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Successful restoration of smuggled corals in the Gulf of Mannar, Southeast India

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On account of their critical importance, corals are protected in India under Schedule I of the Wildlife Protection Act, 1972, Govt. of India. In spite of that, reports of coral smuggling arise from the Indian reef areas, sporadically. Corals being delicate animals, the restoration of corals seized from smugglers is difficult because of the delay involved in legal proceedings, transportation and the fragile nature of the corals. The present study reports the first successful effort in restoring seized live corals in the Gulf of Mannar, Southeast India. Fifty fragments of seized corals belonging to nine genera have been successfully transplanted on perforated trapezoidal artificial reefs deployed around Vaan Island of the Gulf of Mannar with an average survival rate of 62 % after 22 months. The growth rate of these surviving transplants ranged between 1.28±0.12 and 8.56±0.11 cm year^{-1}. The present attempt sets an example in the enforcement history of India, where sensitive marine organisms like corals can be saved after seizure if conservation authorities and researchers work together. However, proper network and coordination between these is critical to restore delicate marine organisms if seized alive.

[**Keywords**: Artificial reefs, Corals, Enforcement, Gulf of Mannar, Restoration, Wildlife crimes]

Introduction

Coral reefs are dynamic marine ecosystems that render critical ecological services and economic benefits. Coral reefs provide food and shelter to thousands of marine species, act as natural barriers to protect the coast, and offer critical hotspots for tourism operations. However, coral reefs around the world undergo severe decline owing to coral bleaching, disease outbreaks, ocean acidification, deoxygenation, destructive fishing practices, coastal development, tourism activities, pollution, etc. Being in the tropical Indo-Pacific realm, India is bestowed with a significant extent (3,063 km^2) of coral reef ecosystems[1]. The major reef areas in India include the Gulf of Mannar and Palk Bay in Tamil Nadu, the Gulf of Kachchh in Gujarat, the Andaman and Nicobar Islands, and the Lakshadweep archipelago. Apart from these major reef regions, there are also reef patches occurring along the west coast of India, bordering Kerala, Karnataka, Goa, and Maharashtra. The livelihood of thousands of fishermen depends solely on the fishery resources associated with these coral reefs[2]. In spite of their critical importance, corals in India are declining due to various natural and human-induced factors[3-6].

The Gulf of Mannar (GoM) in Southeast India is well-known for its coral reefs and coral-associated biodiversity in the state of Tamil Nadu. Unrealizing their importance, the corals were mined for building materials and lime factories during the 1960s and 1970s, when 25,000 tons of corals were mined annually from GoM and Palk Bay together[7]. In the absence of any legislation to prevent coral mining during that time, mining activities were rampant. Considering the importance of corals and associated biodiversity and the danger of their unbridled exploitation, the Government of Tamil Nadu created the Gulf of Mannar Marine National Park in 1986, covering an area of 560 sq km and in 1989, the Government of India declared the Gulf of Mannar Marine Biosphere Reserve, covering the entire Gulf of Mannar with 10,500 sq km area. Despite the legal protection, clandestine coral mining took place every now and then in GoM. In 2001, Government of India, through an amendment to the Wildlife Protection Act 1972, brought reef-building corals under Schedule I of that act. After this amendment, strict enforcement coupled with awareness creation helped to halt coral mining in GoM from 2005[(ref. 8)]. With coral mining

banned by law, the extent of live coral cover in GoM began to increase[8]. However, corals of GoM were severely affected by coral bleaching events caused by increased sea surface temperatures driven by climate change, especially by the events in 2010 and 2016[refs. 6,8,9].

Though the mining of corals for building and lime industries has been stopped, incidents of coral smuggling for ornamental purposes have been reported even after 2005 in GoM[10-12]. These incidents of coral smuggling are mainly related to the aquarium trade, and hence, corals are sometimes seized alive by the enforcement officials. Being fragile and sensitive, corals can withstand only minor variations in the environmental variables[13]. Hence, it is a challenging task to restore the seized corals though they are alive, because of the long time taken for the legal procedures and transportation. Additionally, the success of restoration of the seized corals also depends on the availability of technical skills, facilities, and expertise of dealing personnel. On 16th March 2019, live corals along with other marine organisms such as gorgonians, sponges, and echinoderms, were seized in Tuticorin from an aquarium trader by the Tamil Nadu Forest Department[12]. Staff members of the Tamil Nadu Forest Department and researchers from Suganthi Devadason Marine Research Institute (SDMRI) attempted to restore the seized live hard corals. The present study details the success of this coral restoration initiative, which is the first successful attempt in India.

Materials and Methods

Live corals along with other marine organisms, were seized by the officials at 11 am in Tuticorin, India. The seized fragments of corals upon identification found belonging to nine genera *viz*. *Euphyllia*, *Favites*, *Dipsastraea*, *Platygyra*, *Symphyllia*, *Goniopora*, *Galaxea*, *Turbinaria* and *Acropora*. These corals were identified up to genus level using morphological characters with the help of standard keys (http://www.coralsoftheworld.org/). All the seized fragments were found to be placed in glass tanks. The genus *Euphyllia* has not been reported from GoM before and it is not in the list of 117 reported species[14]. It was presumed that these corals had been collected from the deeper reef patches of GoM using surface-supplied diving where depth can go higher than 20 m, which takes place in the Tuticorin region of GoM[15].

Immediately after the completion of legal procedures, all the seized organisms were taken to the nearby Vaan Island (08°50'30.15" N; 78°12'27.62" E) for restoration. From the time of seizure until transplantation (six hours), all the seized coral fragments were kept in aerated seawater, which greatly reduced the stress on the fragments for better survival probability. Coral fragments were carefully transported to the restoration site in plastic tubs with aerated seawater. Direct sunlight was avoided to keep the coral fragments in good condition. Coral fragments need suitable hard substrates for attachment while growing[16]. Multi-purpose perforated trapezoidal artificial reefs have already been deployed around Vaan Island of GoM to protect the Island from soil erosion and to enhance biodiversity[17]. The dimensions of these modules are 1, 2, 2.5, and 1 m, respectively, in longitudinal length, height, width, and crest length. The modules have been deployed at a depth ranging between 1.5 and 2.5 m. There is a huge supply of coral larvae at this site, as it is evident from the multitude of epibenthic coral recruits on these modules[18]. Though many of the species restored in this study were previously not available at chosen site, it has been proved to be a safe haven for the survival of corals[18].

All 50 fragments of seized live corals were transplanted on the artificial reef modules at a depth between 1.5 and 2.5 m following the transplantation protocols standardized by SDMRI[19-21] with the help of scuba divers. With precision and utmost care, the fragments were secured onto the artificial reef modules with nylon strings. Figure 1 shows the transplanted fragments at different stages. Post-transplantation, maintenance and monthly monitoring were carried out to assess the survival and growth of transplants. The growth rate of the transplanted fragments was measured monthly. The initial sizes of the fragments were measured before the transplantation (Table 1). Linear extension for *Acropora* and increase in diameter for other genera was measured using Vernier callipers with flexible scales[22].

Results and Discussion

The efforts of the state government to build capacity among the staff of the Tamil Nadu Forest Department on corals helped to execute the restoration properly. In any coral restoration program, the transplanted fragments suffer initial mortality due

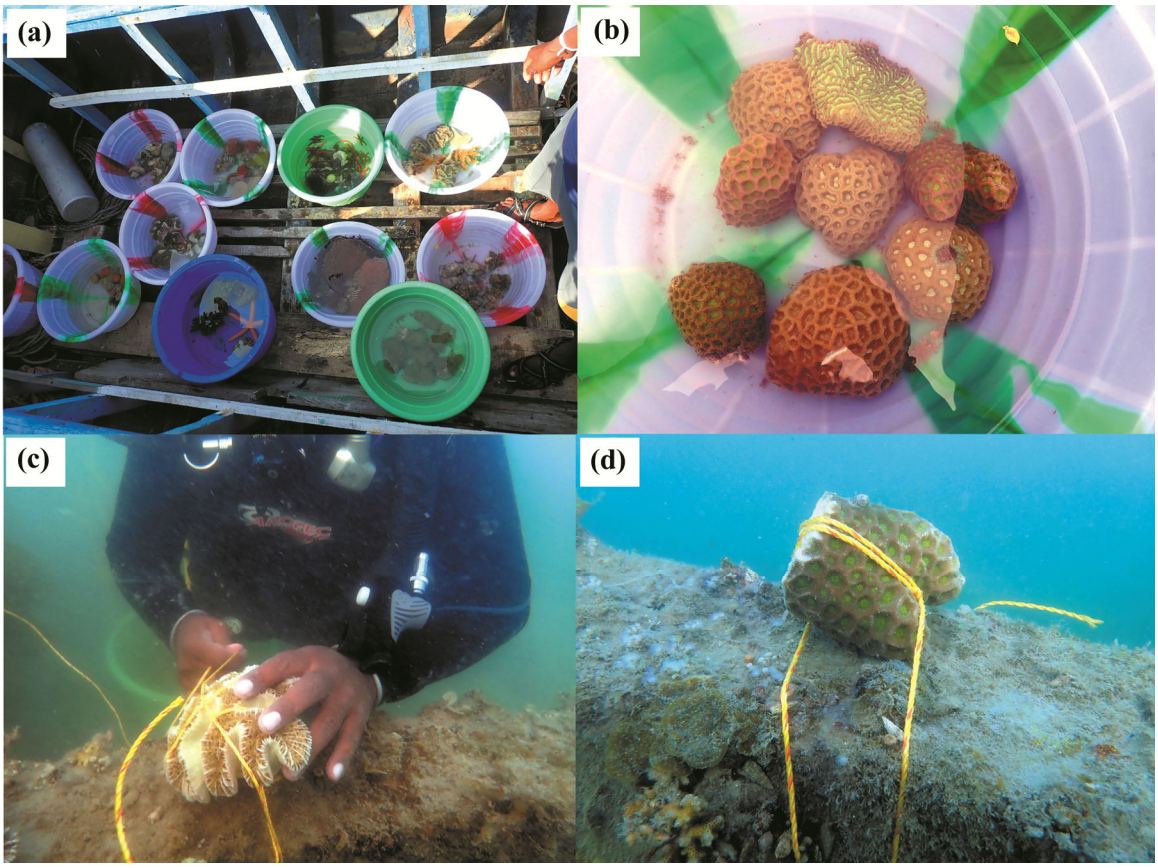

Fig. 1 — Transportation and transplantation of seized coral fragments in the Gulf of Mannar: a) Transportation of corals and other seized organisms to Vaan Island; b) Seized coral fragments; c) Transplantation of a seized fragment on an artificial reef module; and d) Transplanted coral fragment

Table 1 — Overall growth of transplanted fragments during the study period

Genus	Initial: March 2019 (cm)	Final: December 2020 (cm)
Euphyllia	10.5±3.4	15.8±3.6
Favites	7.5±1.2	12.5±1.4
Dipsastrea	6.2±1.2	10.4±1.1
Platygyra	7.9±1.7	12.2±1.9
Symphyllia	6.9±0.5	9.2±0.3
Goniopora	6.7±0.7	13.0±0.0
Galaxea	7.1±1.0	11.6±2.2
Turbinaria	5.2±1.4	7.6±1.3
Acropora	10.3±1.9	26.0±1.8

to stress[22]. The average percentage of survival in the current effort was 78 % in April 2019 and it decreased to 66 % in May 2019 (Fig. 2), which can be ascribed to the initial stress. However, the survival of the rest of the transplanted fragments was very good, and the survival rate was 62 % by December 2020 (after 22 months), in spite of all the stress they underwent before and after the transplantation. Interestingly, the surviving fragments have withstood two mild bleaching events in 2019 and 2020[refs. 23,24]. Corals attached to artificial reef modules have been reported to fare better during temperature anomalies in GoM[25]. In this work, high mortality was observed for the genus *Acropora*, with only 33.33 % of the transplants surviving after 22 months. The fast-growing coral species of GoM, including *Acropora* have been reported to be fragile as they suffered huge mortalities in 2010 and 2016[refs. 6,8]. Transplanted acroporans faced mortalities during the summer of 2019 and 2020 due to their susceptibility to elevated temperature levels and hence showed comparatively lower survival rates. The 100 % survival rate of *Euphyllia* during the study period was surprising and warrants further focused study.

The growth rate of surviving transplants ranged between 1.28±0.12 and 8.56±0.11 cm year^{-1} in which *Acropora* exhibited the highest growth rate, while *Symphyllia* showed the lowest (Fig. 3). As expected, fast-growing *Acropora* had the highest growth rate

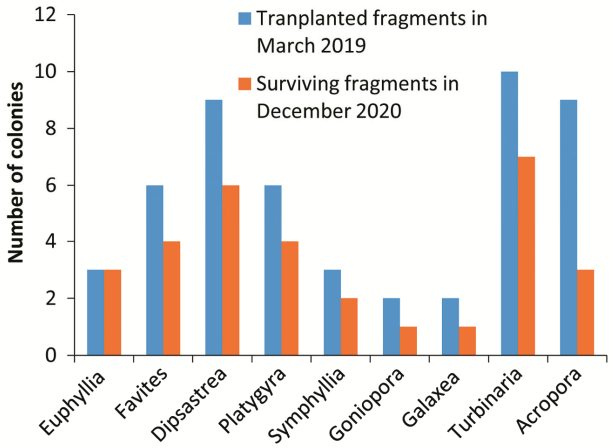

Fig. 2 — Genus-wise numbers of transplanted (March 2019) and surviving colonies (December 2020)

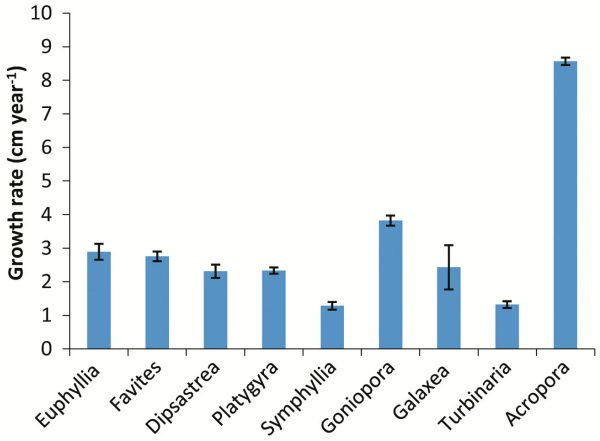

Fig. 3 — Genus-wise annual growth rate of transplanted coral fragments

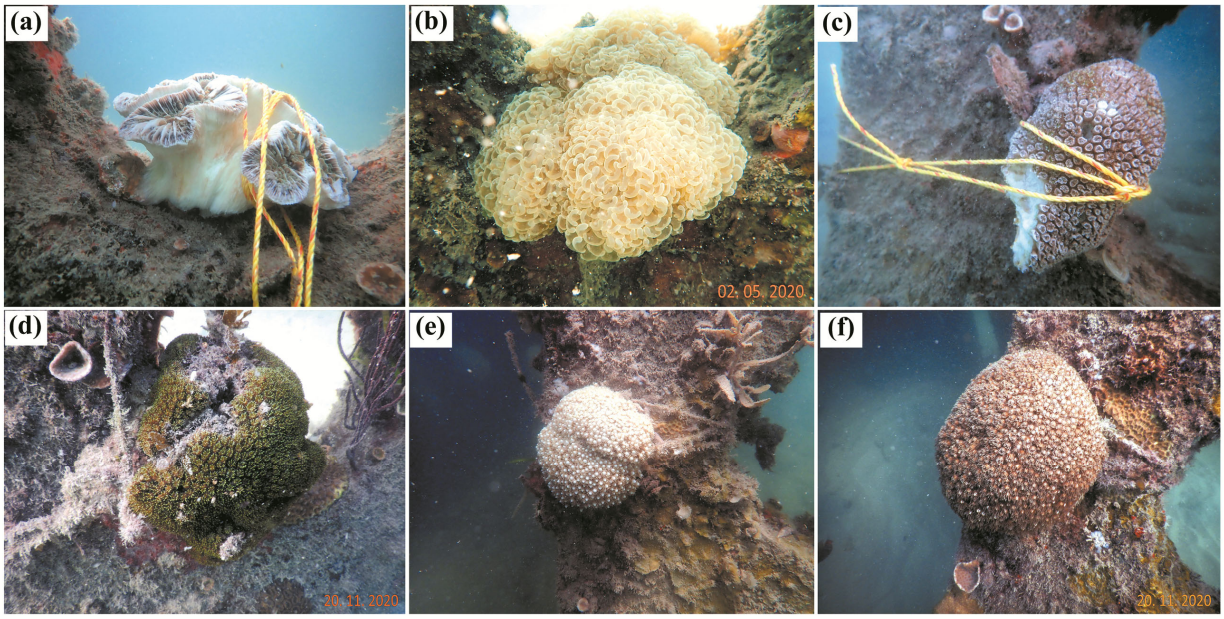

Fig. 4 — Survival of transplanted coral fragments: a) *Euphyllia* sp. – initial; b) *Euphyllia* sp. – 13 months after transplantation; c) *Galaxea* sp. – initial; d) *Galaxea* sp. – 21 months after transplantation; e) *Goniopora* sp. – two months after transplantation; and f) *Goniopora* sp. – 21 months after transplantation

though it had the lowest survival rate. The recovery of coral cover after the 2010 and 2016 bleaching events has been attributed to this faster growth rate of acroporans in the Gulf of Mannar[6,9]. Though the survivorship is comparatively higher for the massive corals, growth rates have been reported to be very slow, as evident in this study and previous reports from the Gulf of Mannar[6,9]. The survivorship and growth of the transplants are influenced by prevailing environmental conditions in the restoration site[26]. Fortunately, the artificial reef modules deployed in Vaan Island have already been proven to possess suitable environmental conditions for coral survival and growth, which is evident from the multitude of naturally occurring epibenthic coral recruits on these modules[18]. Increased temperature levels have been reported to suppress the growth of corals[27]. The highest growth rate was observed during the winter months between November and January for all the transplanted fragments. Though the surviving colonies escaped from mortality during the mild bleaching events in the summer months, the growth was affected. Currently, the survivor colonies are growing well on the artificial reef modules (Fig. 4).

Sexual reproduction in restored coral colonies has been reported from GoM in earlier restoration attempts[28], and hence, in all probability, these transplanted colonies will mature in a few years and start sexual propagation.

Despite of having stringent regulations in India to prevent crimes against wildlife, there are frequent reports of violations of wildlife laws[29]. The Gulf of Mannar, in particular, has been reported to be a hotspot for marine aquarium trade in India[30]. As far as marine organisms are concerned, restoration of seized animals is hard due to the fragility of the marine animals, the delay entailed by the legal formalities, and the lack of necessary facilities. Other organisms seized along with corals in this seizure were released into the sea in good condition. Being sessile benthic dwellers, corals require several environmental conditions conducive to their restoration, such as suitable substrate, apart from the special skill-set for the personnel like scuba diving and experience in coral restoration. Though transplantation of the fragments is the primary step, regular maintenance and monitoring are also critical to get better results. Including the transplantation site, corals in GoM suffer severe space competition from macroalgae and destructive fishing activities[9]. Hence, maintenance includes the removal of overgrowing algae and entangled fishing nets, if any, which are required for the transplants to grow without stress. The current effort is the first in India to have successfully restored the seized corals, and these colonies are being monitored regularly. Artificial reef modules in Vaan Island already provide shelter to naturally attaching coral colonies[17,18], and have now become a refuge for seized coral fragments too.

This attempt sets an example in the enforcement history of India, which demonstrates the successful restoration of sensitive marine animals such as corals. The network and cooperation between the enforcement departments and the relevant research institutions are essential to carry out such activities. If such a network is in place, logistics and technical expertise will be available for the seized marine organisms to be saved before it is too late. The enforcement departments should have separate funding for such unforeseen scenarios to meet the logistical expenses. It should also be noted that the legal proceedings concerning the seized fragile marine organisms should be completed as quickly as possible to enable their successful restoration. In such cases, knowledge on the importance of such sensitive marine organisms is vital for the enforcement officials and the judiciary, and hence, giving suitable training to these officials would certainly help. Above all, illegal smuggling should be completely prevented through stricter regulation frameworks and enforcement, penalties, and through increased awareness. In many cases, the illegal trading of marine organisms is linked with the livelihood of poor people, and hence, alternate livelihood options for the people involved are very important. Corals are critically important for the livelihood of thousands of coastal people in India and elsewhere and hence warrant more conservation initiatives.

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Conflict of Interest

The authors declare that we do not have any competing or conflict of interest.

Ethical Statement

This work does not involve animal experiments which need ethical approval.

Author Contributions

Conceptualization – KDR, TKA, JKP; Funding acquisition – KDR, JKP; Investigation – KDR, RR, AA, GM, RLL, JSE; Resources – JKP, TKA, RR; Roles/Writing - original draft – KDR; Writing - review & editing – JKP, TKA.

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