Biological Forum – An International Journal **12(2): 54-62(2020)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

A Review on Coral Reef Fisheries it's Management and Conservation Strategies

Suman Nama and Sahina Akter
Fisheries Resource Harvest and Post-Harvest Management Division,
ICAR Central Institute of Fisheries Education, Pinch Marg, Off Yari Road, Versova,
Mumbai 400061, India.

(Corresponding author: Suman Nama)
(Received 14 July 2020, Accepted 30 October, 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Coral reefs are the most ecologically diversified and economically valuable underwater ecosystems scattered in tropical and sub-tropical regions of the world's oceans. It occupies only 0.1% area of the ocean floor and supports about 25% of a marine organism. Coral reefs provide habitat for much important fish, shellfish, and other invertebrates targeted for fishing and promote a higher number of species than any ecosystem. Coral reef fisheries provide food, income, recreation, significant cultural and spiritual importance, and essential ecological functions for coral reefs (e.g., herbivory). Coral reef fisheries offer billions of dollars economies of many countries around the globe. It supports various commercial and artisanal fishing, a prominent social safety net for people when other sources of employment are unavailable. Still, the reefs are degrading day by day because of climate change, overfishing, coastal development, destructive fishing practices, and anthropogenic threats. This magnificent natural creature needs to be protected by adopting some advanced management methods ecosystem-based and rights-based fisheries management, satellite-based approach (coral mapping, monitoring), and coral gardening and involvement of the stakeholders and local fishers.

Keywords: Climate change, coral gardening, overfishing, ecology, ecosystem.

INTRODUCTION

The coral reef ecosystem provides us various services, including economic and ecosystem services, tourism benefits of reefs, employment, shoreline protection, and medical discoveries. Around the globe, peoples are mainly dependent on marine fisheries as a crucial source for their food and income. Nearly about one billion people rely on fish as their primary source of animal protein, many of whom are from developing countries (MSC 2014). Coral reefs provide humankind with many products and essential services, but only a few of these goods and services have been appropriately valued economically (Moberg and Folke, 1999). Spiny lobsters are the main fishery for many countries in the Caribbean and contribute significantly to the region's economic development (Burke *et al.*, 2011). More than 1% of total exports are coming from reef-associated exports in 21 countries and territories (Burke *et al.*, 2011). The highest around 40% of the population from New Caledonia relatively involve in reef fishing, and 5–7% of the people from the Turks and Caicos Islands, the Maldives, and Dominica are involved in reef fisheries (Burke *et al.*, 2011). Although coral reef fisheries provide livelihood and food security of billions of people worldwide, the reef fisheries are declined up to a great extent. The other main reasons for the decline of reef fisheries include diseases, pollution, unsustainable fishing practices, and destructive fishing practices. Near about 60% of the world's coral reefs ecosystem are under immediate threat from human activities, including overfishing and pollution (Burke *et al.*, 2011). According to the World Resources Institute report (2011), 75% of the world's coral reefs are endangered, of which a quarter of them have already been damaged beyond repair. The two major problems (overpopulation and poverty) are the significant reasons to increase reef-destructive fishing methods and overexploitation of coral reef resources beyond sustainable levels. So, the appropriate management measures have to be adopted by international agencies and local fisher folk to conserve the coral reef ecosystem and its associated fisheries obtain the maximum yield.

BENEFITS OF CORAL REEF FISH

Livelihood benefits: Approximately 15 million small-scale fishers are depending on coral reef fisheries, which include full-time, part-time, and seasonal male and female anglers (Burke *et al.*, 2011). Coral reef fisheries are particularly attractive to poor and migrant people because most reef fisheries are small-scale and artisanal because most are open-access systems

relatively low entry cost (Burke *et al.*, 2011). Reef fishers in India, Vietnam, Indonesia, China, and the Philippines are ranged between 1 lakh and more than 1 million per country, whereas 300,000 people are employed in the Caribbean fisheries sector.

Economic benefits: Coral reef fisheries provide billions of dollars to the economies of many countries worldwide (Burke *et al.*, 2011). The net of coral reef fisheries is worth $6.8 billion globally, $2.4 billion a year in Southeast Asia, and the Caribbean $395 million a year (Burke *et al.*, 2002 and 2011). In the U.S., coral reef commercial and recreational fisheries are valued at over $100 million per year (Cesar *et al.*, 2003). In the United States, coral reefs and associated habitats, such as sea grasses and mangroves, provide near about half of all federally managed fisheries, both commercial and recreational,

Food supply: In developing countries, coral reef fisheries are the primary protein source for billions of people. Approximately one billion people worldwide benefit directly from coral reef resources for food and sources income through activities related to fishing and tourism (ICRAN, 2004). A well-managed healthy reef can yield with an average of about 5 tons of seafood per km^2 per year, range between 0.2-40 tons seafood/ km^2/year with an annual yield of 1.42 million tons (Newton *et al.*, 2007, Jennings *et al.*, 1995 and Burke *et al.*, 2011). Fishes are also an essential nutrient source such as vitamins A, B, D and several other nutrients, calcium, iron, and iodine. Globally, people consume 29 kg of fish and seafood each year, and consumption of reef fish is maximum at Maldives (180 kg/person), which provides 77% of dietary animal protein (Burke *et al.*, 2011).

Status of reef fisheries:

Fisheries play a vital role in poverty elimination and strengthen the livelihood safety net for billions of people when other employment sources are unavailable (Teleki, 2017). About 6 million fishers and gleaners are employed worldwide from coral reef fisheries (The *et al.*, 2013). Globally, almost 40% of the world's population lived within 100 kilometers of a coral reef, and this quantity is expected to double by 2025 because they benefited from its resources and protection (Creel, 2003).

Threats to the coral reef fisheries

Overfishing: Overfishing is defined as catching more fish than the system can be reproduced in a given time. Overfishing has a severe consequence on coral reefs, as some fish species play a critical role in maintaining the coral reef ecosystem. It is considered the primary cause of the recent collapse of the coastal ecosystems (Bourque et al. 2001).

Causes of overfishing:

High demand for Fish and Seafood Products: The seafood supply is growing at an average annual rate of 3.2%. Per capita, fish consumption increases gradually from 9.9 kg in 1960 to 20.1 kg in 2019 (FAO 2019). The development of marine and freshwater aquaculture and distribution channels actively enhances fish production due to population growth, urbanization, and rising incomes (Garcia *et al.*, 2010).

Lack of Alternative Livelihood: Many coastal communities and small-scale fishing communities directly depend on fisheries. They have few alternative options for livelihood security, which lead to extreme pressure on fishery resources. In these situations, artisanal fisheries, fish processing, and trade provide people with a basic form of the safety net and stable fisher folk's livelihood food security (World Fish Centre).

Adaptation of more Efficient Fishing Methods and Technologies: This innovation reduced the cost of fishing, catching more brooder, juvenile fishes. The more powerful engines used in the fishing vessel for catching fish are suitable for increasing affordability and fishing gear (Garcia *et al.*, 2010). The advanced technology enhances the design of the fishing gear, and navigation equipment has increased the fishing efficiency, encourages more people to join the fishery, which results in further depletion of stocks.

Inadequate Management and Enforcement of Fishing Practices: The small-scale coral reef-associated fisheries are generally unassisted and unmanaged where the fishing effort remains too high, and stocks are typically below sustainable levels to maintain healthy fisheries (CEA, 2012). Nevertheless, the management of large-scale commercial fisheries is a healthy condition in developed nations. Fisheries practices in developed countries (Asia, Africa), Central and South American regions lack management capacity. The multi-gear and multispecies fisheries complicate the monitoring and enforcement of management measures.

Impact of Overfishing:

The significant impacts of overfishing can be divided into

1. Impacts on the ecosystem: Overfishing can change the species' assemblages due to eliminating or reducing prey or predators' populations from an ecosystem. The depletion of some species will increase the abundance of other species, which leads to an imbalance in the function of the coral reef.

2. Impacts on fish stock: Both the targeted and non-targeted fish populations sometimes decrease to the point of extinction due to overfishing

3. Socioeconomic impacts: Nearly 275 million people live close to coral reefs, and their livelihoods are dependent on reefs fisheries. A healthy and well-managed reef ecosystem can produce 0.2-40 tons of seafood/km^2/year. (Newton *et al.*, 1985; Jennings and Polunin, 1995). Overfishing raises a significant threat to coral reef ecosystems and fish stocks, directly affecting coastal communities' livelihoods security.

Destructive fishing:

Dynamite fishing and cyanide fishing are highly destructive and unsustainable because they killed the juveniles. The damage to the coral reef ecosystem reduces the area's productivity, which adversely affects the reef fish populations and fishers' livelihoods and nearby communities.

Muroami fishing: Muroami fishing is the most cataclysmic and cruelest fishing method practiced in South East Asia.

The corals are disturbed by pounding devices and driven the fishes to move out. On reefs, a surrounding net is designed for fishing by active drivers (Carpenter and Alcala, 1977; Alcala *et al.,* 1987).

The resilience of fisheries:

Management actions can increase this. Resistance is a fully functioning system's ability to resist and absorb disturbance while maintaining the essential function and structure (Holling, 1973). In fisheries, resilience can be undermined by Ecological and anthropogenic stressors like pollution, loss of reef habitat, disease, overharvesting, and climate change (Carpenter *et al.*, 2001). A heavily exploited fishery may be resilient to change. In Southeast Asia, coral reefs ecosystems were destroyed by destructive fishing methods such as dynamite fishing, cyanide fishing, and Mourami practices, which transformed rocky reef substrata into unstratified rubble beds that have minimal chances for natural recovery (McManus *et al.*, 1997). Fisheries' resilience is supported by sustainable coral reef fisheries management, including fishery assessment tools, engaging stakeholders (fishers and policymakers), and market transformation efforts. The most effective management practice in the fisheries sector is the integrated social-ecological system, including the coastal and marine environment, marine resources, and the fishing communities dependent upon it.

Coral reef fisheries management:

Successful management of coral reef fisheries enhances the economic and social benefits such as increased profits, food security, and sustainable livelihoods to fisheries stakeholders. Sustainable management of coral reef fisheries directly contributes to maintain the health of the coral reef and provide essential services such as food, tourism, shoreline protection, and other cultural values of local fisher folk. A holistic approach to fishery management measures furnishes specific actions to achieve the ecological-economic and social objectives of coral reef fishery, including fish stock assessment methods, fishery management tools, surveillance, and enforcement methods.

Stock Assessment Methods for Coral Reef Fisheries:

The stock assessment methods help fishery managers to take the appropriate management strategies to achieve the selected target objectives of the fishery, i.e. (catch quota, Vessel entry, and size of the fish to be found). The existing conventional statistical methods (estimation of maximum sustainable yield (MSY) and biomass) do not fulfill the requirements for assessing coral reef fisheries. More advanced techniques such as the age structure population model need to adopt for managing coral reef fisheries. Still, this model requires vast quantities of data, funding, and capacity to be carried out. Therefore, this method is infrequent due to a lack of data, financing, and limited institutional ability to collect and analyze it (Fujita *et al.*, 2014).

Stock Assessment Indicators:

To know about sustainability, biomass, and reproductive capacity, fishery managers can use stock assessment indicators. The indicators need to be very simple, easy to measure, understandable and should be developed collaboratively with scientists, fishery development managers, non-governmental organizations, and local fishers. For a better understanding of the fishery, multiple performance indicators can be used (Caddy, 2002). Generally, two reference points are used to understand the relationship between performance indicators and the fishery's objectives.

1) A target reference point indicates that the value corresponds to the condition of the fishery.

2) A limit reference point is a value that corresponds to the state of the fishing that is undesirable (i.e., overfished).

Fishery management tools:

The knowledge of species composition, fish population changes, and ecosystem conditions are prerequisites for effective fishery management strategy. Effective management and harvest control rules will depend strongly on the fishery and fisher's community's biological, socioeconomic, and governance characteristics. There are two components for managing fishery effectively. i.e., Input control (management tools to control how much fish are taken from the ocean) and output control (harvest control rules that trigger when and how much to adjust management).

Input control:

— Modification of gear and restriction (Worm *et al.,* 2009) minimizes target species catch and by catch. Useful during surveillance and enforcement with little capacity. Ex: Adaptation of square mesh gear rather than diamond mesh gear and setting minimum mesh sizes.

— Limited entry technique: Only a few vessels will be permitted to fish. It can be an odd and even number basis. Limit new vessel licensing per year.

— Prohibition of gear: Gear like bottom trawl, spears, harpooning, bows and arrows can be prohibited.

— Effort limits: Limits on fish traps, Limiting the number of poles or lines per fisherman.

— Close certain fisheries: Closing the heavily exploited fish to replenish in nature.

— Temporary closures: Declaration of the temporal close season in the breeding ground and ecologically sensitive areas to conserve the brooders, juveniles, and ecotone species.

— Spatial closures: This includes the Declaration of Marine Protected Areas and Territorial User Rights for conservation purposes (Dowling *et al.*, 2015).

Output control:

— Individual transferable quotas (ITQs): The main aim of harvest control rules is to increase production and maintain the fishery's sustainability. Fishery managers decide the quantity of fish can be harvested from a particular resource, and the fisher is allowed to catch a portion of the total allowable catch. (Bonzon *et al.,* 2010)

— Limiting average in duration at sea: The average duration time for fishing need to reduce.

— Size limits on individual fish caught: It regulates the maximum size of fish that can be legally captured from particular water bodies. It is challenging to govern if multispecies fisheries are the context.

Managing Fisheries for People and Ecosystem:

Successful managing of the coral reef ecosystem is crucial for maintaining the coral reef's biodiversity and securing the fisher population's livelihood. Multiple objectives are considered for ecosystem-based fishery management (EBFM) to ensure the sustainability of the coral reef ecosystem, fish population, and maintain other ecosystem services. Rights-based approaches that guarantee fishers' access and control over fishing grounds or fish stocks safeguard livelihoods and access food for fishing communities.

Ecosystem-based fisheries management (EBFM): Ecosystem-based fisheries management (EBFM) is a holistic approach for managing fisheries to maintain the ecosystem functions and services of the resources. This approach mainly targets building reef resilience by increasing the alignment in management objectives between fisheries and reef conservation. The significant goals to ensure a resilient coral reef ecosystem is given below-

1. Maintain sustainability of resources: Fishery resource is limited, and the potential yield from a fishery depends on the ecosystem's productivity. In a healthy and unfished coral reef can produce 1,200–1,300 kg/ha. In multispecies fisheries, maximum sustainable yield (MSY) is ranged between 25–50% of the unfished biomass, i.e., 300–750 kg/ha (McClanahan *et al.*, 2011; Karr *et al.*, 2015).

2. Protect functional groups: The main functional groups of a healthy ecosystem are top predators and herbivores. Their protection and conservation are essential for economic and ecological concerns. (protecting sharks support dive tourism, bans on catching herbivorous fish can reduce the risk of algae out-competing corals on reefs). So, the key functional groups need to be protected to support reef resilience, which adds a critical area of collaboration between coral reef managers and fishery scientists.

3. Reduce by-catch: By-catch is the incidental catch of non-target species during fishing operations. Sea turtles, seabirds, juvenile sharks, juvenile fishes, and other species like sea fans and sponges can be significant by-catch in some fisheries. It has a significant impact on coral reef biodiversity.

4. Protect spawning grounds: Protection of spawning or breeding grounds is essential for biodiversity conservation and fishery management. Maintaining a healthy spawning ground, nursery grounds, and mitigation corridors for reef fishes are crucial for the health of coral reef ecosystems and sustainability.

5. Protect critical areas: The ecologically sensitive areas like mangroves, sea grasses need to be protected because reef fishes often migrate for food, shelter, and reproduction in those areas.

6. Manage risk from climate change and ocean acidification: Global climate change stressors (i.e., increasing SST, changes in storm patterns, rising sea-level, changes in oceanic currents trends, and disease outbreak), and ocean acidification are incredibly affecting the coral reef ecosystems.

Rights-Based Fisheries Management (RBFM):

Rights-based fisheries management (RBFM) provides optimal conditions that may revamp an ecosystem's health and sustain the fish populations by establishing private marine protected areas, restoring habitat, and reducing overall fishing effort (Ovando *et al.*, 2013). RBFM upgrades the ecosystem benefits and economic performance of the fishery as a whole. Adaptation of energy-efficient fishing techniques to maximize economic benefits is taken as an incentive since everyone has the rights to share fishery resources. However, RBFM may create conflicts when the distribution of exclusive rights results in a redistribution of wealth with clear winners and losers.

Surveillance and enforcement methods: Effective management of the coral reef ecosystem and reef-associated fisheries requires effective law enforcement, adequate legal framework, and compliance efforts. A survey about environmental and fisheries authorities from every country reveals no sufficient vessels and personnel for implementation. However, when vessels, staff, and equipment are available, lack of funds for fuel, spare parts, and routine maintenance operations, only a few ships are operated. Due to outdated laws and corruption, when patrols are carried out and poachers apprehended, the individuals who defy the law are rarely fined. In collaboration with international authorities, the private sector, NGOs, local communities, academic institutions, and other stakeholders need to create a better fishery management strategy. The primary five critical components in the development and implementation of an active surveillance and enforcement system are:

1. Surveillance and Interception: A surveillance system should include the most cost-effective suite of sensors for detecting illegal activities in a given area. Then, use the information for appropriate response and successful interdiction. There are two types of Surveillance systems that are mainly used for surveillance: collaborative and no collaborative.

Collaborative Surveillance Systems require active transceivers on-board vessels to locate the position, and the use of these systems should be mandated by law. Fisher must be part of the process for implementing these two main types of collaborative technologies: An Automatic Identification Systems (AIS) is an on-board vessel identification system that provides vessel information like ship name, course, speed, and precise location in coastal and inland waters. A Vessel Monitoring Systems (VMS) is also an on-board vessel system that uses satellites to collect and transmit data on vessel name, location, course.

Non-Collaborative Systems: Do not require transceivers or stakeholders' participation in the process to help systems detect vessels in a specific geographic area. Several types of non-collaborative surveillance systems, such as visual, radar, optical (images are taken from a satellite, crewed aerial vehicles), and infrared cameras and are located at strategic sites on the coastline or mounted upon mobile platforms, for example, patrol vessels.

2. Systematic Training: The regulations, systems, and tools are only as useful as those trained to operate and maintain them. A comprehensive training program regarding Operational planning, use of visual and electronic sensors, interrogating suspicious crews operational report, operation of Firefighting devices,

Telecommunication lines, Reading and using nautical charts and using land maps, Search and rescue Providing first-aid services in the field when necessity is necessary to strengthen the management capacity and enforcement teams.

3. Prosecution and Sanction: Effective criminal, civil or administrative sanctions and punitive actions are required for enforcement systems to avoid delays and lost trials, which ultimately cause economic losses for the state in terms of wasted patrol resources and loss of natural capital. The sanctioning process for environmental violations is typically prolonged even though prosecution is different in every country. Criminal and administrative sanctions should be considered in the development of enforcement systems. This should include Administrative Sanctions and Civil Sanctions.

4. Sustainable Finance: The establishment of effective enforcement systems requires funding for a long-standing operation that must be identified and secured. Most marine resource enforcement efforts receive limited financial support from the central government support, which becomes difficult for administrators to enforce laws. The two most common strategies to increase enforcement efforts are user fees and increased cost-effectiveness of operations.

5. Education and Outreach: Education and outreach play a critical role in enhancing the communities' knowledge about the management rules and regulations and can also lead to building a community-based management system. In many places where successful enforcement occurs, well-informed stakeholders play a pivotal role in boosting the community's knowledge. Once regulations are enforced, the managers should develop an education and outreach plan for the local community, local fishers, tourism operators, and foreign fishers. The activities include

— Preparation of simple fact sheet detailing about zoning, restrictions, regulations, fines or sanctions, and distribution among the local community.

— It is broadcasting through the television and radio.

— Involvement of management officers in training activities.

— Note the vital regulation points and display at ports, fishing harbors.

— Provide training to traditional fishers with audio-visual aids.

— Giving great respect to ethics and traditional culture of fisherfolk.

— Considering the recommendation of fishers to form management and regulation plan.

Management strategies: Coral reefs are a vital resource for biodiversity, food security, economic development, community wellbeing, and social resilience. However, the corals are facing supernatural threats from a combination of anthropogenic and natural origin. So, effective management of the coral reef ecosystem has become a focal point for coastal communities by adapting a wide range of strategies to protect the reef biodiversity. The critical strategies for coral reef management are to address local and global stressors, and creating awareness about global climate change is mentioned below.

Threat reduction: An effective reef management strategy at the local level will often require the active involvement of local communities, reef users, and different stakeholders to build up compliance, understanding, support in reducing the stressor to reefs (Pollnac *et al.*, 2001). The management effort taken at the local level can play a vital role in building reef resilience and supporting local communities' viability. The critical management actions needed for local management include:

— **Temporary closures:** During times of severe stress, such as a bleaching event, managers can declare temporary closures for fishing and tourism into critical reef areas and minimize the severity of damage at important reef sites.

— **Managing recreational use of reefs:** Recreation is an essential use of coral reefs, and reefs have to be managed adequately to ensure biodiversity, economic and social benefits, and conservation.

— **Managing risks from invasive species:** Invasive species became a severe threat to coral reef ecosystems, and reef managers need to develop strategies to prevent, detect and control invasive species to ensure the sustainability of coral reef biodiversity.

— **Control of coral predators:** Crown-of-thorns "starfish" and Drupella snails graze upon a coral reef and lead to reduce densities and cause severe damage to the reefs ecosystem. Management strategies to control the predators is yet to develop.

— **Sea urchin management:** Like coral predators, sea urchins can also raise several reefs ecosystems if populations exceed thresholds limit. Depending on situations, managers may wish to reduce urchin densities or enhance them to restore balance to the ecosystem.

— **Reducing land-based impacts:** Land use practices such as construction work, transport of sediment, nutrients, and other pollutants at high-value sites need to control to ensure minimum impact on coral reefs.

Adapting best diving Practices: This strategy is the need of the hour to protect the physical damage of the coral reef. Management measures include:

— Avoid direct contact with corals.

— Avoid driving during the full moon and new moon period.

— Neither chase nor ride any marine animals.

— Avoid collecting live or dead corals while diving.

— Avoid dumping at sea.

— Ensure all equipment is securely packed so that it cannot drag or snag on the coral's ecosystem.

— Avoid feeding and photography of marine animals.

— Avoid using kneepads and gloves while diving in coral reef environments.

Adapting best anchoring Practices: In proper anchoring cause extreme physical damages to coral reef habitat. So, the best management measures need to adopt to protect the coral reef habitat. Some best practices include

— Survey the area before anchoring,

— Anchor in sandy or muddy areas away from corals habitat.

— Avoid anchoring in protected areas and indigenous heritage sites.

— Look out for the lifesaving equipment before dropping anchor.
— Never wrap the anchor rope or chain significant coral habitat.
— Use the correct anchor and maintain enough chain depth to ensure minimum damage to the environment.
— Bring back the anchor when the line is vertical and never retrieve forcefully when caught on the reef.

Declaration of Marine Protected Areas (MPAs): An MPA is declared for long-term conservation of natural resources and its associated ecosystem, ecological and economic services. MPA is an important management tool to regenerate the degraded reef ecosystem. It can help to:
— Manage the fishing fleet.
— Restrict the overuse of resources.
— Control anthropogenic threats such as sedimentation and pollution.
— MPAs are most effective when combined with integrated coastal zone management (ICZM) to cope with the MPA boundary threats.
— MPAs ensure the protection of coral reef diversity by restricting illegal entry.
— The scaling up from individual MPAs to resilient MPA networks allows for the protection of habitats, species maintenance of ecological processes, structure, and function.

Finding Advice on Monitoring:
Finding well skilled and qualified managers or scientists who can give relevant advice and essential information is a prerequisite for effective monitoring practices. In the case of disease outbreak, critical advice for managing coral can be taken from The Coral Reef Targeted Research (CRTR) and Coral Disease and Health Consortium (CDHC). The CDHC involved in coral health assessments, diseases outbreak responses within the U.S. and associated territories. It provides capacity-building efforts such as research plans, training programs, and technology transfer for disease diagnostics and pathology (Raymundo *et al.*, 2008). The Coral Reef Targeted Research (CRTR) program regional Centers of Excellence in the Philippines, Mexico, Australia, and Tanzania provide information on sample collection and send samples (Raymundo *et al.*, 2008). There are four main elements of a coral disease outbreak response plans are:

1. **Identifying the Disease:** Most challenging and critical elements. Coral disease is generally categorized by various lesions that occur across the dead coral tissue and spread more rapidly to cause total colony mortality.
2. **Monitoring the Disease:** It is essential to share the pictures of diseased coral colonies and report the disease to confirm the disease. The collection of information about the disease and reporting it to the responsible authority is an essential step for monitoring.
3. **Rapid Response:** Since the disease spreads quickly, it is critical to plan how to respond to the disease if sighted in any location.
4. **Community Engagement:** In a better management strategy, community members should actively engage with coral reef resources in areas where spread may be likely, and once the disease has been confirmed.

Future issues: There are several projected issues that create threats for the coral reef ecosystem, such as Climate change, Ocean acidification, Overpopulation, Careless tourism, Harbor development, Waste disposal, and pollution.

Future research area: Although the reef ecosystem is destroyed worldwide, there are some critical research areas that we need to adapt to conserve the sustainability of the reef environment. The future research direction could be
— Details survey of reef ecosystem throughout the globe and restoration of degraded habitat by Coral Transplantation.
— Artificial reef installation.
— Impact of coastal development on coral reef
— Status of coral reef biodiversity
— Study the effect of climate change on coral reef and mitigation measures
— Effect of anthropogenic threats on coral reef
— Satellite-based approach for mapping coral reef habitat
— Identification of coral diseases

CONCLUSION

The coral reef is the most diverse and economically valuable ecosystem. It provides immense economic and ecological services for humankind. Instead of providing huge benefits, the value of corals is underestimated. The reef ecosystem is under extreme threat due to natural and anthropogenic threats such as pollution, sedimentation, climate change, and coral bleaching. Overexploitation of commercially important fishes from the coral reef makes the ecosystem vulnerable to sustain the fishery. So, the appropriate management measures need to be adopted to protect the reef ecosystem. The strategies like community and ecosystem-based management approach with international authorities' collaboration can be a better option to ensure the conservation of the beautiful underwater resources.

REFERENCES

Aeby, G., Hutchinson, M. and MacGowan, P. (2008). Hawaii's rapid response contingency plan for events of coral bleaching, disease or crown-of thorns starfish outbreaks Hawaii. Hawaii Division of Aquatic Resources.

Alcala, A.C., Gomez, E.D. and Yap, H.T. (1987). Philippine coral reefs: status and human responses to changes. *Resource Management and Optimization*, **4**(3-4): 297-340.

Andersson, A.J., Mackenzie, F.T. and Lerman, A. (2006). Coastal ocean CO_2–carbonic acid–carbonate sediment system of the Anthropocene. *Global Biogeochemical Cycles*, **20**.

Anthony, K.R., Maynard, J.A., Diaz Pulido, G.U.I.L.L.E.R.M.O., Mumby, P.J., Marshall, P.A., Cao, L. and Hoegh Guldberg, O.V.E. (2011). Ocean acidification and warming will lower coral reef resilience. *Global Change Biology*, **17**(5): 1798-1808.

Ault, J.S., Smith, S.G., Bohnsack, J.A., Luo, J., Stevens, M.H., DiNardo, G.T., Johnson, M.W. and Bryan, D.R. (2019). Length-based risk analysis for assessing sustainability of data-limited tropical reef fisheries. *ICES Journal of Marine Science*, **76**(1): 165-180.

Babcock, E.A., Harford, W.J., Coleman, R., Gibson, J., Maaz, J., Foley, J.R. and Gongora, M. (2015). Bayesian depletion model estimates of spiny lobster abundance at two marine protected areas in Belize with or without in-season recruitment. *ICES Journal of Marine Science*, **72**: 232-243.

Bonzon, K., McIlwain, K., Strauss, C.K. and Van Leuvan, T. (2010). Catch share design manual: a guide for managers and fishermen. *Environmental Defense Fund.*, 184.

Burke, L., Selig, L., and Spalding, M. (2002). Reefs at risk in Southeast Asia.

Burke, L., Reytar, K., Spalding, M. and Perry, A. (2011). *Reefs at risk revisited*. World Resources Institute.

Burke, L., Reytar, K., Spalding, M. and Perry, A. (2011). Reefs at risk revisited: technical notes on modeling threats to the world's coral reefs. *Washington, DC: World Resources Institute*.

Caddy, J. (2002). Limit reference points, traffic lights, and holistic approaches to fisheries management with minimal stock assessment input.

California Environmental Associates (CEA). (2012). Charting a Course to Sustainable Fisheries.

Carpenter, K.E. and Alcala, A.C. (1977). Philippine coral reef fisheries resources. Part 2. Muro-ami and kayakas reef fisheries, benefit or bane? *Philippine Journal of Fisheries*, **15**(2): 217-235.

Carpenter, S., Walker, B., Anderies, J.M. and Abel, N. (2001). From metaphor to measurement: resilience of what to what? *Ecosystems*, **4(**8): 765-781.

Cope, J.M. and Punt, A.E. (2009). Length-based reference points for data-limited situations: applications and restrictions. Marine and Coastal Fisheries Dynamics. *Management, and Ecosystem Science*, **1**(1): 169-186.

Cooley, S.R. and Doney, S.C. (2009). Anticipating ocean acidification's economic consequences for commercial fisheries. *Environmental Research Letters*, **4**(2): 024007.

Cooley, S.R., Kite-Powell, H.L. and Doney, S.C. (2009). Ocean acidification's potential to alter global marine ecosystem services. Oceanography, **22**(4):172-181.

Coulthard, S. (2012). Can we be both resilient and well, and what choices do people have? Incorporating agency into the resilience debate from a fisheries perspective Ecology and Societ.y **17**(1).

Creel, L. (2003). *Ripple effects: population and coastal regions* (pp. 1-7). Washington, DC: Population Reference Bureau.

Cunningham, S., Dunn, M.R. and Whitmarsh, D. (1985). Fisheries economics: An introduction. Mansell.

Dalton, S.J., Godwin, S., Smith, S.D.A. and Pereg, L. (2010). Australian subtropical white syndrome: a transmissible, temperature-dependent coral disease. *Marine and freshwater research*, **61**(33): 42-350.

Dick, E.J. and MacCall, A.D. (2011). Depletion-Based Stock Reduction Analysis: A catch-based method for determining sustainable yields for data-poor fish stocks. *Fisheries Research*, **110**(2): 331-341.

Dowling, N.A., Dichmont, C.M., Haddon, M., Smith, D.C., Smith, A.D.M. and Sainsbury, K. (2015). Guidelines for developing formal harvest strategies for data-poor species and fisheries. *Fisheries Research*, **171**: 130-140.

Dudley, N. ed. (2008). *Guidelines for applying protected area management categories*. Iucn.

Friend, M., Franson, J.C. and Ciganovich, E.A. eds. (1999). Field manual of wildlife diseases: general field procedures and diseases of birds US Geological Survey.

Froese, R. (2004). Keep it simple: three indicators to deal with overfishing. *Fish and fisheries*, **5**(1):86-91.

Froese, R., Demirel, N., Coro, G., Kleisner, K.M. and Winker, H. (2017). Estimating fisheries reference points from catch and resilience. *Fish and Fisheries*, **18**(3): 506-526.

Fujita, R., Thornhill, D.J., Karr, K., Cooper, C.H. and Dee, L.E. (2014). Assessing and managing data limited ornamental fisheries in coral reefs. *Fish and Fisheries*, **15**(4): 661-675.

Garcia, S.M. and Rosenberg, A.A. (2010). Food security and marine capture fisheries: characteristics, trends, drivers and future perspectives. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **365**: 2869-2880.

Graham, N.A., Bellwood, D.R., Cinner, J.E., Hughes, T.P., Norström, A.V. and Nyström, M. (2013). Managing resilience to reverse phase shifts in coral reefs. *Frontiers in Ecology and the Environment*, **11**(10): 541-548.

Haddon, M., (2010). *Modelling and quantitative methods in fisheries*. CRC press.

Hudson, J.H. (2000). First aid for massive corals infected with black band disease, Phormidium corallyticum: an underwater aspirator and post-treatment sealant to curtail reinfection.

Holling, C.S. (1973). Resilience and stability of ecological systems. *Annual review of ecology and systematic*, **4**(1): 1-23.

Hughes, T.P. (1994). Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. *Science*, **265**: 1547-1551.

International Coral Reef Action Network. (2004). *People and reefs: Successes and challenges in the management of coral reef marine protected areas* (No. 176). United Nations Publications.

Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandol, J.M. and Peterson,

C.H. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science*, **293**(5530): 629-637.

Jennings, S. and Polunin, N.V.C. (1995). Comparative size and composition of yield from six Fijian reef fisheries. *Journal of Fish Biology*, **46**(1): 28-46.

Johnson, M.D., Price, N.N. and Smith, J.E. (2014). Contrasting effects of ocean acidification on tropical fleshy and calcareous algae. *Peer J*., **2**: p. e411.

Karr, K.A., Fujita, R., Halpern, B.S., Kappel, C.V., Crowder, L., Selkoe, K.A., Alcolado, P.M. and Rader, D. (2015). Thresholds in C aribbean coral reefs: implications for ecosystem based fishery management. *Journal of Applied Ecology*, **52**(2): 402-412.

Kelly, R.P., Foley, M.M., Fisher, W.S., Feely, R.A., Halpern, B.S., Waldbusser, G.G. and Caldwell, M.R. (2011). Mitigating local causes of ocean acidification with existing laws. *Science*, **332**: 1036-1037.

Kennedy, J., Jónsson, S.Þ., Olafsson, H.G. and Kasper, J.M. (2016). Observations of vertical movements and depth distribution of migrating female lumpfish (Cyclopterus lumpus) in Iceland from data storage tags and trawl surveys. *ICES Journal of Marine Science*, **73**(4): 1160-1169.

Link, J.S., Brodziak, J.K., Edwards, S.F., Overholtz, W.J., Mountain, D., Jossi, J.W., Smith, T.D. and Fogarty, M.J. (2002). Marine ecosystem assessment in a fisheries management context. *Canadian Journal of Fisheries and Aquatic Sciences*, **59**(9): 1429-1440.

MacCall, A.D. (2009). Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations. I*CES Journal of marine Science*, **66**(10): 2267-2271.

McClanahan, T.R., Graham, N.A.J., MacNeil, M.A. and Cinner, J.E. (2015). Biomass based targets and the management of multispecies coral reef fisheries. *Conservation Biology*, **29**(2): 409-417.

McGilliard, C.R., Hilborn, R., MacCall, A., Punt, A.E. and Field, J.C. (2011). Can information from marine protected areas be used to inform control-rule-based management of small-scale, data-poor stocks? *ICES Journal of Marine Science*, **68**(1): 201-211.

Mcleod, E., Anthony, K.R., Andersson, A., Beeden, R., Golbuu, Y., Kleypas, J., Kroeker, K., Manzello, D., Salm, R.V., Schuttenberg, H. and Smith, J.E. (2013). Preparing to manage coral reefs for ocean acidification: lessons from coral bleaching. *Frontiers in Ecology and the Environment*, **11**(1): 20-27.

Marshall, P.A., Schuttenberg, H.Z. and West, J.M. (2006). A reef manager's guide to coral bleaching.

Moberg, F. and Folke, C. (1999). Ecological goods and services of coral reef ecosystems. *Ecological economics*, **29**(2): 215-233.

Newton, K., Côté, I.M., Pilling, G.M., Jennings, S. and Dulvy, N.K. (2007). Current and future sustainability of island coral reef fisheries. *Current Biology*, **17**(7): 655-658.

Ovando, D.A., Deacon, R.T., Lester, S.E., Costello, C., Van Leuvan, T., McIlwain, K., Strauss, C.K., Arbuckle, M., Fujita, R., Gelcich, S. and Uchida, H. (2013). Conservation incentives and collective choices in cooperative fisheries. *Marine Policy*, **37**: 132-140.

Patrick, W.S., Spencer, P., Link, J., Cope, J., Field, J., Kobayashi, D., Lawson, P., Gedamke, T., Cortés, E., Ormseth, O. and Bigelow, K. (2010). Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing. *Fishery Bulletin*, **108**(3): 305-322.

Pitcher, T.J. and Preikshot, D. (200)1. RAPFISH: a rapid appraisal technique to evaluate the sustainability status of fisheries. *Fisheries Research*, **49**(3): 255-270.

Pollnac, R.B., Crawford, B.R. and Gorospe, M.L. (2001). Discovering factors that influence the success of community-based marine protected areas in the Visayas, Philippines. *Ocean and Coastal Management*, **44**(11-12): 683-710.

Pomeroy, R.S. and Williams, M.J. (1994). Fisheries co-management and small-scale fisheries: a policy brief.

Prince, J.D., Dowling, N.A., Davies, C.R., Campbell, R.A. and Kolody, D.S. (2011). A simple cost-effective and scale-less empirical approach to harvest strategies. *ICES Journal of Marine Science*, **68**(5): 947-960.

Rau, G.H., Mcleod, E. and Hoegh-Guldberg, O. (2012). Ocean conservation in a high CO_2 world: the need to evaluate new approaches. *Nature and Climate Change*, **2**: 720-724

Raymundo, L.J., Couch, C.S., Harvell, C.D., Raymundo, J., Bruckner, A.W., Work, T.M., Weil, E., Woodley, C.M., Jordan-dahlgren, E., Willis, B.L. and Sato, Y. (2008). Coral disease handbook guidelines for assessment, monitoring and management.

Roberts, D., and Declaration, M. (2009). Monaco Declaration.

Teh, L.S., Teh, L.C. and Sumaila, U.R. (2013). A global estimate of the number of coral reef fishers. *PLoS One*, **8**(6): 65397.

Teleki, K. (2017). The global transition to sustainable fisheries: Taking stock. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **27**(4): 740-747.

Westlund, L., Holvoet, K. and Kébé, M. (2008). Achieving poverty reduction through responsible fisheries. Lessons from West and Central Africa. FAO.

Wilson, J.R., Valencia, S.R., Kay, M.C. and Lenihan, H.S. (2014). Integration of No Take Marine Reserves in the Assessment of Data Limited Fisheries. *Conservation Letters*, **7**(5): 451-458.

Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S. and Jensen, O.P. (2009). Rebuilding global fisheries. *Science*, **325**(5940): 578-585.

Woodley, C.M., Bruckner, A.W., McLenon, A.L., Higgins, J.L., Galloway, S.B. and Nicholson, J.H. (2008). Field manual for investigating coral disease outbreaks.

How to cite this article: Nama, S. and Akter, S. (2020). A Review on Coral Reef Fisheries it's Management and Conservation Strategies. *Biological Forum – An International Journal*, **12**(2): 54-62.