity and rich marine resources.

Cite This Article:
Rudiyono, A., Juanda, E. T., & Buditama, G. (2025). Combination of non-renewable and renewable natural resources for sustainable energy provision in Indonesia. *Bioculture, 2*(2), 91-105. https://doi.org/10.61511/bioculture.v2i2.2025.1466

Diving in coral reef areas and swimming with sharks (some of which replace traditional fishing) are some of the things that attract tourists to support the growth of the ecotourism industry. There are also medicines and other high-value commodities that are sourced or harvested from the sea. Such as fish, crustaceans and molluscs which are caught to be used as food, fertilizer, and other products (Baker et al., 2009).

Even though the ocean is very wide, that doesn't mean it has no boundaries. Marine resources are under very strong pressure to meet increasing needs and demands due to human population growth and globalization. Several sectors of the world's valuable fisheries have collapsed and increasingly many species are threatened with extinction due to human activity. Changes such as habitat loss and environmental degradation pose significant threats to marine life (Baker et al., 2009). Karimunjawa is known for its natural beauty, one of which is the beauty of the underwater. Coral reefs are a typical ecosystem that can be found in tropical oceans. Coral reefs are marine ecosystems composed of massive calcium carbonate ($CaCO_3$) deposits formed mostly by coral animals (phylum Cnidaria, Class Anthozoa, Order Scleractinia), a small percentage of calcareous algae, and CaCO3-secreting organisms (mollusca, sponges, and segmented worms). This ecosystem is inhabited by various types of biotas, such as coral reefs, algae, invertebrates, coral reef fish, etc. This ecosystem is one of the most productive ecosystems in the marine ecosystem and has been formed since millions of years ago (Nybakken & Bertness, 2005).

Karimunjawa National Park is a national park located in the north of Java. The national park area is within the administration of Jepara Regency. Karimunjawa was designated as a national park on February 29, 1988, but at that time its status was known as a Nature Conservation Area. This determination was based on the Ministry of Forestry decree No. 161/Menhut-II/1988 covering 111,625 ha of land and sea. The status was finally changed to a national park on February 22, 1999 through the Ministry of Forestry decree No. 78/Kpts-II/1999, change of function of the Karimunjawa nature reserve area and its surrounding waters, located in the Jepara Regency. Central Java Province covering an area of 111,625 hectares into a National Park under the name of Karimunjawa National Park. Its consist of mainland of Karimunjawa 1.285,50 Ha, land of Kemujan 222,20 Ha and sea 110.117,30 Ha (tnkarimunjawa.id, 2011). However, due to ineffective management, the zone Karimunjawa National Park eventually underwent two zone revisions in 2005 and 2012. The Directorate General of Natural Resources and Ecosystem Conservation (Ditjen KSDAE) established the zoning of Karimunjawa. The zoning determination was updated on March 6, 2012, by the Decree of the Director General of PHKA No. SK.28/IV-SET/2012. The nine zones of Karimunjawa National Park are as follows – Core Zone 444,629 Ha, Forest Zone 1,451,767 Ha, Marine Protection Zone 2,599,770 Ha, Land Utilization Zone 55,933 Ha, Marine Tourism Utilization Zone 2,733,735 Ha, Marine Cultivation Zone 1,370,729 Ha, Religious, Cultural, and Historical Zone 0.859 Ha, Rehabilitation Zone 68,329 Ha, and Traditional Fishing Zone 102,899,249 Ha.

Coral reefs are dynamic ecosystems with high biodiversity. Therefore, coral reefs have a significant role in the environment. Ecologically, coral reef habitats generally live on the edge of the coast or areas that are still exposed to sunlight, at a depth of about 50 meters below sea level. Coral reefs are home to fish and plant organisms that find food and shelter. Physically, coral reefs can protect the coast and the life of shallow water ecosystems from sea abrasion (Suryanti et al., 2011).

Coral reefs are major geological structures built by biological activity. Corals are found along the coast, and look like rocks. Coral is a skeleton that is inhabited by many small marine animals such as coral fish. Each of these animals is known as a coral “polyp.” Coral polyps are soft animals and their bodies are almost transparent. Because it does not have a backbone, it is an invertebrate animal. Corals that have a hard skeleton are called stony corals. They have special cells on the periphery of their bodies that produce lime, which makes them hard like rock. Polyps are part of coral like parts of the skeleton. Corals belong to a large group of invertebrates that include jellyfish, sea anemones, and hydroids (Balasubramanian, 2011).

Table 1. The types of corals

Stony corals	Soft corals
1. Stony corals	1. Sea fan
2. Finger corals	2. Bushy soft corals
3. Fungus coral	3. Sea Feather
4. Brain coral	4. Black coral
5. Tube coral	
6. Rose coral	
7. Staghorm coral	
8. Lettuce-leaf coral	

(Balasubramanian, 2011)

The coral reef habitat in TNKJ is dominated by fringing corals with less extreme oceanography, making the richness of reef fish species in TNKJ relatively high (Campbell et al., 2013). A high diversity of coral genera can be found in areas from 8-12 m depth, including 72 coral genera from 19 families. Acropora and Porites are coral genera that dominate throughout the cluster on the reef with various growth forms such as branching, tabulate, digitate and massive (Pardede et al., 2016). An ecosystem is a set of organisms within a defined area of land or volume of water that interact with one another and with their environment of nonliving matter and energy (Miller & Spoolman, 2018).

Coral reef ecosystem is a limited resource that can be degraded therefore a management effort is needed to ensure that coral reef resources remain sustainable and utilized sustainably. To prevent further deterioration of coral reef conditions, coral reef ecosystem management is required. Management is a process of controlling human actions so that the utilization of resources can be done wisely by considering the rules of environmental sustainability. The process of resource management, especially coral reefs, should be done with the involvement of coastal communities, because coastal communities are the main direct users of these marine resources.

Coral reef fish are a very important biota for the sustainability of the coral reef ecosystem especially in Karimunjawa National Park. Coral reef are one of the most fertile and food-rich marine ecosystems. The physical structure of coral reefs is complex, with branches, caves and passages. The physical structure of coral reefs makes this ecosystem a habitat for many types of marine life including coral reef fish. Coral reef fish utilize coral reefs as a place to live, shelter and find food. Almost the entire life cycle of reef fish is in the coral reef area (Syahrul, 2021).

According to their food type, reef fish can be divided into several families (Randall et al., 1990). First, Acanthuridae, known as surgeonfish, feeds on bottom algae and has a long digestive tract. Their primary diet consists of zooplankton or detritus. Surgeonfish are capable of cutting other fish with the sharp spines on their tail fin. Second, Balistidae, also known as triggerfish, are solitary daytime carnivores that feed on a variety of invertebrates, including hard-shelled mollusks and echinoderms. Some species also feed on algae or zooplankton. Third, Blennidae typically live in small holes on the reef and are mostly bottom-digging species that feed on a mix of algae and invertebrates. Some species are plankton eaters, while others specialize in feeding on the skin or fins of larger fish as cleaners. Fourth, Caesonidae, known as yellowtails, are often found clustered in the water column over reef areas, shelf beds, and pinnacles. Although they are active swimmers, they tend to stay still to catch zooplankton and usually seek refuge on the reef at night. Fifth, Centriscidae swim upright with their snout pointing down and feed on small zooplankton. Sixth, Chaetodontidae, known as butterflyfish, are generally brilliantly colored and feed on coral tentacles or polyps, small invertebrates, other fish eggs, and filamentous algae. Some species are also plankton eaters. Seventh, Ephippidae, with their flat, flattened body shape and small mouth, are generally omnivorous and feed on algae and small invertebrates. Eighth, Gobiidae, commonly found in shallow waters and around coral reefs, are mostly bottom-digging carnivores that feed on small bottom invertebrates, though some also feed

on plankton. Some species have symbiotic relationships with other invertebrates (e.g., shrimp) and are known to remove ectoparasites from other fish. Ninth, Labridae, which are economically important, have varied shapes, sizes, and colors. Most species are sand-diggers and carnivores of bottom invertebrates, although some eat plankton, and smaller species transfer ectoparasites from larger fish. Tenth, Mullidae, known as goatfish, have a pair of scutes on their chin containing chemical sensory organs used to detect bottom invertebrates or small fish in sand or reef holes. Many species are brightly colored. Eleventh, Nemipteridae are carnivorous fish that mainly feed on small bottom fish, cuttlefish, shrimp, or worms, although some species are plankton eaters. Twelfth, Pomacentridae, or damselfish, display a variety of colors that differ individually and locally within the same species. Some species are herbivorous, omnivorous, or plankton-eating. Damselfish lay their eggs on the bottom, which are guarded by male fish. This group also includes anemonefish (Amphiprioninae), which live in association with sea anemones. Thirteenth, Scaridae, known as parrotfish, are herbivores that typically obtain algae from dead coral substrates. By chewing on coral and algae, they produce coral sand, making them one of the important sand producers in coral reef ecosystems. Scaridae are also economically important. Fourteenth, Serranidae, known as seabass or grouper, are bottom-digging predators that feed on crustaceans and fish, and are important commercial fish. Fifteenth, Sygnathidae, or seahorses and pipefish, are generally restricted to shallow waters and feed on invertebrates by sucking through their snouts. Some species have beautiful colors. Lastly, sixteenth, Zanclidae resemble Acanthuridae but have a tabular mouth without spines on their tail. They feed on sponges as well as bottom invertebrates.

Coral Reef fish are a community that has a very close relationship with coral reef. Coral reef provide shelter and camouflage for coral reef fish. Coral reef fish get their food supply from around the reef. Both from algae attached to corals and corals themselves that are used as food. Coral reef fish will be in large numbers in areas with healthy coral reef, because coral reef are home to coral reef fish (Syahrul, 2021). The coral reef fish is an indicator of the condition of coral reef, they can be found in coral reef ecosystems that are in good condition and vice versa.

Parrotfish is a fish from the scaridae family that is popularly consumed in Indonesia. There are several species of fish called by this name, such as blue parrotfish, green humphead parrotfish, rainbow parrotfish, stoplight parrotfish, and scarus. Parrotfish is a species known for its role in safeguarding marine ecosystems. Some parrotfish feed on algae that attach to coral reefs. They spend 90% of their time each day chewing and eating. Uncontrolled algae populations can lead to coral reef death, posing a threat to marine ecosystem sustainability. Coral reef can thrive if there is a sufficient population of parrotfish to consume the algae. Parrotfish are also significant sand producers (Bangun, 2021). Sustainability is the capacity of the earth's natural systems that support life and human social systems to survive or adapt to changing environmental conditions indefinitely (Miller & Spoolman, 2018). Sustainability is closely related to the environment, because human activities will always have an impact on the environment. Therefore, in order for humans to survive, a comprehensive approach is carried out through environmental science which aims to make life on earth survive and develop, understand how to interact with the environment and find ways to overcome environmental problems and live sustainably (Miller & Spoolman, 2016).

The condition of Karimunjawa National Park has changed with the overfishing of parrotfish for consumption by the residents and tourists. In addition, the declining parrotfish population affects underwater conditions and coral reefs. The destruction of the coral reef ecosystem causes coastal abrasion in Karimunjawa National Park. So, the role of society in the management of parrotfish resources is needed in order not to threaten their populations for the sustainability of marine ecosystems.

2. Methods

This research adopts a qualitative approach with descriptive analysis that aims to present a comprehensive understanding of marine ecosystem conservation strategies through parrotfish conservation and its influence on the sustainability of the coral reef ecosystem. This research utilizes literature studies or theoretical studies sourced from scientific literature references and other relevant reading materials. Literature study has a very important role in supporting this research, because scientific literature is the main basis that supports and provides substance to every aspect of the research.

The first step in this research was to collect supporting literature and information related to parrotfish capture behavior and existing conservation strategies. This process involved examining the literature to ensure the accuracy and reliability of the information obtained. Afterwards, an analysis of the literature was conducted to develop an in-depth understanding of the research questions. This research used secondary data from various sources deemed relevant and reliable, such as scientific journals, books, articles, news, reports, and other sources. The next process is data analysis using the method of examining, grouping, and compiling secondary data. The results of this analysis were used to formulate answers to the research questions, providing deeper insights into parrotfish conservation and its impact on coral reef ecosystems. Finally, the data was analyzed from other perspectives related to community behavior and its interaction with the marine ecosystem.

3. Results and Discussion

As one of the tourist destinations in Central Java, the Karimunjawa National Park/*Taman Nasional Karimunjawa* (TNKJ) area has received visits from domestic and foreign tourists. In 2016, the number of visitors to the TNKJ area amounted to 7,202 people. Based on the origin of visitors in general, there were 7,074 domestic visitors and 128 foreign visitors. Based on the purpose of the visit, there were 971 visits for education and research, 6,220 for recreation, and 11 for other purposes (BTNKJ, 2017).

The people who live and settle on the islands within the TNKJ mostly make a living as fishermen and tour guides; the rest are farmers, laborers, traders, and civil servants and pensioners. The fishermen who are off the sea because the weather does not allow it (for example, big waves), switch professions to become tour guides or rent out their boats to tourists. The community consists of various ethnic groups, including Javanese, Madurese, Makasarese, Bugis, Mandarese, Bajau and Buton. These local communities settled long before Karimunjawa was designated as a national park. According to Karimunjawa National Park Management Office/*Balai Taman Nasional Karimunjawa National* (BTNKJ) (2017), the population of the Karimunjawa Islands is 8,842 people, spread across five islands namely Karimunjawa, Kemujan, Genting, Parang and Mosquito Islands. The lives of these people are highly dependent on the natural resources of the islands.

Increasing the number of tourists requires synergy between institutions related to the management of conservation areas and fisheries activities, as well as local communities as permanent residents of the islands in the TNKJ area. Implementation of mass tourism program development policies with an ecotourism approach in TNKJ, processed with predetermined stages and procedures. Karimunjawa Sub-district, the Tourism Office, and BTNKJ along with the community play an important role in efforts to maintain the ecosystem. The implementation of the policy is coordinated collectively and carried out in accordance with the decisions and agreements of the various parties.

In reality, the policy implementation process does not always go as expected. The main problem is the lack of coordination between government agencies as policy implementers. One example is that the increase in tourist visits to TNKJ is not accompanied by comprehensive public education about the preservation of ecosystems and fish resources. Based on interviews with several tour guides, some tourists who are not good at swimming are forced to step on corals when snorkeling. To anticipate this, a synergy of regulations

between institutions related to tourism, fisheries and conservation area management is needed.

In fact, BTNKJ's regulations are relatively comprehensive to deal with the increasing number of tourists coming to Karimunjawa, for example by increasing the entrance fee to BTNKJ. The aim is to limit tourists and provide reserve funds for the management of the TNKJ conservation area. However, the implementation of the entrance fee increase regulation has encountered obstacles, especially from hotel and home stay owners. They are worried that there will be a decrease in the number of tourists if the entrance fee is increased and will eventually reduce their income. Therefore, intensive socialization is needed to implement the entry fee increase regulation and its reasons.

Indonesia's coral reefs have the highest diversity in the world (Veron, 1995) and are one of six countries that make up the coral triangle located along the equator. Over 75% of the world's estimated 600 coral species are found in the coral triangle (Veron, 1995). Coral cover is more than 30% of the world's coral reef cover and more than 3,000 species of fish live in it (Green et al., 2011). Indonesia and the Philippines have 77% of this coral reef area and nearly 80% is threatened (Burke et al., 2002). Reef fishes are reef-dwelling organisms that are relatively numerous and conspicuous when compared to another reef-dwelling biota (Nybakken, 1993). Fish can influence coral reef community interactions, ecological processes and production (Mc Clanahan, 2002). Fish communities in coral reef ecosystems support the various relationships that occur within them.

3.1 Parrotfish, coral reefs and biodiversity

Environmental biodiversity is one of the things that cannot be separated from life. The natural environment and ecosystems are the balance of life on earth. One component that plays an important role as a controller in the coral reef ecosystem is reef fish. In several surveys of coral reefs in several island locations by Conservation International, there are about 58-63% of reef species are benthic carnivores, 16-18% planktivorous, 15-17% omnivores and only about 8-10% are herbivores (Allen & Adrim, 2003). Although the composition of herbivorous reef fishes is small, they are critical controllers because they can suppress macroalgae and facilitate coral reef recruitment, growth, survival and resilience (Burkepile & Hay, 2011). Littler et al. and Albert et al. classified herbivorous reef fishes as factors controlling the rise and fall of algal abundance (Littler et al., 2006; Albert et al., 2008). Several studies have shown the importance of herbivorous reef fishes in controlling interactions between corals and macroalgae, as well as reef resilience (Bellwood et al, 2004; Mumby et al, 2006).

Parrotfish is a coral reef herbivore that is in short supply in nature. The number will decrease if parrotfish continue to be caught. The fewer parrotfish cause the number of algae to increase in the sea, causing unhealthy coral reef conditions. As a result, in addition to disrupting the ecosystem, the sea is not beautiful to dive into or enjoy for marine tourism purposes. Conversely, a large population of parrotfish can make the sea beautiful and other types of fish will increasingly live around the coral reef. Therefore, policy interventions in parrotfish fishing are needed to improve ecosystem balance and increase the sustainability of fisheries and supporting ecosystems in the face of climate change. Several previous studies have found that Parrotfish fishing in conservation areas can affect the environment, especially coral reefs.

The occurrence of various environmental damage and uncontrolled exploitation activities is feared to disrupt fish resources in the future, so it is necessary to manage parrotfish fishing to ensure the sustainability of the coral reef ecosystem. Without good management, it is feared that parrotfish resources will continue to decline and threaten its sustainability and its ecosystem. Parrotfish play an important role in the health of coral reefs. They also help restore white sandy beaches near coral reefs in the tropics. In some species, a single parrotfish can excrete nearly 453kg of pearly white sand each year.

Through this literature review, it was found that Parrotfish affect the abundance of coral reefs. The abundance of coral reefs will increase the abundance of fish living around the coral reefs so that it can further increase fish catches. The results also showed that coral cover and parrotfish abundance are influenced by variable seawater environmental parameters such as brightness, DO, salinity and pH. In addition, this study also found that coral mortality can also be influenced by several environmental parameters such as temperature, depth, and current speed.

Karimunjawa as one of the marine conservation areas in Indonesia has very potential natural resources with high diversity of biota and relatively intact ecosystems compared to other areas along the Northern Java Waters. The main attraction of this area lies in the coral reef ecosystem and reef-dwelling fish as marine tourism objects. Nature tourism depends on good environmental conservation so that it can support and benefit each other, where conservation is related to the health of the community. The problem of damage faced by marine protected areas is generally caused by commercial and recreational activities and fisheries activities. Along with the increasing number of tourists to Karimunjawa, research related to the presence of reef fish inhabitants is needed.

3.2 Karimunjawa case study

The first research case was in the waters of Karimunjawa National Park and coral reefs were the object of study. Karimunjawa National Park is a national park located in the north of Java. The area of this national park is within the administration of Jepara Regency. Its management consists of core zone, protection zone and utilization zone.

Karimunjawa National Park is located in the Karimunjawa Archipelago which includes 27 islands with a designated area of 111,625 ha. In addition to its nature, the people and traditions make Karimunjawa tourism has a tourist attraction that is admired by travelers. The high level of tourism in Karimunjawa National Park is not only beneficial for the community around the National Park but has an impact on the marine environment of the National Park, namely coral reefs. The percentage of coral cover at a depth of 3 meters is 70.42% and at a depth of 10 meters is 66.55%. The highest percentage of coral cover is on the west side of site B with a depth of 3 meters, which is 82.50%, while the lowest percentage of coral cover is on the east side of site A with a depth of 10 meters, which is 64.80% (Suryanti et al., 2011).

The condition of Karimunjawa National Park has changed with the rampant capture of parrotfish for consumption by the surrounding community. In addition, the declining parrotfish population affects underwater conditions and coral reefs. The destruction of the coral reef ecosystem causes coastal abrasion in Karimunjawa National Park.

Fig. 1. Parrotfish fishing in Karimunjawa
(Bangun, 2021)

Parrotfish are a species of fish that protect marine ecosystems. Some parrotfish feed on algae attached to coral reefs (Fig. 1). Every day they spend 90% of their time chewing or eating. Uncontrolled algae populations can cause the death of coral reefs. This can jeopardize the sustainability of the marine ecosystem. Coral reefs can be sustained if the parrotfish population that feeds on them is sufficient. Parrotfish are sand producers.

Parrotfish are a large group of marine fish species that inhabit tropical and subtropical shallow waters around the world. They live on coral reefs, reef beaches, and seagrass beds. These fish are usually white, green, or blue in color with a beautiful green pattern. The head is slightly rounded, similar to a cockatoo bird.

Parrotfish densities support high fish diversity on coral reef sites, resulting in much higher fisheries production in Karimunjawa. Overfishing of parrotfish not only reduces the population but also causes damage to coral reefs, because it triggers an increase in algae and seaweed populations so that the photosynthesis process of coral reefs is disrupted and eventually causes the death of coral reefs. Parrotfish are also producers of white sand because their feces are coral reefs that have been naturally pulverized. With an average production of 380 kg of white sand per year for large cockatoo sizes. It is estimated that the decline in the parrotfish population can cause bioerosion of white sand around it.

One of the human efforts in the framework of Karimunjawa nature conservation activities in 2017, the Committee together with the Karimunjawa National Park Office (BTNKJ) organized coral reef transplantation activities, continuing the same activities in 2016. It took place in the waters of Menjangan Kecil Island, Marine Tourism Utilization Zone of Legon Lele Resort SPTN Region II Karimunjawa BTNKJ. The activity was attended by school children from SMP Negeri Karimunjawa, SMK Negeri Karimunjawa, HPI Karimunjawa and foreign tourists with escorts from the Barikan Committee and BTNKJ rangers, with a total of 56 participants. The implementation of coral reef transplantation was divided into two teams, the first team took the fragments, and the second team prepared the coral media.

3.3 Caribbean case study

The second research case is in a region of Caribbean countries (Fig. 2). Marine resources and coral reefs are central to people's livelihoods and provide ecosystem services. Although the Caribbean has maintained stable coral cover, the region has lost 60-80% of its coral cover since the 1970s (Jackson et al., 2014). This decline is attributed to overfishing and multiple pressures from human activities (Jackson et al., 2014).

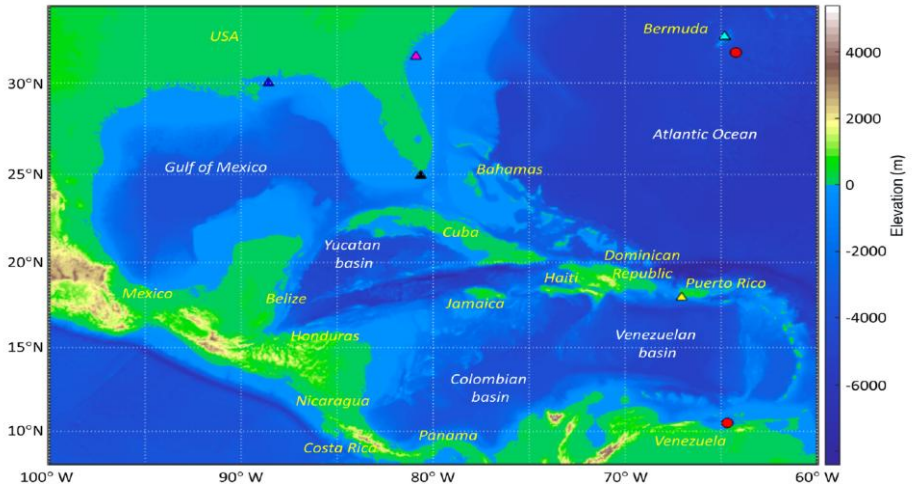

Fig. 2. Map of the Caribbean and West Atlantic region (Sutton et al., 2019)

Reduced coral populations can lead to changes in coral population dynamics, causing coral reefs to be in a degraded state (Mumby et. al, 2013). The transition to macroalgal dominance provides relatively little value to fisheries (Carpenter, 1990). Macroalgal dominance is typically associated with less complex coral habitats, which in turn are associated with lower biodiversity and less ecosystem function (Done et al. 1996). Coral reef restoration in the Caribbean region is needed to be resilient to the pressures of change

including rapid climate change and ocean acidification. Restoration programs have been well developed in many coral reef areas in the Caribbean, including the establishment of coral nurseries in some locations.

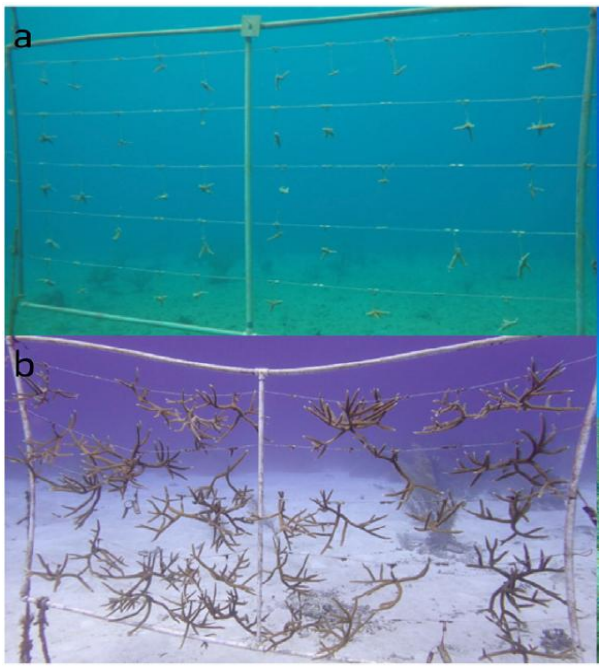

Fig. 3. Examples of coral nurseries in the Caribbean. (A) Vertically framed nurseries in the Cayman Islands in 2016 and, (B) in 2017 show significant growth over a 12-month period (Maneval, 2018)

Previous research proposed two approaches to coral reef restoration: (1) coral gardening and sexual propagation and (2) selective harvesting. In this case, both active methods of human involvement (e.g. coral outplanting) and passive methods involving enhancing natural reef growth (e.g. larval colonization) are required. Coral outplanting involves growing coral colonies in nurseries and transferring them to reefs, initially using asexual reproduction (Albright & Cooley, 2019).

Fig. 4. Coral reef transplantation activity by tourists in Karimunjawa (Directorate General of Natural Resources and Ecosystem Conservation, 2017)

These initiatives aim to increase genetic diversity and resistance through sexual propagation techniques. The Caribbean has more than 150 coral outplanting programs, which offer opportunities to integrate "assisted evolution" approaches, such as symbiotic

algae or stress-resistant microbial communities. The selection of coral species for restoration is critical, given their ecological role and impact on reef biodiversity. Genetic diversity in outplanted corals is also important for disease resistance and adaptation. Physical engineering approaches can complement outplanting efforts to stabilize reef conditions. The Caribbean is seen as a potential hotspot for advancing assisted evolution techniques due to the presence of nurseries and the support of research institutions. However, it was emphasized that while assisted evolution is common in plants in terrestrial ecosystems, its application to coral reef restoration is still experimental and requires further research.

While selective harvesting is a fish utilization practice designed to increase reef resilience by targeting specific species. For example, on macroalgae-dominated reefs, selective fish species focus on herbivorous predators of the reef to reduce algal cover. Direct harvesting of macroalgae by humans is another method to decrease algal competition with corals. Selective harvesting can also target species that cause reef accretion. However, these approaches are complex and unpredictable, requiring careful consideration and investigation before implementation.

3.4 Caribbean fisheries comparative study

In some countries efforts in ecosystem-based fisheries management have been directed at reducing the adverse impacts of fishing gear on ecosystems, including bycatch and habitat destruction (Link J., 2010; Pikitch EK, et al. 2004). A more complex consideration is maintaining ecosystem function of target species. The impact of fishing is profound on the most complex marine ecosystem, the coral reef. In the Caribbean, parrotfishes (Labridae, Scarinae) are dominant herbivores at intermediate depths, between 5-15 meters (Lewis & Wainwright, 1985; Williams & Polunin, 2001). Parrotfish help control large algae and seaweed and facilitate coral recovery and growth (Burkepile & May, 2008; Mumby et al., 2014). Parrotfish are thus a very important fishery species in coral reef ecosystems.

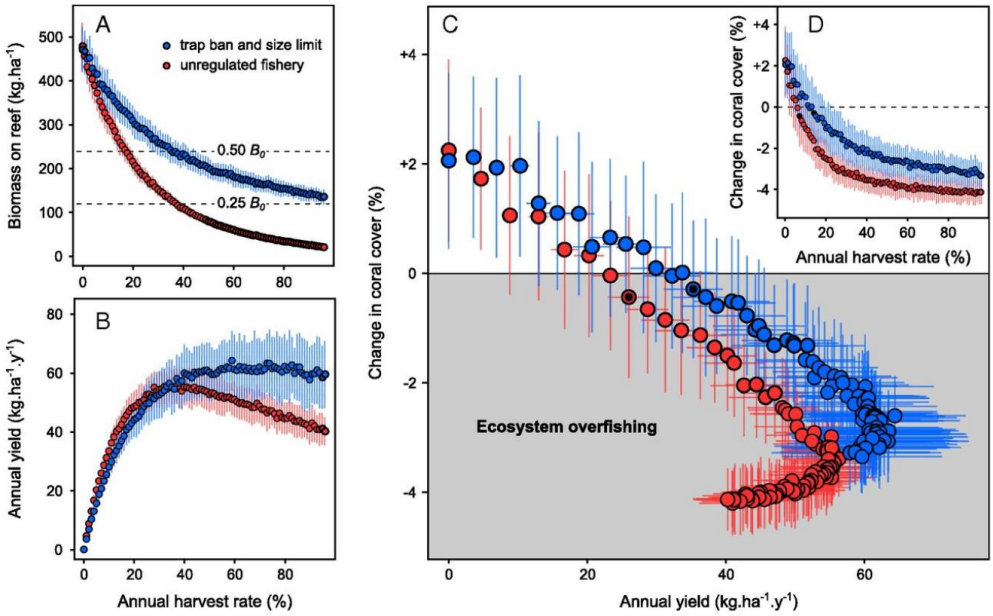

Fig. 5. Impact of fishing rate on parrotfish and coral reefs.
(Bozec et al., 2016)

Reduced coral populations can lead to changes in coral population dynamics, causing coral reefs to be in a degraded state (Mumby et. al, 2013). The transition to macroalgal dominance provides relatively little value to fisheries (Carpenter, 1990). Macroalgal dominance is typically associated with less complex coral habitats, which in turn are

associated with lower biodiversity and less ecosystem function (Done et al. 1996). Although some countries, such as Belize, Bonaire, and Bermuda have implemented a ban on Parrotfish fishing (Jackson et al. 2014). However, most other countries do not have fishing limits to sustain future catches (Hawkins, 2014).

The results of this comparative study through a literature review sought to obtain a more informed approach to fisheries management in the Caribbean that has taken into account the function of parrotfish in the ecosystem and examined strategies for balancing parrotfish fisheries and the future resilience of coral reef populations. Research conducted by Y.M. Bozec et al. in the Caribbean concluded that fisheries management should avoid adverse ecosystem impacts as much as possible, especially if the target species has important ecosystem functions. In their research Caribbean coral reefs have provided an example where herbivorous Parrotfish are an important fishery and a key driver of ecosystem resilience. YM Bozec et al. developed and tested a multispecies fishery model of Parrotfish and linked it to coral reef ecosystems undergoing climate change as shown in Figure 5.

Figure 5 shows the impact of increasing exploitation/fishing rates on Parrotfish and coral reefs. Graphs A and B are: average unfished biomass (A), and average annual catch (B) of Parrotfish at equilibrium for a regular increase in annual fishing through the first two catch charts (red, 15 cm fish; blue, 30 cm fish). Graph (C) is the predicted coral reef change (in units of absolute percent cover) for an average Caribbean coral reef starting at 15% coral cover and subjected to fishing over a 5-year time horizon. Fishing is represented by the annual yield of Parrotfish under the two harvest scenarios of the red and blue graphs. Graph (D) is a prediction of coral reef change based on annual fishing rates. The black circle shows the fishing value that causes a decrease in the number of coral reefs. The results of YM Bozec et al. found that coral reefs can survive well if less than 10% of parrotfish biomass can be caught, applying a minimum size policy of 30 cm that can be caught

4. Conclusions

One of the components that plays an important role in the marine ecosystem is coral reef fish. Herbivorous coral fish are important in controlling the interaction between coral and macroalgae, as well as the resilience of coral reefs that play a very important role in the marine ecosystem. Parrotfish are herbivorous coral fish that are few in number in nature. This number will decrease if parrotfish continue to be caught by humans.

The decreasing number of parrotfish can cause an increase in the abundance of algae in the marine ecosystem, resulting in unhealthy coral reef conditions, as well as making the sea less beautiful for diving or marine tourism. On the other hand, a large population of parrotfish will make the waters more beautiful because healthy coral reefs will increase the types and number of fish that live around coral reefs. Therefore, human intervention is needed to preserve marine ecosystems. One of them is through the parrotfish fishing policy which aims to improve ecosystem balance and increase the sustainability of fisheries and marine ecosystems.

Previous research found that parrotfish fishing in marine conservation areas can have a negative impact on the environment, especially coral reefs. Without good fisheries management, it is feared that parrotfish resources will continue to decline and even threaten the sustainability of marine ecosystems. TNKJ as a conservation area has high biodiversity, especially coral reefs and coral fish. This diversity must be protected to preserve the ecosystem. The beauty of coral reefs and coral fish is the main factor in attracting tourists to visit TNKJ.

The Resident have a good understanding of the importance of marine ecosystem sustainability and the impacts of parrotfish depletion, but overfishing continues. Parrotfish overfishing is still happening because the need and demand for parrotfish is high, another pressure is because the Karimunjawa community only relies on marine natural resources as their main livelihood. Restriction and prohibition of parrotfish fishing cannot be done

because there is no national law that regulates the restriction and prohibition of parrotfish fishing in conservation areas. For this reason, local government should do strict supervision. It is necessary to support external parties to be able to invest in opening new opportunities to people around Karimunjawa for proper jobs.

Besides that, to achieve ecosystem sustainability, TNKJ needs to be managed using the concept of integrated coastal management by viewing KNP as one ecosystem. Tourism is considered as one part of an ecosystem in which there are other activities. All these activities must work together towards one goal, namely preserving the ecosystem and alleviating poverty in coastal communities. Public education (tour guides and tourists) is also needed to build their awareness about conservation. With this education, it is hoped that tourism activities in TNKJ will not damage the aquatic environment in TNKJ. Furthermore, the TNKJ conservation area will become an area that is well managed and preserved and able to support the preservation of the marine environment.

Acknowledgement
The authors gratefully acknowledges the reviewers for their valuable critiques and insightful recommendations, which greatly improved this manuscript. Additional thanks are extended to colleagues and mentors who provided guidance and support throughout the research process.

Author Contribution
All authors contributed to the conceptualization, methodology, data collection, analysis, writing, critical review, manuscript editing, and supervision throughout the research process.

Funding
This research received no external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Not available.

Data Availability Statement
Not available.

Conflicts of Interest
The authors declare no conflict of interest.

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