Biodiversity of Selected Herbivorous Coral Reef Fishes and Their Role in Coral Management, India

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Abstract: **Marine herbivorous fishes (Acanthuridae - Surgeonfishes and Scaridae - Parrotfishes) play a significant role in the prevention of coral smothering and aiding in their resilience. Unaccountable herbivorous reef fishery and bioinvasion of exotic seaweed in corals pose a danger in the healthy status of corals. An attempt is made not only on the biodiversity of these fishes in coral reefs in India (Gulf of Kachchh; Lakshadweep islands; Ratnagiri, Malvan, Goa, Gulf of Mannar and Andaman and Nicobar islands); their fishery but also recommends to have long-term monitoring studies in herbivorous reef fishery in the management of corals in India.**

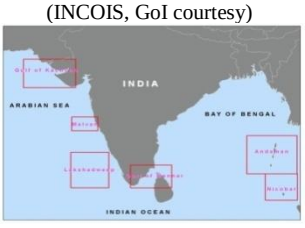
Key words: Surgeonfishes; Parrotfishes; Biodiversity, Bio-Invasion, Herbivorous Reef Fishery, Coral Management

I. INTRODUCTION

Corals offer their ecosystem services in fisheries productivity, coastal protection and economic revenue associated with tourism. The coastal water temperature fluctuations, heavy sedimentation, salinity changes and frequent emersion during low tides degrade the status of corals. However, the coral reef fishery is yet another important contributing factor in the degradation of corals. The herbivorous coral reef fishes consume benthic primary producers and regulate competition between fleshy algae and reef-building corals. Many of these herbivorous coral reef fishes are important fishery targets, yet little is known about their fishery status.

Both Bay of Bengal and Arabian Sea harbors major coral reef areas (Figure 1). The corals are known to occur off Ratnagiri (Angria Bank); off Malpe (Gaveshani Bank), Malvan; Goa and Quilon to Enayam[1] on the west coast of India. The diversity of corals in the Gulf of Kachchh is relatively low among all Indian reefs due to its geographical isolation and extreme environmental conditions [2]. Their occurrence and diversity are high in Lakshadweep islands, Andaman and Nicobar islands and Gulf of Mannar. In India, the most commonly occurring genera of corals are *Acropora*, *Montipora*, *Porites*, *Astreopora* and *Pocillopora* sp.

Figure 1. Major coral reef areas, India
(INCOIS, GoI courtesy)



The most important families of herbivorous reef fishes are 1) Acanthuridae (Surgeon fishes); 2) Scaridae (Parrot fishes); 3) Pomacentridae (Damsel fishes) and 4) Siganidae (Rabbit fishes). The distribution of herbivores is constrained by their algal food supplies. Different functional groups of herbivorous reef fishes like Scarpers, Excavators, Detritivores, Bioeroders and Browsers have been shown by [3] which may be reef dwelling or associated with reef and support considerable fishery. The largest bodied taxa such as *Bolbometopon*, *Chlorurus* and some *Scarus*species, are highly prized in many artisanal fisheries. The biggest reductions occurred in the large-bodied browser group, followed by the grazer/detritivores and scraper/excavators. IUCN has marked *Bolbometoponmuricatum* under 'vulnerable' on the Red List due to its high levels of exploitation and declining populations in the range.

Fishing-induced declines in parrotfish populations are known to result in the loss of reef resilience [4].It is probable that declines in biomass and changes in community structure associated with fishing alter the capacity of the group as a whole to control algal communities on reefs. The browser functional group appears to be most susceptible to fishing, with a biomass decline of approximately 80% at fished locations worldwide [5]. The fishes in the grazer/detritivores group (mostly Acanthurids) feed almost exclusively on organic matter/detritus or turf algae. This group also plays an important role in keeping algal turfs cropped and clearing organic matter from the reef benthos and the large impacts on this group are probably affecting reef health to some degree in fished locations. The needs to have long monitoring studies on these herbivorous fishes and to record them systematically in the management of corals are highlighted in this paper.

II. BIODIVERSITY OF PARROTFISHES

In 2011, [6] has validated about 10 genera under the family Scaridae and have shown that about 99 species of brightly colored parrotfishes swim in coral reefs around the world (1.*Scarus*-52species; 2.*Chlorurus*-18species; 3.*Sparisoma*-14species; 4.*Calotomus*-5species; 5.*Nicholsina*-3species; 6.*Cetosaurus*-2species; 7.*Hipposcarus*-2species; 8.*Bolbometo pon*-1species; 9.*Leptoscarus*-1species and 10.*Cryptotomus*-1species). Generally, *Bolbometopon, Cetoscarus, Chlorurus, Hipposcarus and Scarus* occur solely on or around coral reefs. In addition, two genera (*Calotomus* and *Sparisoma*) have four reef-associated species. Besides, the

remaining species in these two genera and the species in the remaining three genera (*Nicholsina*, *Cryptotomus* and *Leptoscarus*) are found on rocky reefs or in seagrass beds [7].

Parrotfishes have fused teeth (beaklike plates) that give them a parrot like appearance whose feeding behaviour renders them highly unsuitable for most marine aquaria despite their striking colors (Figure 2). Their coloring ranges from reds to greens, blues and yellows, as well as grays, browns and blacks.

Figure 2. Fused teeth of Parrotfish [9]

The excavators (*Bolbometopon, Cetosaurus, Chlorurus*and *Sparisomaviride*) have powerful oral jaws which excavate the substratum, leaving distinct grazing scars while the scrapers (all *Scarus* and *Hipposcarus* species) have less powerful jaws and rarely scar the substratum. Sex reversal is seen in parrotfishes and female parrotfishes may change into males. Abundance of parrotfishes during monsoon seasonhas been by [8]. The Table 1 represents the recorded parrotfishes in India.

III. BIODIVERSITY OF SURGEONFISHES

The Family Acanthuridae comprises of 80 described species, distributed under 6 genera (1.*Acanthurus*-37species; 2.*Naso*-19species; 3.*Ctenochaetus*-9species; 4.*Prionurus*-7species; 5.*Zebrasoma*-7species and 6.*Paracanthurus* -1species) [27]. Many are important food and aquarium fishes. However, [28] has mentioned about the presence of 83 species of surgeonfishes and dissolved the genus *Ctenochaetus* into the genus *Acanthurus* based on molecular analyses besides morphological evidences. Table 2 represents recorded Surgeonfishesin India.

Algal matter and ecological importance of herbivorous fishes

The benthic algae of coral reefs range from small filaments to thick mats of tough algae and large leathery macrophytes[33,34]. The presence of fleshy macroalgae on the reefs in Lakshadweep had been noted in 2005 [21] and reefs with green slime in 2008 [35]. Presence of macroalgae like *Sargassum, Gracilaria, Gelideilla, Turbinaria, Caulerpa, Padina, Halimeda, Ulva, Hypnea, Dictyosphaeria* besides *Kappaphycusalvarezii* in Gulf of Mannar was noted by [36]. Not only the macroalgal competition decreases coral growth rates but also leaves them to have persistent states of hypoxia. The ecological status of coral reef in India is shown in the Table 3.

Table 3. Ecological status of coral reef in India
Source: [11]

Year	Location	Coral status
2004-06	Andaman & Nicobar islands	Vulnerable
2005	Gulf of Mannar, Palk Bay	Vulnerable with algae and sea grasses
2005-06	Gulf of Kachchh, Gujarat	Degrading condition with majority area occupied by macroalgae, mud and sand.

The Surgeonfish (*A.triostegus*) is the most important browser within the Kavaratti lagoon, Lakshadweep island and is responsible for maintenance of coral tops of *Poriteslutea* and *P.solida*[32]. Acanthurids and Scarid fishes are the constant gardeners of the reef. Intensive grazing by these herbivorous fishes limits the establishment of macroalgae[37]. The exclusion of herbivorous fishes through reef fishery causes an explosion of macroalgae that prevents reestablishment of corals [38] and was suggested to be the strongest driver in smothering of corals [39].

The coral-macroalgal shift / Bio-invasion

The coral-macroalgal shifts have been reported from the Eastern Pacific [40], Caribbean [41,42] and Eastern Africa [43]. In India, such a shift was noticed by the presence of exotic red algae (seaweed), *Kappaphycusalvarezii*(native to Philippines). This seaweed is the most desirable seaweed for its aquaculture production due to its high growth rate, high carrageenan content and can double its biomass in 15 to 30 days.

However, this seaweed was not preferred by native Acanthurids and Scarids which enabled this invasive alga to grow very rapidly [44]. The bio-invasion of this seaweed on *Acropora* corals in Kurusadai islandhas been reported in 2008 [45]. This alga invaded the Gulf of Mannar Biosphere Reserve and no part of the coral reef was visible in most of the invaded sites [5, 35, 45] (Figure 3).

Figure 3.*Kappaphycus*(seaweed) mounds over corals
[Source: 47,36]

The invaded coral colonies were dead because of the shadowing and smothering effects of the attached fragments, which attached firmly and formed a thick mat on the coral colony and also penetrated deep up to 5–10cm. The coral mortality occurs 150-180 days after invasion by *K. alvarazii*[46].

IV. REEF FISHERY

About one billion of people are dependent globally on coral reefs for food [48,49].It is estimated that one km^2 of healthy reef can produce 10-30tons of fish biomass through sustainable fishing [50]. Reefs provide 25% of fish catches and upto 75% of the animal protein consumed [51]. Besides fishery, reef fishes are harvested for the aquarium trade due to their amazing colour patterns.Colour intensity variation, in relation to depth, is common among Acanthurids and Scarids.

For aquarium purposes, young ones of *Scarusgibbus* (<10 cm) and *S.rubroviolaceus* (10-20cm) fetch Rs.200/- per fish in Gulf of Mannar and are exported. The present level of exploitation of *S.gibbus* is 0.46 against the optimum exploitation for this species is 0.50 [52]. Though most of the species were recorded in lesser numbers in the reef islands, *S.gibbus* occur in large numbers and are exploited more for ornamental fish trade in Gulf of Mannar. Many entrepreneurs like Britto Sea Foods Exports Private Limited, Tuticorin; MsLogistics,Tuticorin; Sara Sea Foods,Kochi are engaged in coral reef fish trade.

In India, the fisher folk use to collect important ornamental marine fishes using scoop nets. The operation of shore seine is a common scene in the coastal villages of Gulf of Mannar region and the operation of purse seines happens illegally, leading to the capture of all the fishes. As there is a huge demand for marine ornamental fishes, fishermen set indigenous fish traps in the reef areas and about 20–25 traps are carried in one boat to catch the fish mainly to catch reef-dwelling herbivore fish which in turn causes proliferation of algae over live coral colonies, leading to coral mortality and subsequent ecological imbalance.

Parrotfish harvest is often largely a subsistence fishery and goes unreported [53]. The stock size and the maximum yield of Scaridae as ~2101MT and 1265MT and for Acanthuridaeas 1817.4MT and 782MT respectivelyin Lakshadweep islands in2002 [54]. The studies made in Gulf of Mannar showed that *S.gibbus* formed a year round fishery (9.4tons) and the diversity and evenness of parrotfish were higher at Thoothukudi coast than Mandapam coast [52].A depleting stock of Acanthurids in Tuticorin Fishing harbour in 2009, 2010 and 2011 (5.85; 5.41 and 4.94tons respectively has been reported [16]. The status of Surgeonfish exploited for ornamental purposes in Gulf of Mannar is shown in the Table 4.

Table 4. Status of Surgeonfish, exploited for ornamental purposes in Gulf of Mannar(Source: 55)

Scientific name	Common name	Status in 2002	Status in 2008
A.triostegus	Convict surgeon fish	Common	Rare
A.blochii	Ring tail surgeon fish	Common	Rare
A.leucosternon	Powder blue surgeon fish	Rare	Highly threatened
A.lineatus	Clown surgeon fish	Rare	Highly threatened

Overfishing disturbs the natural balance of the reef community. Internationally, in other areas, scarids like *S.guacamaia* (rainbow parrotfish) is listed as vulnerable to extinction [56]; *S.trispinosus* (Greenback parrotfish) as endangered; and *Chlorurusbowersi* and *S.hypselopterus* as nearly threatened and in India, the *Bolbometoponmuricatum* has been listed as under vulnerable category [57].

V. MANAGEMENT STRATEGIES

Fishing impacts in coral reef areas, when ecologically unsustainable, can lead to the depletion of key functional groups of reef species with cascading impacts on coral reef habitats and associated species and ecosystems. Illegal exploitation of reef-associated fishes for commercial purposes through traps, skin diving, nets and invasion of exotic seaweed like *K.alvarezii* pose challenges and invites adequate conservation strategies for the protection and management of coral reef ecosystems.

. The work of [58] throws light on the significance of reducing fishing pressure whose work reveals that the biomass of Scarid was low in Andavadoaka region, Madagaskar (81.04kg/ha). A much higher biomass was recorded in Marine Protected Areas (MPAs) (247.6kg/ha) when compared to fished areas (29.3kg/ha) on Tanzanian reefs. [59] highlighted the importance of managing scarid populations since a depletion of scarids may result in a dramatic reduction in coral production. The current fishing pressure will have an impact on carnivorous fish, which may ultimately lead to trophic cascade effects in the future [60]. The work of [61] highlighted a rapid increase in Scarids followed by a slower increase in Acanthurids following a closure of reefs to fishing in Kenyan MPAs. In 2012, [62] have perceived fishing pressure also as a factor to be incorporated into management plans for preserving coral-reef resilience in the context of climate change.

Creation and effective management of areas (as Marine Protected Areas) where fishing is prohibited can prove to be a valuable tool for managing the fisheries. Though the surgeonfish and parrotfish harvest is a subsistence fishery, it should be reported and recorded. A good way of monitoring the industry could be through a licensing system (limited number of permits being issued each year), whereby collection effort is regulated after estimating the resource base and sustainable harvest quotas[63]. Size limits are equally important to ensure that sufficient numbers of breeding adults remain on the reef. A ban on fishing during the times of spawning aggregations, a ban on the use of small-mesh gill nets that may allow smaller fish to escape and grow to a bigger size and a ban on fishing for parrotfish using spears at night (as a community action), could be implemented effectively.

Intentional introduction of species that are known to harm the coral should be avoided and should not be promoted [35].In 2008, [47] has quoted the opinion of a lawyer as to "Whoever is deemed responsible could be prosecuted for

damaging habitat under the Indian Wild Life Protection Act of 1972".

VI. CONCLUSION

The biodiversity of the herbivorous coral reef fishes i.e. Acanthurids (Surgeonfish) and Scarids (Parrotfish) in the coral reefs (Gulf of Kachchh; Lakshadweep islands; Ratnagiri, Malvan, Goa on the western side and Gulf of Mannar; Andaman and Nicobar islands on the eastern side of India) has been highlighted. They play an important role in maintaining the healthy status of coral reefs from smothering. The best way to protect the coral reefs from smothering is to have a healthy fish community in coral areas. Marine Protected Areas (MPAs) could act as an important tool for keeping the fish community and corals healthy. Scientific documentation of the biodiversity and mapping of the threats to the marine life could suggest the need for regulatory interventions from conservation point of view. Only scanty information is available on the resource available v/s sustainable yield and hence harvest of these reef associated fishes (surgeonfish and parrotfish) should be reported and recorded for future validation.A ban on fishing during the times of spawning aggregations; a ban on the use of small-mesh gill nets and a ban on fishing for parrotfish using spears at night (as a community action) could be implemented effectively to have a healthy reef fish populations. This study also recommends having long-term monitoring studies on the impacts in the propagation of exotic sea weed which is not desired by these herbivorous fishes (ultimately end up with smothering of corals) and the associated healthy status of corals in India.

REFERENCES

[1]. Pillai, C.S.G. 1996. Coral reefs of India: Their Conservation and Management. In: Marine Bio-diversity, Conservation and Management (Eds. Pillai,C.S.G and Menon,N.G). CMFRI, Cochin, India. pp.16-31.

[2]. Dixit,A.M., P.Kumar, L.Kumar, K.D.Pathak and M.I.Patel. 2010. Economic valuation of coral reef systems in Gulf of Kachchh. Final report. World Bank aided integrated coastal zone management (ICZM) project. Submitted to Gujarat Ecology commission. 158pp.

[3]. Green,A.L and D.R.Bellwood. 2009. Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience – A practical guide for coral reef managers in the Asia Pacific region. IUCN working group on Climate Change and Coral Reefs. IUCN, Gland, Switzerland. 70 pp. ISBN: 978-2-8317-1169-0.

[4]. Bellwood D.R, Hoey A.S, Hughes T.P.2012 Human activity selectively impacts the ecosystem roles of parrotfishes on coral reefs. Proc. R. Soc. B *279*, 1621–1629.

[5]. C.B. Edwards, A.M. Friedlander, A.G. Green, M.J. Hardt, E. Sala, H.P. Sweatman, I.D. William,B.Zgliczynski, S.A.Sandi n, J.E.Smith. 2013. Global assessment of the status of coral reef herbivorous fishes: evidence for fishing effects. Proc.Roy.Soc. B: BiologicalSciences. DOI: DOI: 10.1098/rspb.2013.1835.

[6]. Parenti,P and J.E.Randall. 2011. Checklist of the species of the families Labridae and Scaridae: An update. Smithiana Bulletin. 13: pp.29-44.

[7]. Bellwood,D.R. 1994. A phylogenetic study of the Parrotfishes, Family Scaridae (Pisces: Labroidei), with a revision of Genera. Records of the Australian Museum. Supplement 20. ISBN 0 7310 3663 8.

[8]. Vijayan,V. 2002. Present status and future exploitation for Tuna fishing in Indian EEZ. Fishery Technology, 39(2): pp.81–84.

[9]. Green,A.L and D.R.Bellwood. 2009. Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience – A practical guide for coral reef managers in the Asia Pacific region. IUCN working group on Climate Change and Coral Reefs. IUCN, Gland, Switzerland. 70 pp. ISBN: 978-2-8317-1169-0.

[10]. Devaraj,M and V.S.Murty. 1996. The fisheries and the mariculture potential of Groupers, Red Snappers, Breams and other coral reef fishes in India. In: Proc. Workshop on Sustainable Aquaculture and Management of Groupers and coral reef fisheries. Network Aquaculture Centre in Asia-Pacific (NACA) at Sabah, Malaysia.

[11]. Rao,D.V. 2012. Reef fish diversity of Andaman and Nicobar Islands, Bay of Bengal. In: Coral reefs in India - Status, threats and conservation measures. (Eds. Bhatt, J.R., J.K.P.Edward, D.J.Macintosh and B.P.Nilaratna. IUCN, International Union for Conservation of Nature and Natural Resources, ISBN 978-2-8317-1262-8. pp.165-177.

[12]. Rajan,P.T, C.R.Sreeraj and T.Immanuel. 2013. Fishes of Andaman and Nicobar islands. A Checklist. J.AndamanSci.Assoc. 17(1): pp. 47-87.

[13]. Rajaram,R and T.Nedumaran. 2009. Ichthyo-faunal diversity in Great Nicobar Biosphere Reserve, Bay of Bengal. Journal of Threatened Taxa. 1(3): pp.166-169.

[14]. Murty,V.S. 1969. Catalogue of Fishes (excluding from the Laccadives) in the Reference Collections of the Central Marine Fisheries Research Institute. Bull. Cent. Mar. Fish. Res. Inst. Bulletin No.10. Central Marine Fisheries Research Institute,Mandapam.

[15]. Venkataramani,V.K. and N.Jayakumar. 2006. Biodiversity and Biology of marine ornamental reef fishes of Gulf of Mannar – Parrotfishes (Family: Scaridae). In: Proc: Seminar on Biodiversity: Life to our Mother Earth (Ed. S.John William), Loyola College, Chennai. pp.153–167.

[16]. Sivaramakrishnan,T, G.Mathews, K.Saritha and J.Patterson. 2012. By-Catch exploitation of Ornamental Fishes in Tuticorin Coast of Gulf of Mannar, India. American-Eurasian Journal of Scientific Research. 7(6): pp.252-256.

[17]. Kumar,J.S.Y, S.Geetha, R.Sornaraj. 2013. Diversity and distribution of reef fishes in Gulf of Mannar islands, India. In: Ecology and Conservation of Tropical Marine Faunal Communities. (Eds. K.Venkataraman, C.Sivaperuman and C.Raghunathan). Springer-Verlag.Berlin. pp.297-310. ISBN: 978-3-642-38199-7 (Print) 978-3-642-38200-0 (Online)

[18]. Varghese,M, K.Balachandran and C.Kasinathan. 2009. Length-weight relationship and relative condition of *Scarusghobban*Forsskal, 1775 from Palk Bay. Indian J. Fish. 56(4): pp.323-324.

[19]. Veeramani,T, V.Ravi, K.Kesavan and T.Balasubramanian. 2010. Length-Weight relationship of Parrotfish *Scarusghobban*, Forsskal 1775 from Nagapattinam, South East Coast of India. Advances in Biological Research. 4(3): pp.182-184.

[20]. Varadharajan,D, N.Pushparajan and P.Soundarapandian. 2012. Fish Resources in Mallipattinam Coast, South East Coast of India. International Journal of Pharmaceutical & Biological Archives. 3(4): pp.871-876.

[21]. Arthur,R. 2005. Patterns and processes of reef recovery and human resource use in the Lakshadweep islands, Indian Ocean. Ph.D.Thesis. School of Tropical Environment Studies and Geography, James Cook University. Queensland, 135pp.

[22]. Kelkar, N., R.Arthur, N.Marba and T.Alcoverro. 2010. Consequences of green turtle herbivory on seagrass meadow dynamics, fish communities and subsistence fishing in the Lakshadweep Islands, India. Final report submitted to the Rufford Small Grants Foundation, U.K. 59 pp.

[23]. Zacharia,P.U, P.K.Krishnakumar, A.P.Dineshbabu,

K.Vijayakumaran, P.Rohit, S.Thomas, G.Sasikumar, P.Kaladharan, R.N.Durgekar and K.S.Mohamed. 2008. Species assemblage in the coral reef ecosystem of Netrani island off Karnataka along the southwest coast of India. J.Mar.Biol.Ass.India, 50(1): 87-97pp.

[24]. Sluka, R.D. 2013. Coastal marine fish biodiversity along the western coast of India. Journal of Threatened Taxa. 5(1): pp.3574–3579.

[25]. Ghosh,S.K and M. Fernandes. 2014. Angria Bank Expedition - Studies on the Marine Biodiversity. Intrim Report. GOI-UNDP-GEF Project (Sindhudurg), Malvan, Maharastra. 40pp.

[26]. Subburaman,S, S.Goutham, D.Joshi, M.Venkatesh, B.M.Praveenkumar, M.Matwal, R.D.Kamboj, M.V.M.Wafar, R.Kaul and B.C.Choudhury. 2014. Daring to Restore – Coral Reef Recovery in Mithapur. Wildlife Trust of India, Noida,Uttar Pradesh, India.

[27]. Randall, J.E. 2002. Surgeonfishes of Hawaii and the World. Mutual Publishing and Bishop Museum Press.

[28]. Sorenson,L, F.Santini, G.Carnevle and M.E.Alfaro. 2013. A multi-locus time tree of surgeon fishes (Acanthuridae, Percomorpha), with revised family taxonomy. Mol. Phylogenet. Evol. 68: pp.150-60.

[29]. Ray,B.C, N.R.Chattopadhyay and S.D.Roy. 2013. Reef Fish Biodiversity and Complexity in the North Bay Reef of Andaman and Nicobar Islands, India. International Journal of Advanced Fisheries and Aquatic Science. 1(1): pp.15-31.

[30]. catalogueoflife.org/col/details/species/id/17978720

[31]. Anand,V.P.E and N.G.K. Pillai. 2002. Habitat distribution and species diversity of coral reef fishes in the reef slope of the Kavaratti atoll, Lakshadweep, India. J. Mar. Biol. Ass. India. 45(1): pp.88-98.

[32]. Apte,D, I.Babu and S.Dutta. 2012. Density estimation of *Tridacna maxima* in Lakshadweep Archipelago In: Coral reefs in India - Status, threats and conservation measures. Bhatt, J.R., J.K.P.Edward, D.J.Macintosh and B.P.Nilaratna (Eds). IUCN, International Union for Conser- vation of Nature and Natural Resources, ISBN 978-2-8317-1262-8. pp.147-154.

[33]. Walter,L.J, C.M.Smith and M.G.Hadfield. 2003. Recruitment of sessile marine invertebrates on Hawaiian macrophytes: Do pre-settlement or post-settlement processes keep plants free from fouling? Bulletin of Marine Science. 72: pp.813–839.

[34]. Birrell,C.L, L.J.McCook, B.L.Willis and G.A.Diaz-Pulido. 2008. Effects of benthic algae on the replenishment of corals and the implications for the resilience of coral reefs. In: Oceanography and Marine Biology: An Annual Review. (Eds. R.N.Gibson, R.J.A.Atkinson, and J.D.M.Gordon), Taylor & Francis. 46: pp.25-63.

[35]. Pala,C. 2008. Corals, already in danger, are facing new threat from farmed algae. In: Environment. The NewYork Times. July 8th.

[36]. Kamalakannan,B, J.J.J.Jeevamani, N.A.Nagendran, D.Pandiaraja and S.Chandrasekaran. 2014. Impact of removal of invasive species *Kappaphycusalvarezii* from coral reef ecosystem in Gulf of Mannar, India. Current Science. 106(10): pp.1401-1408.

[37]. Vincent,I.V, C.M.Hincksman, I.R.Tibbetts and A.Harris. 2011. Biomass and abundance of herbivorous fishes on coral reefs off Andavadoaka, Western Madagascar. Western Indian Ocean. J.Mar.Sci. 10(1): pp.83-99.

[38]. Knowlton,N. 2001.The future of coral reefs. In:Proc.National Academy of Science of the USA. 98: 541954.

[39]. Szmant,A.M. 2002. Nutrient enrichment on coral reefs: Is it a major cause of coral reef decline? Estuaries. 25: pp.743–766.

[40]. Hunter,C.L and C.W.Evans. 1995. Coral reefs in Kaneohe Bay, Hawaii—two centuries of western influence and two decades of data. Bull.Mar.Sci. 57: pp.501–515.

[41]. Ostrander,G.K, K.M.Armstrong, E.T.Knobbe, D.Gerace, E.P.Scully. 2000. Rapid transition in the structure of a coral reef community: The effects of coral bleaching and physical disturbance. Proc: Natl. Acad. Sci. USA. 97: pp.5297–5302.

[42]. Rogers,C.S and J.Miller. 2006. Permanent 'phase shifts' or reversible declines in coral cover? Lack of recovery of two coral reefs in St. John, US Virgin Islands. Mar.Ecol. Prog.Ser. 306: pp.103–114.

[43]. Ledlie,M.H, N.A.J.Graham, J.C.Bythell, S.K.Wilson, S.Jennings, N.V.C.Polunin and J.Hardcastle. 2007. Phase shifts and the role of herbivory in the resilience of coral reefs. Coral Reefs. 26: pp.641–653.

[44]. Samuel,D.V, J.Patterson and J.K.P.Edward. 2002. Destructive fishing in the reef and mangrove areas of Tuticorin coastal waters. SDMRI Res. Publn.,2: pp.98–103.

[45]. Chandrasekaran,S, N.ANagendran, D.Pandiaraja, N.Krishnankutty, B.Kamalakannan. 2008. Bioinvasion of *Kappaphycusalvarezii* on corals in the Gulf of Mannar, India. Current Science. 94(9): pp.1167-1172.

[46]. Edward,J.K.P, and J.R.Bhatt. 2012. Impacts of cultivation of *Kappaphycusalvarezii* on coral reef environs of the Gulf of Mannar and Palk Bay, Southeastern India. In: Invasive Alien Plants: An Ecological Appraisal for the Indian Subcontinent (Eds. J.R. Bhatt, J.S.Singh, S.P.Singh, R.S.Tripathi and R.K.Kohli). CAB International. 89-98pp.

[47]. Bagla,P. 2008. Seaweed Invader Elicits Angst in India. Science. 320. pp.1271.

[48]. Whittingham,E, J.Campbell and P.Townsley. 2003. Poverty and reefs - A global overview. DFID-IMM.IMM Ltd. Innovation Center, Exeter, UK, 101pp.

[49]. Wilkinson,C. 2004. Status of coral reefs of the world. AIMS: Townsville (Australia), 557pp.

[50]. White,A, and A. Cruz-Trinidad. 1998. The values of Philippine coastal resources: Why protection and management are critical. Coastal Resource Management Project, Cebu City, Philippines.

[51]. Venkataraman,K., C.H.Satyanarayana, J.R.B.Alfred and J.Wolstenholme. 2003. Handbook on Hard Corals of India, ZSI, Kolkata. 266pp.

[52]. Venkataramani,V.K. and N.Jayakumar. 2006. Biodiversity and Biology of marine ornamental reef fishes of Gulf of Mannar – Parrotfishes (Family: Scaridae). In: Proc: Seminar on Biodiversity: Life to our Mother Earth (Ed. S.John William), Loyola College, Chennai. pp.153–167.

[53]. Western Pacific Regional Fishery Management Council. 2008. Biology of Parrotfish in Hawaii. Report. Hawaii Cooperative Fishery Research Unit, University of Hawaii. 37pp.

[54]. Murty,V.S. 2002. Marine ornamental fishes of Lakshadweep. CMFRI,Kochi. Spl.Pub.72: 134pp.

[55]. Mathews,G, V.D.Samuel and J.K.P.Edward. 2012. Status of ornamental reef fishes of the Gulf of Mannar Marine National Park, Southeastern India. In: Coral reefs in India - Status, threats and conservation measures. (Eds.Bhatt, J.R., J.K.P.Edward, D.J.Macintosh and B.P.Nilaratna. IUCN, International Union for Conservation of Nature and Natural Resources, ISBN 978-2-8317-1262-8. pp.155-163.

[56]. The World Conservation Union. 2002. The IUCN Red List of Threatened Species. August 02, 2003 (on-line) at http://www.iucnredlist.org/

[57]. The International Union for Conservation of Nature, 2011. "The IUCN Red List of Threatened Species 2011.2". http://www.iucnredlist.org/

[58]. McClanahan,T.R, N.A.Muthiga, A.T.Kamukuru, H.Machano and R.W.Kiambo. 1999. The effects of marine parks and fishing on coral reefs of northern Tanzania. Biological Conservation. 89: pp.161-182.

[59]. Mumby,P.J. 2006. Grazer impacts on coral dynamics. Ecological applications. 16: pp.747-769.

[60]. Mumby,P.J, C.P.Dahlgren, A.R.Harborne, C.V.Kappel and F.Micheli. 2006. Fishing, trophic cascades and the process of grazing on coral reefs. Science. 311: pp.98–101.

[61]. McClanahan,T.R, S.D.Donner, J.A.Maynard, M.A.MacNeil,

N.A.J.Graham. 2012. Prioritizing key resilience factors to support coral reef management in a changing climate. PLoS ONE 7: e42884. doi: 10.1371/journal.pone.0042884

[62] Wood,E. 2001. Collection of coral reef fish for aquaria: Global trade, conservation issues and management strategies. Marine Conservation Society, UK: 60 p.

Table.1 Parrotfishes in Indian coral reefs

No.	Genus	Species	Reference
1.	*Bolbometopon*	*muricatum*	Andaman and Nicobar islands [10, 11,12]
	Calotomus	*carolinus, spinidens,viridescens*	
	Cetoscarus	*bicolor*	
	Chlorurus	*bleekeri, enneacanthus, japanensis, sordidus*(syn. *S.sordidus*), *strongylocephalus*	
	Hipposcarus	*harid*	
	Leptoscarus	*vaigiensis*	
	Scarus	*dimidiatus, dubius, ferrugineus, festivus, flavipectoralis, frenatus, ghobban, globiceps, niger, prasiognathos, psittacus, rivulatus, quoyi, rubroviolaceus, scaber, gibbus*(Syn. *Chlorurusgibbus*), *taeniurus (*syn.*S.psittacus)*	
2.	*Chlorurus*	*sordidus*	Great Nicobar Biosphere Reserve [13]
3.	*Bolbometopon*	*muricatum*	Gulf of Mannar [10, 14,15,16, 17]
	Scarus	*ferrugineus, ghobban, gibbus, globiceps, niger, psittacus, rubroviolaceus, russellii, caudofasciatus*	
	Chlorurus	*oedema (syn.S.oedema)*	
	Leptoscarus	*vaigiensis,coeruleopunctatus (*syn.*L.vaigiensis*	
4.	*Scarus*	*ghobban*	Palk Bay [10, 18]
	Leptoscarus	*vaigiensis*	
5.	*Scarus*	*ghobban*	Nagapattinam fish landing harbor, Tamilnadu[19]
6.	*Scarus*	*ghobban*	Mallipattinam coast, Tamilnadu [20]
7.	*Scarus*	*falcipinnis,frenatus,ghobban,globiceps,niger,prasiognathos,psittacus,rubroviolaceus,scaber*	Lakshadweep islands [10, 21,22]
	Cetoscarus	*bicolor*	
	Chlorurus	*atrilunula, sordidus, strongylocephalus*	
	Calotomus	*spinidens, carolinus*	
	Leptoscarus	*vaigiensis*	
8.	*Chlorurus*	*bleekeri, troschelii*	Netrani island, Karnataka; Grande island, Goa[23,24]
	Scarus	*hoefleri, ghobban, rubroviolaceus*	
9.	Scarus	--	Angria Bank, Malvan, Maharastra[25]
10.	*Scarus*	*ghobban*	Mithapur reef, Gujarat[26]

Table.2Surgeonfishes in Indian coral reefs

No.	Genus	Species	Reference
1.	*Acanthurus*	*leucosternon, lineatus, mata*(syn. *A.bleekeri*), *triostegus, tristis*	Andaman and Nicobar islands [10,11,12, 29].
	Ctenochaetus	*Strigosus*(Syn.*A. strigosus*), *striatus*	
	Naso	*hexacanthus, unicornis*	
	Zebrasoma	*desjardinii, scopas, veliferum*	
2.	*Acanthurus*	*elongates, leucosternon, lineatus, nigricauda, nigrofuscus* (syn.*A.matoides*), *tennentii, thompsoni, triostegus, xanthopterus*	Lakshadweep[10,21,30].
	Ctenochaetus	*strigosus*(Syn. *A.strigosus*), *striatus*	
	Paracanthurus	*hepatus*	
	Naso	*brachycentron,brevirostris, hexacanthus,lituratus,tuberosus, unicornis, vlamingii*	
	Zebrasoma	*desjardinii, scopas, veliferum*	
3.	*Acanthurus*	*leucosternon, lineatus, triostegus*	Kavaratii atoll [31,32].
	Naso	*brevirostris,lituratus, unicornis, vlamingii*	
	Zebrasoma	*veliferum*	
4.	*Acanthurus*	*auranticavus,leucocheilos,thompsoni*	Netrani island, Karnataka [21, 23, 24].
	Zebrasoma	*desjardinii*	
5.	*Acanthurus*	*auranticavus, leucocheilos*	Grand island, Goa[21, 24].
6.	Acanthurus	*bariene, leucocheilos,leucosternon, lineatus, mata* (syn.- *A.bleekeri*), *nigricauda,tennentii, triostegus*	Between Vizhinjam and Muttom [24]
7.	*Acanthurus*	*dussumieri, lineatus, mata* (syn.- *A.bleekeri*)	Tuticorin Fishing harbour[16]
8.	*Acanthurus*	*gahhm, nigrofuscus* (syn. *A.matoides*)	Gulf of Mannar / Palk Bay [10,14].
	Ctenochaetus	*strigosus*(syn. *A.strigosus*)	
	Naso	*brevirostris*	
	Zebrasoma	*veliferum*	
9.	*Acanthurus*	*grammoptilus, leucosternon*	Van, Koswari and Upputhanni islands (Gulf of Mannar) [16]
10.	*Acanthurus*	*gahhm, mata* (syn. *A.bleekeri*)	Vedalai (Gulf of Mannar) [20]
11.	*Acanthurus*	*nigrofuscus*(syn. *A.matoides*)	Hare island (Gulf of Mannar) [14]
12.	*Ctenochaetus*	*Strigosus*(syn. *A.strigosus*)	Keelakarai (Gulf of Mannar) [14]
13.	*Naso*	*brevirostris*	Pamban (Gulf of Mannar) [14]
14.	*Acanthurus*	*lineatus,thompsoni,xanthopterus*	Great Nicobar Biosphere Reserve [13]
	Ctenochaetus	*striatus*	
	Naso	*vlamingii*	
15.	*Acanthurus*	*xanthopterus*	Mithapur reef, Gujarat [26]
16.	*Naso*	*hexacanthus*	Angria Bank, Malvan[25]