5. Tropical Coral Reefs and Seagrass Beds as Fish Habitats: Reef Fish-Based Ecosystem Services under Anthropogenic Stresses in the Kuroshio Region

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The area from the Philippines to the Pacific coast of Japan has a very high coral and fish species diversity. The Kuroshio Current, which flows to Japan from the Philippines, transports many tropical organisms, resulting in highly developed coral reefs and many coral species (ca. 380 species) in Okinawa (26˚ N, southern Japan) and over 100 species of reef-building corals in Kochi (33˚ N, western Japan) despite the high latitude (Ministry of Environment and Japanese Coral Reef Society, 2004). Biological transport by the Kuroshio Current affects biodiversity and the livelihoods and cultures of the people who use it. Sato et al. (2021) examined the relationship between the latitudinal patterns of potential stocks of reef-fish-based ecosystem services, including fisheries production, aquarium fish production, and recreational diving, and fish diversity in 10 coral habitats from tropical to temperate zones in the Kuroshio region (8˚37' N to 33˚24' N). They found a regional decline in two ecosystem services, aquarium fish production and recreational diving, from south to north, while another ecosystem service, fisheries production, peaked in both tropical (Philippines) and subtropical (Okinawa) regions. They also noted that biodiversity had a strong positive effect on the three ecosystem services and stressed the importance of the conservation of a diversity of fish species to maintain high levels of multiple ecosystem services.

The Philippines and Okinawa rely heavily on coral reef fishes as fishery and tourism resources, and the conservation of coral reef fish diversity is an important issue. However, reef fish resources in these regions are currently declining. The importance of conserving coral reef biodiversity has been known for decades, and some actions have been taken, so why are fish resources declining? Are there any functional aspects of the fish habitat that we have failed to protect? Are there problems with current conservation and management measures? These questions need to be verified. This chapter outlines the functions of seagrass beds and coral reefs, which are representative habitats of the coastal areas along the Kuroshio Current, especially in the Philippines and southern Japan, as fish habitats as well as their reef-fish-based ecosystem services, current state of decline, management, and existing conservation issues.

1. Seagrass Beds

Seagrasses are marine flowering plants with underground roots and rhizome systems, which form extensive monospecific or mixed species beds or meadows (Green and Short, 2003; Short et al., 2007). Seagrass beds are widely distributed along the protected coastlines of temperate and tropical regions, except for Antarctica (Short et al., 2007), with recent estimates of seagrasses covering an area of 160 387 km^2 globally (McKenzie et al., 2020). Globally, there are six seagrass bioregions, which are based on species assemblages, distribution ranges, and climate: temperate North Atlantic, tropical Atlantic, Mediterranean, temperate North Pacific, tropical Indo-Pacific, and temperate Southern Ocean (Short et al., 2007). A total of 72 seagrass species have been identified worldwide (Short et al., 2011), and of these, 24 are found in the tropical Indo-Pacific, which supports the highest seagrass diversity out of the six bioregions (Short et al., 2011). About 22 seagrass species have been recorded along the coastline of the Kuroshio region: 15 species in Japan (Kuo et al., 2006), 12 species in Taiwan (Lin et al., 2005; Yu et al., 2014), and 18 species in the Philippines (Fortes, 2013). Seagrass beds are found in two tidal zones: subtidal seagrass beds are constantly submerged throughout the tide cycle and are commonly found throughout all the bioregions, and intertidal seagrass beds are exposed to air for a few hours during low tide and typically occur in tropical Indo-Pacific bioregions with wider tidal fluctuations (Krumme, 2009; Unsworth et al., 2007; Figure 1).

Figure 1 Exposed intertidal seagrass beds during low tide at Mindanao Island, Philippines

Seagrass beds provide vital ecosystem services, as they serve as nursery and foraging grounds to a variety of fishes and invertebrates, including some of commercial value (Pollard, 1984; Nagelkerken, 2009). According to Pollard's (1984) global review of seagrass fish studies, most of which have been conducted in temperate regions, seagrass fish assemblages are commonly comprised of permanent residents, which are fishes that remain in seagrass beds throughout their life cycle, seasonal residents, which are fishes that utilize seagrass beds as a nursery, transients, which are fishes that forage in seagrass beds, and occasional migrants, which are fishes that occasionally appear in seagrass beds. These patterns of habitat use by fishes are mostly recognized in temperate subtidal seagrass beds. However, some permanent residents, such as gobiids and syngnathids, and transient fishes, such as mugilids, also occur in temperate intertidal beds (Edgar and Shaw, 1995; Polte and Asmus, 2006). Similar patterns have also been found in tropical regions, which have very diverse fish assemblages, with at least 60 fish species being recorded in only a few square meters at some locations (Kopp et al., 2007; Nakamura and Tsuchiya, 2008). In the Caribbean, juveniles of *Haemulon parra, Lutjanus apodus*, and *Ocyurus chrysurus* depend highly on seagrass beds compared with coral reefs as nursery habitat (Nagelkerken et al., 2001; Verweij et al., 2008). Adults of Lutjanidae and Haemulidae undergo nocturnal migration. They emerge from their daytime resting sites, such as mangroves and coral reefs, and migrate at night to seagrass beds to feed on the high abundance of prey items, including small crustaceans and shellfish (Nagelkerken et al., 2000; Ogden and Ehrlich, 1977). In the Indo-Pacific region, seagrass beds harbor high densities of juvenile Lethrinidae, Lutjanidae, and Scaridae, seeking refuge on the complex seagrass structures, which reduce the risk of predation, and food, with foraging being optimized before these juveniles move to coral reefs via ontogenetic migration (Berkström et al., 2013; Nakamura et al., 2012). Moreover, large piscivores, such as *Hemiramphus far* and *Caranx melampygus*, migrate to seagrass beds from nearby coral reefs, and they are assumed to feed on the high abundance of small fishes found in seagrass beds (Unsworth et al., 2007).

Most of the studies that highlight the habitat function of tropical seagrass beds for fishes have been conducted on subtidal seagrass beds, and only limited research has been conducted on tropical intertidal seagrass beds, particularly in the Philippines, which is a hotspot of reef fish biodiversity (Carpenter and Springer, 2005). Recently, Espadero et al. (2020) used video survey to show that many fishes are present and feed in intertidal seagrass beds as soon as the tide starts to inundate the beds, and the number of fish species gradually increases with tide. Most of the fishes observed foraging were small juveniles (< 10 cm TL) of Siganidae and benthic-invertebrate feeders, such as Labridae, Lethrinidae, and Lutjanidae (Figure 2). One of the possible drivers of the migration of these fish to intertidal seagrass beds is the high abundance of potential food resources, such as small and large crustaceans, mollusks, and polychaetes (Espadero et al., 2021). Piscivorous fishes, such as *Cheilio inermis* (>15 cm TL) and *Sphyraena barracuda* (>20 cm TL), also occur in intertidal seagrass beds at later tides, and they are motivated to migrate to the beds because of the increasing number of small prey fishes with the rising tide. Although intertidal seagrass beds are exposed during low tide, many site-attached fishes dominate the seagrass beds, as these fishes seem to reside in tidal pools or in the residual water available under the canopy during exposed periods (Espadero et al., 2021). These newly identified foraging and permanent habitat functions indicate that tropical intertidal seagrass beds are an essential habitat for coastal fishes.

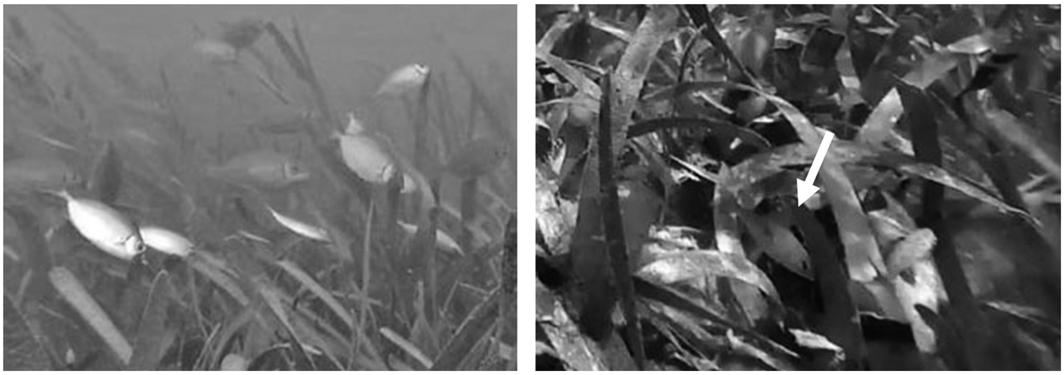

Figure 2 Feeding associated behaviors of the two commercially important fish species during high tide in an intertidal seagrass bed at Mindanao, Philippines; left. schooling *Siganus fuscescens*, feeding on seagrass epiphytes; right. *Lethrinus harak*, feeding on benthic organism under seagrass canopy

Seagrass beds are rapidly declining worldwide due to increasing anthropogenic stressors (Orth et al., 2006; Waycott et al., 2009). Since the 1980s, a loss of 35% has been recorded, with coastal developments, dredging activities, and declining water quality being major causes of decline (Waycott et al., 2009). In Japan, apart from land reclamations and eutrophication, natural disasters, such as strong typhoons, have contributed to the decline of seagrasses (Nakamura, 2010). The 2011 Tohoku tsunami alone led to the loss of 76% of seagrass along the Pacific coast of northeastern Japan (Hamaoka et al., 2020), resulting in changes in the fish community composition of the coast, with dominant seagrass-associated fishes being replaced by sand- or mud-associated species (Shoji and Morimoto, 2016). In the Philippines, land-based activities, such as forest conversion to agriculture, near seagrass beds influence habitat loss the most due to increased siltation (Quiros et al., 2017). The global decline of seagrasses poses significant consequences to coastal populations, as habitat loss has negative consequences on food security for those who directly depend on the goods and services that seagrasses provide (Unsworth and Cullen, 2010). Although conservation efforts focused on seagrass beds have been undertaken in recent decades, most seagrass areas are still under the threat of habitat loss (Unsworth et al., 2019). Enhancing societal awareness and understanding on the importance of protecting seagrass beds to sustain marine biodiversity and coastal fisheries (Unsworth et al., 2019) could help to increase support in the campaign, urging policy-makers to integrate seagrass conservation into their coastal management policies, particularly in developing countries.

2. Coral Reefs

Coral is a biological substrate that is critical for providing food and shelter for reef fishes and other associated organisms (Caley and St John, 1996; Cole et al., 2008). Live coral, in particular, interacts moderately, such as through competition and predation, with associated fishes by providing refuge spaces and specific feeding niches within a coral colony (Webster and Hixon, 2000; Stewart and Jones, 2001; Schmitt and Holbrook, 2002). The high diversity of scleractinian corals and their physical structure provide a refuge that could substantially enhance individual survivorship and species co-existence and moderate key processes (Kerry and Bellwood, 2012). Corals and associated organisms collectively form a diverse ecosystem of interacting individuals, which is known as a coral reef (Figure 3).

Figure 3 Fishes on a coral reef at northern Mindanao Island, Philippines

Coral reefs consist of reefs made of calcium carbonate, which is mostly secreted by reef-building corals and encrusting macroalgae. They occupy less than 0.1% of the ocean floor yet play multiple important roles throughout the tropics, housing high levels of biological diversity and providing key ecosystem goods and services, such as habitat for fishery resources, coastal protection, and appealing environments for tourism (Wild et al., 2011)(Figure 4). Coral reefs are considered among the most biologically rich and productive ecosystems in the world (Birkeland, 1997; Burke et al., 2012), and they are the most biologically diverse shallow-water marine ecosystem (Roberts et al., 2001). They extend across about 250,000 km^2 of the ocean, which is less than one-tenth of 1% of the marine environment, yet they are possibly home to 25% of all known species in the marine environment (McAllister, 1995).

Figure 4 Coral reef fishes at the fish market in Okinawa

An ecological region in the marine environment where there is a greater concentration of coral and reef fish species than anywhere else on earth is the Coral Triangle (Burke et al., 2012; Veron et al., 2009). It spans parts of insular Southeast Asia and the western Pacific, and it is recognized as the global center of marine biological diversity, with the highest coral diversity in the world (76% of all coral species) and the highest diversity of coral reef fishes in the world (37% of all species). Coral bleaching is a natural phenomenon that poses threats to coral reefs. A recent global coral bleaching event spanned three years from mid-2014 to mid-2017 and was assessed as the most widespread and damaging coral bleaching event, with many reefs subjected to multiple periods of thermal stress, as the oceans warmed repeatedly (Kimura et al., 2018). The same study reported that the bleaching event in East Asia's reefs was also widespread, with the greatest bleaching severity reported in 2016.

Although the Southeast Asian region, including the Philippines, only occupies 2.5% of the ocean surface, it contains 30% of the world's coral reefs. Climate, oceanographic, and geological conditions in the region are favorable for coral growth and the result is an unparalleled species richness (Chou, 1998). The Philippines marine and coastal habitats have at least 4,951 species of marine plants and animals. The majority of these are fishes, non-coral invertebrates, and seaweeds. The country's coral reef area is estimated at 26,000 km2 (Burke et al., 2002), which is the second-largest area of coral reef in Southeast Asia. Approximately 400–500 species of scleractinian or "stony" coral species exist in the area (Chou, 1998; Veron, 1995), and 12 species are considered endemic (Veron, 1995).

Dubbed as the global epicenter of marine shore fish biodiversity because of its exceptional species richness per unit area (Carpenter and Springer, 2005), the Philippines is home to 3,053 species of fish (Allen and Erdmann, 2009), of which 2,724 are marine-based, and 1,658 (61%) are coral reef-associated species (Figure 3). The region is endowed with unprecedented biodiversity (Bellwood and Hughes, 2001; Carpenter and Springer, 2005), and coral reefs support ~20% of total marine fisheries production (Burke et al., 2012; Alcala and Russ, 2002). However, coral reefs are an anthropogenically-threatened marine environment (Roberts et al., 2002).

Fishery yield records indicate that areas of relatively shallow water with a dense cover of live coral can produce extremely high fish yields (Wass, 1982; Munro, 1996). Fishery products provide 11.7% of the total Filipino food consumption (Bureau of Fisheries and Aquatic Resources, 2014) and 5–6 million Filipinos depend directly on the fishing industry for livelihoods (National Economic Development Authority, 2011), with about one million Filipinos directly dependent on reef fisheries (Barut et al., 2003) . Reef fisheries have been estimated to directly contribute to ~15–30% of total national municipal fisheries production (Carpenter and Alcala, 1977). Additionally, the total economic valuation of Philippine reefs amounted to 140,000 US$/km^2/yr (Tamayo et al., 2018). Therefore, it is no surprise that the anthropogenic impacts on Philippine coral reefs and reef fishes are diverse. A comparison of the integrated threats in the Coral Triangle countries (Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste) shows that the Philippines is second highest number of reefs subjected to high and very high local integrated threats relative to its total reef area (Table 1).

Table 1 Coral reefs under high and very high integrated local threats based on reef risk analysis

Countries	Total Reef Area (Km^2)	Reef Under High and Very High Local Integrated Threat	
		Area (Km^2)	Percent (%)
Indonesia	39,538	15,009	38
Malaysia	2,935[a]	1,254	42.7
Papua New Guinea	14,535	4,161	28.6
Philippines	22,484[a]	15,358	68.3
Solomon Islands	6,743	1,975	29.3
Timor-Leste	146	134	91.8
Total	**86,381**	**37,892**	**43**

[a] Statistics for Malaysia and the Philippines do not include certain areas in the South China Sea. For further details on these areas, see Burke et al. (2012).
Source: Data from Burke et al. (2012).

The widespread reduction in the abundance of fishes following extensive coral loss (Jones et al., 2004; Graham et al., 2006; Cheal et al., 2008) provides evidence of the strong reliance of many reef fishes on live corals. A large portion of Philippine coral reefs has been subjected to severe degradation, which has reduced their productivity (Yap and Gomez, 1985). Major destructive factors include sedimentation and siltation from coastal development and illegal and destructive methods of fishing and overfishing (Gomez et al., 1994). Overfishing remains a significant problem in many areas. In one decade (2002−2012), overfishing was the biggest threat (about 40%) followed by destructive fishing practices (36%) (Figure 5), and except for destructive fishing practices, the impact of most major threats to the country's coral reefs had intensified (Burke et al., 2002; MPA Support Network, 2012). Nañola et al. (2011) reported a low abundance of species in the Visayas region, which is an indication of intense fishing and habitat degradation that subsequently led to declines in species stocks. More than 50% of the reef fish sites in the Philippines that were surveyed between 1991 and 2004 were overfished (Nañola et al., 2002). Municipal and commercial overfishing and the destructive fishing methods often used in both sectors are the root causes of coral reef destruction and the depletion of coral reef resources.

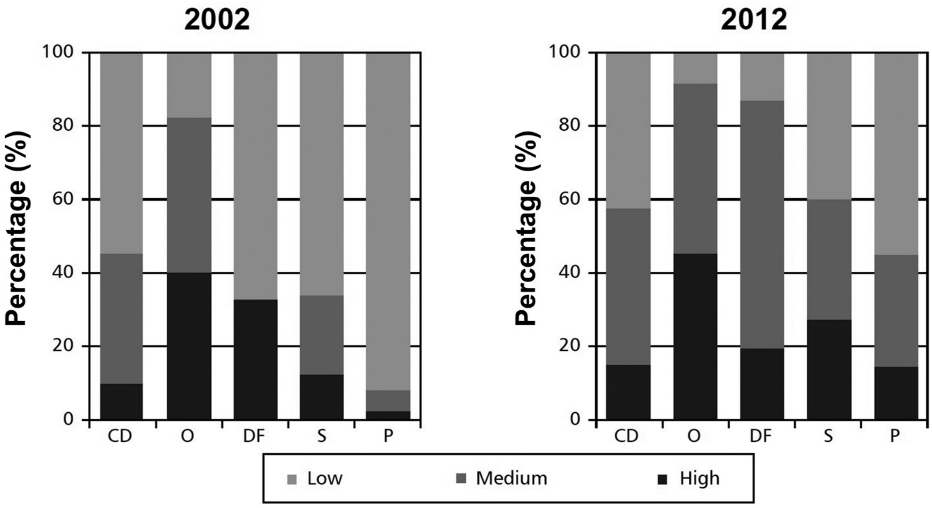

Figure 5 Change in the estimated intensity of major environmental threats to coral reefs in the Philippines, 2002 and 2012 (%). CD = Coastal development, DF = Destructive fishing, O = Overfishing, P = Pollution, and S = Sedimentation. Source: Burke et al. (2002), MSN (2012)

Resource management in coral reef areas of the developing world needs to be simple, inexpensive, easy to enforce, and require limited data (Roberts and Polunin, 1993). One of the solutions that is often applied to the problem of coral reef resource degradation is marine protected areas (MPAs), which fall under one of five management regimes: 1) traditional management, 2) community-based management, 3) state control, 4) co-management, and 5) integrated coastal management.

In the southern part of mainland Luzon, the Bicol region is one of the few areas of the Philippines with several types of established MPAs (Weeks et al., 2010). Furthermore, the Bicol region is the first landmass and bifurcation point of the North Equatorial Current (NEC). The NEC is strongest during the trade winds (March to May) when it is summer in the Philippines, and it splits near 14° N (Qiu and Lukas, 1996) to form the western boundary of the equatorward-flowing Mindanao Current and the nascent poleward-flowing Kuroshio. The NEC and subsequent poleward flow of the Kuroshio Current endow the Lagonoy gulf with a diverse fishery. The mouths of the Lagonoy Gulf and nearby Albay Gulf along the Bicol shelf open into the NEC, possibly linking offshore to inshore productivity, yielding estimated fishery production of 19,000 − 26,000 t/yr (Soliman, 2013). Half of the annual fishery production of the gulf is primarily comprised of reef and reef-associated fisheries (Dioneda et al., 2004), and the fishery requires rational management and protection of the gulf coral reefs.

MPAs in Lagonoy gulf are either coral reef MPAs or major habitats that protect corals and coral reefs (Mendoza et al., 1998). The 60 km^2 total area of MPAs (Soliman and Mendoza, 2000) is only 1.6% of the gulf area (3,701 km^2), which is much less than the mandate of the Philippine Fisheries Code to set aside 10 −15% of its fishing ground. Furthermore, the typical size of an MPA (1 km^2) in the gulf yields no fishery benefits and is ineffective in protecting commercially important fishes (Bobiles et al., 2016). Design and size must also be taken into account in establishing MPAs to attain their goal. Conventional design and size of more than 1 km^2 for an MPA and management over a longer period can guarantee its effectiveness as a conservation approach (Bobiles and Nakamura, 2019). Despite unequivocal success stories of MPAs (Russ and Alcala, 1996, 2003; Russ et al., 2005) and the increasing number of MPAs established in the Philippines (Weeks et al., 2010), fisheries production continues to decline. Therefore, the establishment of MPAs alone does not guarantee the recovery or ceasing of the deterioration of the fishery resource: it must be coupled with other measures complimenting the holistic approach of MPA’s.

3. Conclusions

The continued benefits of coastal biodiversity to our livelihoods will largely depend on how we use it. Coral reefs, which once supported many people’s lives, began to show an evident global decline in marine vertebrate resources, such as fish, from the 1980s (Mora et al., 2011a). Measures, such as MPAs, which are considered effective tools in conserving coral reef fishes, have not always been managed well in many regions, especially south-east Asia (Mora et al., 2006). Additionally, since the 1990s, we have been faced with a new problem: climate change. Extreme weather events, such as heatwaves, have led to mass coral mortality (Hughes et al., 2018), leading to a significant decline in fish diversity and abundance (Shibuno et al., 1999; Graham et al., 2006) and ecosystem services, including fisheries production, aquarium fish production, and recreational diving (Sato et al., 2020). One of the measures to combat global warming is to build the resistance and resilience of coral reef ecosystems to rising water temperatures by minimizing anthropogenic stresses, such as sediment runoff, eutrophication, and overfishing to herbivorous fishes (e.g., parrotfishes, surgeonfishes, and rabbitfishes) (Baker et al., 2008). The human population of countries near coral reefs is expected to double in 50 to 100 years (Mora et al., 2011b). In conjunction with measures to combat climate change, it will become increasingly important to balance coastal resource production with coastal resource consumption by the increasing human population.

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