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Marine aquarium trade in India: Challenges and opportunities for conservation and policy

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ABSTRACT

The collection of marine taxa for the aquarium trade continues to demand live animals be extracted from reefs, but in doing so, offers economic benefits for local communities. To improve our understanding of the status of marine aquariumtrade in India, information on harvested species and their volume was gathered at the major collection hubs (Tuticorin, Kilakarai and Mandapam) in the Gulf of Mannar region, and compared to the export data. During one year, 87 species of fish (51% belonging to the family Pomacentridae) and 21 species of invertebrates were harvested for the trade. The conservation status of exploited species revealed that nearly 50% (n=43) have not been assessed for their extinction risk by the IUCN, while of the 44 species assessed, 41 were Least Concern (LC), and one each was in the Data Deficient (DD), Near Threatened (NT) and Endangered (EN) categories. While many fish were collected, only a few were exported from India. The sea anemones were the major export as they were of a higher value in the international markets, largely attributed to their color patterns. Price discrepancies within the trade value of marine fishes and invertebrates used for the aquarium trade indicated that price increased approximately 200% at each transition in the value chain (collectors to wholesalers, wholesalers to retailers). Management strategies and conservation plans for India's marine ornamental taxa subjected to exploitation are provided so as to ensure long-term sustainability of the coral reef ecosystems, as well as the livelihood that are dependent on them.

1. Introduction

The marine aquarium trade has developed into a vibrant multi-million dollar industry offering livelihood prospects to people who depend on the coral reef ecosystems [1,2], but ensuring sustainability in this sector has always been contentious in view of its trade-off with biodiversity conservation [3]. Marine ornamental fish and invertebrates are widely collected from the coral reef habitats throughout the Indo-Pacific, as well as the Caribbean regions, but the exact number of species that are currently available in the trade is still difficult to estimate due to the unorganized, multifaceted and fragmented supply system [4,5]. Rhyne et al. [6] estimated that around 3002 marine ornamental species (2278 fishes and 724 invertebrates) involved in the trade were imported into the US between the years 2008–2011 (see www.aquariumtradedata.org). While fish and corals contribute to the bulk of the trade in terms of quantity and value, demand for invertebrates such as sea anemones, crustaceans, sponges, molluscs and echinoderms are increasing as a result of the growing interest in keeping mini-reef aquaria [7–9]. Previous studies on marine aquarium trade have focused on the role of Brazil, the Caribbean islands, European Union, Kenya and the United States [2,3,5,10–21], and comparatively very little is known regarding the exploitation and trade in continental Asia [22–25].

In India, a highly biodiverse nation, aquarium fish trade is gaining popularity and becoming an important facet of the fisheries sector. The exploitation and trade of wild-caught freshwater ornamental fishes while contributing to the national economy, has been considered as a major conservation challenge in the biodiversity rich regions of the

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country [26–28]. Although, nearly 400 species of marine ornamental fishes belonging to 175 genera and 50 families are known to occur in India's marine ecosystems [29], very little is known regarding their exploitation and trade. For example, India did not appear on the list of countries that export marine aquarium fish to the US [5].

The Gulf of Mannar Marine Biosphere Reserve (henceforth GOMMBR), on the south-east coast of India is the only coral reef region within the country that can meet the demand for marine ornamental taxa [30]. The collection of marine taxa for the aquarium trade is nevertheless an addition to the increasing anthropogenic stressors, including, but not limited to destructive fishing and near-shore trawling that has already threatened the coral reefs and associated fisheries of this region [31]. Even though, the entry into the GOMMBR islands is restricted to local fishers, collection of various marine taxa continues unabated. Such exploitation is illegal, and continuous exploitation may cause ecological imbalance given there are no laws in effect to protect the coral reef fishes that are harvested for the aquarium trade [32]. In this context, the present study investigated the status of exploitation of marine ornamental taxa from the GOMMBR for the aquarium trade and evaluated the role it plays in supporting local livelihoods. The species-wise harvest volumes were assessed over an entire year (July 2014 to June 2015), determined the conservation status/extinction risk of exploited species and calculated the value of living coral reef organisms along the value chain. The harvest volumes to those being exported were calculated. Finally, in order to improve the overall sustainability of the trade, several conservation and policy options were recommended.

2. Materials and methods

2.1. Study area

The Gulf of Mannar (78°5′ and 79°30′E & 8°45′N and 9°25′N)in the Bay of Bengal (south east coast of India) extending from Rameswaram to Tuticorin (140 km long; 25 km wide; total area of 560 km^2) encompasses a group of almost 21 islands (1. Shingle, 2. Krusasai, 3. Pullivasal, 4. Poomarichan, 5. Manoliputti, 6. Manoli, 7. Hare, 8. Mulli, 9. Valai, 10. Thalaiyari, 11. Appa, 12. Poovarasanpatti, 13. Valimunai, 14. Anaipar, 15. Nallathanni, 16. Puluvinichalli, 17. Upputhanni, 18. Kariyachalli, 19. Vilanguchalli, 20. Koswari, 21. Vaan) that are running parallel to the coastline (Fig. 1). The Gulf of Mannar is exceptionally rich in marine biodiversity [33] and was recognized as the first marine biosphere reserve in South Asia [34].

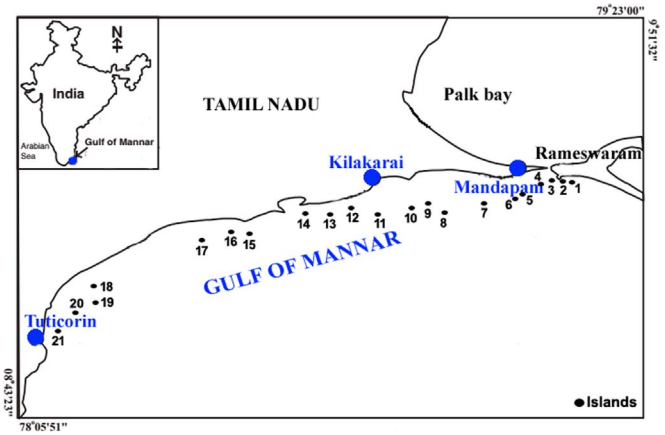

Fig. 1. Map showing the Gulf of Mannar region (21 islands that are running parallel to the coast) and the major hubs for collection of ornamental taxa (Tuticorin, Kilakarai and Mandapam).
Modified from Sundararaju et al. [74].

2.2. Data collection (Field)

Three important towns, viz., Mandapam, Kilakarai and Tuticorin are recognized as major collection hubs for the marine aquarium trade in the GOMMBR, from where the local fishers sell to the wholesalers (Fig. 1). A total of eight major wholesalers were identified i.e. three in Mandapam, four in Tuticorin and one in Kilakarai. A list of species (all marine taxa except gastropods) harvested in GOMMBR was obtained from the wholesalers on a daily basis for a year during July 2014 to June 2015. Initially the common names of the taxa were noted, and subsequently verified with species names available in standard literature [35]. For fishes, FishBase [36] as well as locally relevant species checklists and field guides were used [37,38]. Standard and regionally relevant identification manuals were consulted for invertebrates such as sea anemones, sea stars, worms, nudibranch and shrimps [39–41] and for scleractinian corals [42,43].

2.3. Data collection (export data)

The daily export data of live aquatic animals maintained by TIPS Software Service Private Limited, a company that maintains an Exim (Export-Import) database including foreign trade statistics (see www.dailyexportimportdata.com) were used, and followed the same methodology as adopted by Raghavan et al. [27] for their study on the trade in wild-caught freshwater aquarium fishes. For the present study, the marine ornamental taxa (at species level) that are exported from the Indian airports were sorted out and their value in US$ was calculated based on currency rates available on www.xe.com.

2.4. Market discrepancies

Marine aquarium trade is known to improve livelihoods of coastal communities who are entirely dependent on the collection and supply of coral reef ecosystem-associated taxa [1,44,45]. However, the market/trade values of various species is known to vary significantly during the different phases of the supply chain, as it has to pass through critical stages of quarantine, maintenance, handling and shipping before reaching the hobbyists [1]. Even though the collectors use different methods, the price per individual fish sold by the collectors is known to be constant throughout the study area (P. Sanjeevi, Pers. Observ.). In order to understand the market discrepancy of fishes and invertebrates traded from GOMMBR, and collected the price details of all species involved in the trade, and categorized the costs of each species into landing price (price paid by wholesalers to the collectors), wholesale price (price paid by retailers to the whole salers) and retail price (price paid by hobbyists to the retailers). To understand the benefit for local fishers, wholesalers and retailers, the wholesale price was divided by the landing price, and retail price was divided by the wholesale price, and the profit percentage between them calculated and expressed as:

Eg. Wholesaler cost increase (%) = wholesale cost / landing price x 100.

Retailer cost increase (%) = retail cost / wholesale cost x 100.

2.5. Conservation status and extinction risk

Information on the conservation status/extinction risk of all species included in the study was retrieved from the IUCN's Red List of Threatened Species™ (www.iucnredlist.org), the underlying assessments for which are based on the IUCN Red List Categories and Criteria (Version 3.1) [46].

2.6. Species protected by National legislation

The Indian Wildlife (Protection) Act (WLPA) of 1972 (and amended up to 2011) forms the legal framework for conservation of India's flora

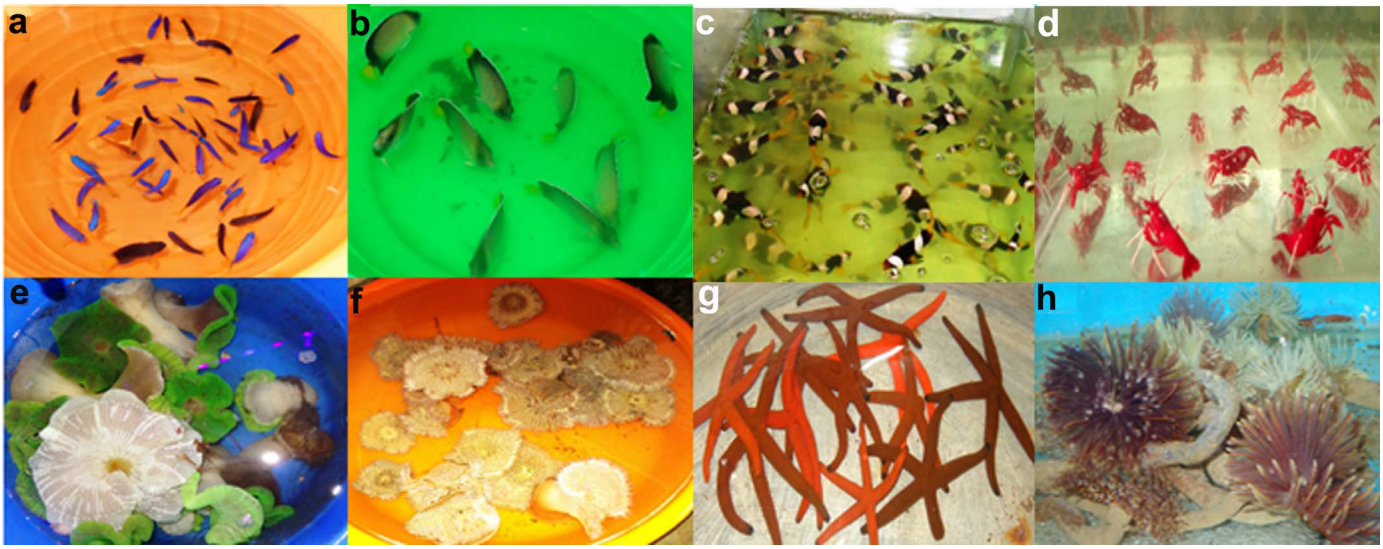

Fig. 2. Marine ornamental fishes and invertebrates ready for packing in the wholesalers' custody. a, blue damsel *Pomacentrus caeruleus*; b, smoke angel *Apolemichthys xanthurus*; c, sebae clown *Amphiprion sebae*; d, blood shrimp *Lysmata debelius*; e, green carpet anemone *Stichodactyla haddoni*; f, carrot anemone *Phymanthus* sp.; g, finger star *Ophidiaster confertus*; h, sabellid worm *Sabellastarte spectabilis*.

and fauna. The details on the coral-reef associated fauna listed in the different schedules of the Wildlife (Protection) Act, 1972 were retrieved from the website of the MoEFCC (www.moef.nic.in/sites/default/files/wildlife1l.pdf), which is amended up to the year 2003.

3. Results

In the GOMMBR, marine ornamental taxa were collected using bamboo cage, shore seine nets, scoop/hand nets, diving and trawling (Prakash et al., Unpubl) [47]. After collection, the fish and invertebrates were maintained in aerated water baths until reaching the shore. Subsequently, they were sold to wholesalers, who acclimatize the animals in a recirculating aquarium from two to ten days. After successful acclimation, the wholesalers sold the fishes to retailers, and subsequently from there to hobbyists and exporters (Fig. 2). Marketing channel of the marine ornamental trade in the region was fairly straightforward, involving four steps in the value chain from fishermen to wholesalers, retailers, to exporters, hobbyists, or researchers (Fig. 3).

3.1. Species diversity and abundance

Eighty seven fish species (166,416 individuals) belonging to 55 genera and 22 families contributed to the marine ornamental trade from the GOMMBR during July 2014 to June 2015 (Table 1). The top ten species constituted 67.6% of the trade, with members of the family Pomacentridae including the sebae clown *Amphiprion sebae* (33197 individuals; 19.95%), blue damsel *Pomacentrus caeruleus* (25117 individuals; 15.1%) and three spot damsel *Dascyllus trimaculatus* (12439 individuals; 7.47%) contributing to the top three positions (Table 2). While the top ten fish species contributed the major share in the trade (67.6%), remaining 77 species together contributed to one third of the trade (53,926 individuals).

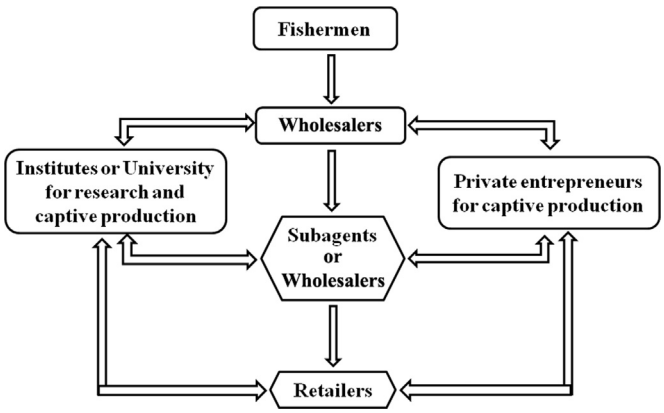

Fig. 3. Market channel of marine ornamental taxa from the GOMMBR (arrows indicate method of supply).

Although family-wise diversity of fishes were high (22 families), Pomacentridae contributed 57.9% of the trade in volume (96342 individuals), followed by Labridae (12.8%; 21371 individuals), Chaetodontidae (7.9%; 13149 individuals), Serranidae (5.3%; 8891 individuals), and Pomacanthidae (4.0%; 6692 individuals). Fishes not identified to the species level constituted only 0.5% of the trade. Among the top five families, Labridae (mainly wrasses) was the most diverse with 16 species belonging to 10 genera, followed by Pomacentridae (clowns and damsels), Chaetodontidae (butterfly fishes), Acanthuridae (surgeons and tang) and Pomacanthidae (angel fishes) (Fig. 4). Differences in exploited fish diversity were observed between the various collection hubs, with Tuticorin contributing to the highest diversity (83 species of fishes) followed by Kilakarai (62 species) and Mandapam (57 species, Fig. 5).

For marine invertebrates, 21 taxa (17498 individuals, excluding corals) frequently contributed to the marine aquarium trade in the GOMMBR (Table 3). Top ten invertebrates contributed 86.9% (15207 individuals) of the trade, with the carpet anemone, *Stichodactyla haddoni* being the most abundant (19.9%; 2957 individuals) followed by anemone shrimp, *Periclimenes brevicarpalis* (15.0%; 2631 individuals) and finger star, *Ophidiaster confertus* (13.6%; 2378 individuals) (Table 2). A comparatively lesser number of invertebrates was exploited from Mandapam (seven species) and Kilakarai (eight species) than Tuticorin (21 species) (Fig. 5).

The invertebrates in trade included six species of sea anemones belonging to five genera, *Heteractis* (two species), *Stichodactyla*, *Entacmaea*, *Phymanthus* and *Cerianthus* (one species each), ornamental shrimps such as stenopodids (coral banded shrimp *Stenopus hispidus*) and carideans (six species), echinoderms including four species of star fish under the family Ophidiasteridae (1 species) and Oresasteridae (3 species). Three species of sea anemones, *Heteractis crispa*, *Cerianthus* sp. and *Dardanus* sp. were found to be rare throughout the study and contained less than 100 individuals. In

Table 1
List of marine ornamental fishes exploited from the Gulf of Mannar for the aquarium trade along with their conservation status based on IUCN Red List of Threatened Species™.

Family	Groups	Common name	Species name	IUCN status*
Pomacentridae	Clown fish	Sebae clown	*Amphiprion sebae*	NE
		Clark's clown	*A. clarkii*	NE
	Damsels	Three spot	*Dascyllus trimaculatus*	NE
		Blue damsel	*Pomacentrus caeruleus*	NE
		Humbug damsel	*Dascyllus aruanus*	NE
		Electric blue damsel	*Chrysiptera cyanea*	NE
		Coral demoiselle	*Neopomacentrus nemurus*	NE
		Cocoa damsel	*Stegastes variablis*	NE
		Cloudy damsel	*Dascyllus carneus*	NE
		Scissor tail damsel	*Neopomacentrus* sp.	NE
		Green damsel	*Chromis viridis*	NE
	Sergeant	Indo-Pacific sergeant	*Abudefduf vaigiensis*	NE
Pomacanthidae	Angels	Smoke angel	*Apolemichthys xanthurus*	LC
		Midnight angel	*Centropyge multispinis*	LC
		Koran angel	*Pomacanthus semicirculatus*	LC
		Blue ring angel	*Pomacanthus annularis*	LC
		Emperor angel	*Pomacanthus imperator*	LC
Chaetodontidae	Butterfly	Pakistan butterfly	*Chaetodon collare*	LC
		Eight band butterfly	*C. octofasciatus*	LC
		Thread fin butterfly	*C. auriga*	LC
		Rainbow butterfly	*C. trifasciatus*	LC
		Vagabond butterfly	*C. vagabundus*	LC
		Indian Vagabond	*C. decussatus*	LC
		Chevron butterfly	*C trifascialis*	NT
		Lined Butterfly	*C. lineolatus*	LC
		Blue blotch butterfly	*C. plebius*	LC
		Melon butterfly	*C. melanotus*	LC
	Banner fish	Banner fish	*Heniochus acuminatus*	LC
Balistidae	Trigger	Red toothed trigger	*Odonus niger*	NE
		Half moon trigger	*Sufflamen chrysopterum*	NE
		Titan trigger	*Balistoides viridescens*	NE
		Brown trigger	*Sufflamen fraenatus*	NE
		Orange lined trigger	*Balistapus undulatus*	NE
Scorpaenidae	Lion fish	Short fin lionfish	*Dendrochirus brachypterus*	NE
		Plane tail lionfish	*Pterois russelii*	NE
		Lionfish	*Pterois volitans*	NE
Labridae	Wrasse	Cleaner wrasse	*Labroides dimidiatus*	LC
		Six bar wrasse	*Thalassoma hardwicki*	LC
		Moon wrasse	*Thalassoma lunare*	LC
		Queen wrasse	*Coris formosa*	LC
		Razor fish	*Iniistius bimaculatus*	LC
		Jewel wrasse	*Macropharyngodon meleagrides*	LC
		Jansen's wrasse	*Thalassoma jansenii*	LC
		Rainbow wrasse	*Coris dorsomacula*	LC
		Bird wrasse	*Gomphosus caeruleus*	LC
		Common wrasse	*Halichoeres nigricans*	NE
		Bicolor wrasse	*Labroides* sp.	NE
		Banana wrasse	*Halichoeres chrysus*	LC
		Hump head wrasse	*Cheilinus undulatus*	EN
		Triple tail wrasse	*Cheilinus trilobatus*	LC
		Spotted wrasse	*Anampses lineatus*	DD
		Checker board wrasse	*Halichoeres hortunalus*	LC
	Hog fish	Hog fish	*Bodianus neilli*	LC
Scaridae	Parrot fish	Eclipse parrot fish	*Scarus russelii*	LC
		Blue barred parrot	*S. ghobban*	LC
Apogonidae	Cardinal	Striped cardinal	*Ostorhynchus taeniophorus*	NE
		Red cardinal	*O. fleurieu*	LC
Acanthuridae	Tang	Brown surgeon	*Acanthurus nigrofuscus*	LC
		Powder blue surgeon	*A. leucosternon*	LC
		Convic tang	*Acanthurus triostegus*	LC
		Black tang	*Zebrasoma* sp.	NE
		Sail fin tang	*Zebrasoma veliferum*	LC
Pseudochromatidae	Dotty back	Dotty back	*Pseudochromis dilectus*	NE
Tetraodontidae	Puffer	White spotted puffer	*Arothrodon hispidus*	LC

(continued on next page)

Table 1 *(continued)*

Family	Groups	Common name	Species name	IUCN status*
		short nose puffer	*Canthigaster solandri*	LC
Zanclidae	Moorish	Moorish idol	*Zanclus cornutus*	NE
Gobiidae	Goby fish	Sand goby	*Amblyleotris* sp.	NE
		Watchman goby	*Cryptocentrus* sp.	NE
		Two lined goby	*Valenciennea helsdengenii*	NE
		Neon goby	*Oxyurichthys* sp.	NE
Lutjanidae	Snapper	Blue striped snapper	*Lutjanus bengalensis*	NE
		Red snapper	*Lutjanus vitta*	NE
Blennidae	Blenny	Common blenny	*Petroscirtes mitratus*	NE
		Bicolor blenny	*Ecsenius bicolor*	LC
Serranidae	Grouper	Blue blotch grouper	*Cephalopholis argus*	LC
		Tomato hind	*Cephalopholis sonnerati*	LC
		Bluelined grouper	*Cephalopholis formosa*	LC
	Anthias	Marcia anthias	*Pseudanthias marcia*	NE
	Hawk fish	Red Hawk fish	*Cirrithichthys bleekeri*	NE
Haemulidae	Sweet lips	Sweet lips	*Plectorhynchus vittatus*	NE
		Sweet lips	*Plectorhynchus lineatus*	NE
Holocentridae	Squirrel	Red Squirrel	*Sargocentron rubrum*	NE
Ephippidae	Batfish	Longfin batfish	*Platax teira*	NE
		Orbicular Batfish	*Platax orbicularis*	NE
Plotosidae	Catfish	Striped catfish	*Plotosus lineatus*	NE
Ostraciidae	Cowfish	Yellow box fish	*Ostracion cubicus*	NE

* NE: Not Evaluated; DD: Data Deficient; LC: Least Concern; NT: Near Threatened; EN: Endangered.

Table 2
Percentage wise composition of the top ten fishes and invertebrates involved in the ornamental trade from the GOMMBR.

Fishes			Invertebrates		
Species name	**No. of individuals**	**% share**	**Species name**	**No. of individuals**	**% share**
Amphiprion sebae	33197	19.95	*Stichodactyla haddoni*	2957	16.9
Pomacentrus caeruleus	25117	15.1	*Periclimenes brevicarpalis*	2631	15.04
Dascyllus trimaculatus	12439	7.47	*Ophidiaster confertus*	2378	13.59
Labroides dimidiatus	8899	5.35	*Rhynchocinetes durbanensis*	2272	12.98
Amphiprion clarkii	8391	5.04	*Lysmata debelius*	1489	8.51
Pseudanthias marcia	7289	4.8	*Heteractis magnifica*	970	5.54
Neopomacentrus nemurus	5612	3.4	*Entacmaea quadricolor*	678	3.87
Pseudochromis dilectus	4344	2.61	*Lysmata amboinensis*	618	3.53
Apolemichthys xanthurus	3841	2.31	*Sabellastarte spectabilis*	616	3.52
Chaetodon octafasciatus	3361	2.1	*Phymanthus* sp.	598	3.42

addition, sabellid worm, *Sabellestarte spectabilis*, spiny lobster, *Palinurus versicolor*, nudibranch, *Phyllidida varicosa* and hermit crab, *Dardanus* sp. were also often encountered in the trade (Table 3). Nearly one-quarter of the invertebrates were not identified up to species level including two species of sea anemones, one species each of caridean shrimp, starfish and hermit crab.

Other ornamental invertebrates such as hard corals (scleractinians) and soft corals (ancylonaceans) which are widely distributed in the GOMMBR were also frequently harvested for the aquarium trade particularly from Tuticorin. Among hard corals, 22 species were identified, with Merulinidae (seven species under three genera) followed by Acroporidae (six species under two genera) and Poritidae (three species under two genera) being the most speciose families (see Table 4). Among branching corals, genus *Acropora* (Acroporidae) contributed to majority of the trade that includes, *A. humilis, A. formosa, A. nobilis* and *A. intermedia* (P. Sanjeevi, personal observ.). Several other species under the genus *Montipora* (Acroporidae) *Favites, Dipsastrea and Goniastrea* (Merulinidae), *Symphyllia* (Lobophyllidae), *Pocillopora* (Pocilloporidae), *Goniopora* and *Porites* (Poritidae) were also frequently harvested from the GOMMBR. *Cycloseris* sp. (Fungiidae) and *Euphyllia* sp. (Euphyllidae) were rarely observed in the trade (P. Sanjeevi, Pers. Observ.). Few species of soft corals under the genus *Dendronephtya* (Nephthidae) and *Sinularia* are also available in the trade along with several species of sponges, which was however not included in the study due to its rarity in the trade (only few individuals were encountered).

3.2. Conservation status

Only 44 of the 87 species of marine fish exploited from India for the aquarium trade have been assessed for their conservation status by the IUCN. The humpheadwrasse, *Cheilinus undulatus*was assessed as Endangered (EN) while the chevron butterfly, *Chaetodon trifascialis* was assessed as Near Threatened (NT) and spotted wrasse, *Anampses lineatus* as Data Deficient (DD). Remaining 41 species were assessed as Least Concern (LC) (Fig. 6 and Table 1). Among marine ornamental invertebrates, corals were the only group whose conservation status has been comprehensively assessed by the IUCN. The conservation status of the exploited hard corals suggested that most of the species were assessed as Near Threatened (NT) and Least Concern (LC) (Table 4).

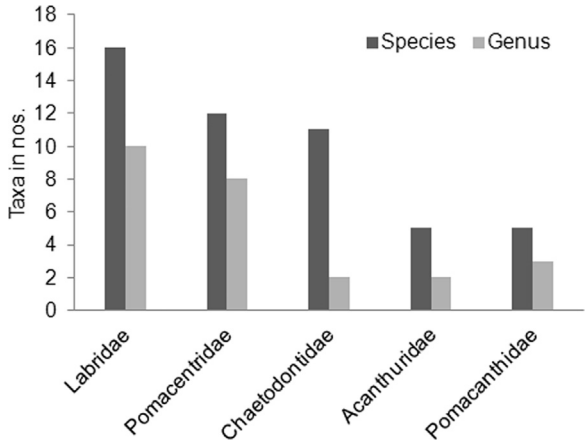

Fig. 4. Family wise (top 5) species diversity of marine ornamental fishes collected and exported from the GOMMBR.

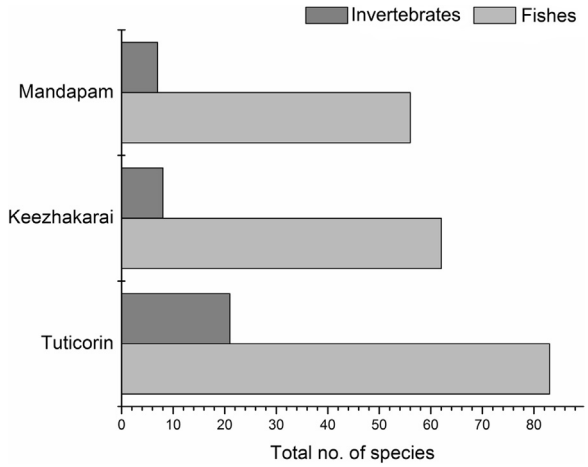

Fig. 5. Region wise species diversity of marine ornamental fishes and invertebrates from within the GOMMBR.

Table 3
List of marine ornamental invertebrates exploited from Gulf of Mannar for the aquarium trade.

Family	Common name	Species name
Stichodacylidae	Carpet anemone	*Stichodactyla haddoni*
	Tentacle anemone	*Heteractis magnifica*
	Beaded anemone	*Heteractis crispa*
Actiniidae	Bubble tip anemone	*Entacmaea quadricolor*
Cerianthidae	Tube anemone	*Cerianthus* sp.
Phymanthidae	Carrot anemone	*Phymanthus* sp.
Rhynchocinetidae	Camel shrimp	*Rhynchocinetes durbanensis*
Palaemonidae	Anemone shrimp	*Periclimenes brevicarpalis*
	Anemone shrimp	*Ancylomenes magnificus*
	Cleaning partner shrimp	*Urocaridella* sp.
Hippolytidae	Cleaner shrimp	*Lysmata amboinensis*
	Blood shrimp	*Lysmata debelius*
Stenopodidae	Boxer shrimp	*Stenopus hispidus*
Ophidiasteridae	Finger star	*Ophidiaster confertus*
Oreasteridae	Horned star	*Pentaceraster tuberculatus*
	Crimson knobbed star	*Protoreaster linckii*
	Feather star	*Himerometra* sp.
	Hermit crab	*Dardanus* sp.
Sabellidae	Worm	*Sabellastarte spectabilis*
Palinuridae	Reef lobster	*Palinurus versicolor*
Phyllididae	Nudibranch	*Phyllidia varicosa*

Table 4
Tentative list of coral species involved in the trade along with their conservation status based on IUCN Red List of Threatened Species™.

Family name	Species name	Conservation status
Merulinidae	*Favites abdita*	NT
	Favites complanata	NT
	Dipsastrea speciosa	LC
	D. favus	LC
	D. pallida	LC
	Dipsastrea sp.	–
	Goniastrea sp.	–
Lobophyllidae	*Symphyllia radians*	LC
	S. recta	LC
Acroporidae	*Acropora formosa*	NT
	A. *humulis*	NT
	A. *intermedia*	NE
	A. *nobilis*	LC
	Montipora digitata	LC
	M. foliosa	NT
Poritidae	*Goniopora minor*	NT
	G. stokesi	NT
	Porites sp.	–
Pocilloporidae	*Pocillopora* sp.	–
Fungiidae	*Cycloseris* sp.	–
Dendrophyllidae	*Turbinaria* sp.	–
Euphyllidae	*Euphyllia* sp.	

NE, Not Evaluated; NT, Near Threatened; LC, Least Concern.

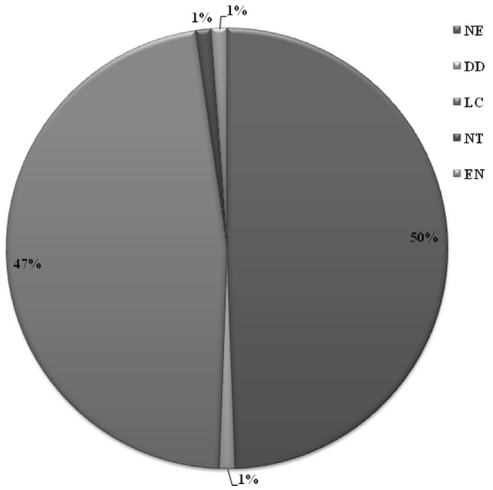

Fig. 6. Conservation status of marine ornamental fishes based on the IUCN Red List categories. NE: Not Evaluated; DD: Data Deficient; LC: Least Concern; NT: Near Threatened; EN: Endangered.

3.3. Collected/exported species listed in the Indian WLPA

The Indian Wildlife Protection Act, 1972 did not list any of the coral reef associated fishes and invertebrates that are involved in the aquarium trade. However, all the reef building corals (scleractinians), black corals (antipatharians), organ pipe coral (*Tubipora musica*), fire coral (*Millepora* sp.) and gorgonians (sea fans) were mentioned under the Schedule I, (PART IVA) since the year 2001. In the present study, 22 species of reef building corals were identified in the aquarium trade, indicating the presence of illegal collections in the vicinity of Gulf of Mannar (see Table 4 for species list). Hence, a detailed study on the species-level trade in corals will provide insights into their protection and management.

Table 5
Quantity and value of exported marine ornamental taxa from India.

Common name	Species name	Quantity exported (in nos.)	Total value of exports in (INR)	Averge. cost/piece (INR)	Average. cost/piece (USD*)
GC anemone	*Stichodactyla haddoni*	1735	662660.25	381.93	5.61
BC anemone		46	51851.15	1127.2	16.57
RC anemone		1	2291.99	2291.99	33.67
Pakistan butterfly	*Chaetodon collare*	10	2460	246	3.61
Blue damsel	*Pomacentrus caeruleus*	13	1444.11	111.08	1.63
Electric blue damsel	*Chrysiptera cyanea*	2	517.26	258.63	3.80

GC: Green carpet; BC: Blue carpet; RC: Red carpet.
* USD are mentioned as per current exchange rate (1 USD = INR 68.01) as accessed in www.xe.com on 20-01-2016.

3.4. Exports

Exports of marine ornamentals from India during July 2014 to June 2015 comprised of < 1% of the individuals harvested from the GOMMBR and were restricted to only a few species. The total value of export was calculated as US $10,605, where a single species of sea (carpet) anemone (*Stichodactyla haddoni*) dominated the exports. Bangalore (52.9% of exports) and Mumbai (47.1% of exports) were the major exit points, while United Kingdom and Sri Lanka were the major importing nations. The carpet anemone possesses three different colors morphs (green, blue, and red) of which, the blue and red carpet were rarely collected (P. Sanjeevi pers. comm. with fish collectors) from the GOMMBR. Among exports, the green carpet anemone was the most exported (1735 individuals, 96.01%), followed by blue (2.55%, 46 individuals) and red (0.06%, 1 individual) varieties. Price of anemones was negatively correlated to abundance, with the price per individual for green, blue, and red anemones averaging US $5.61, $16.57 and $ 33.67 respectively. Among fishes, only very few species such as *Chaetodon collare* (0.55%), *Pomacentrus caeruleus* (0.72%) and *Chrysiptera cyanea* (0.11%) were exported (Table 5).

3.5. Market discrepancies

The total value of the harvest and sale of ornamental fish and invertebrates in India was US $7,089,945 at the point of harvest, $17,623,700 at wholesale, $32,412,315 at retail. The profit generated by the wholesalers (243% ± 60% for fish and 265% ± 71% for invertebrates) and retailers (179% ± 29% for fish and 218% ± 46% for invertebrates) were much higher than those obtained at the harvest/collection stage (Fig. 7). Compared to fishes, invertebrates contributed more profit to both the wholesalers and retailers.

4. Discussion

Recent advances in fishing has led to a continuous supply of marine organisms throughout the world pushing the global aquarium industry into a multibillion dollar enterprise helping generate income for reef-side economies [1,2]. However, this industry has already threatened the coral reef associated biodiversity due to unsustainable harvest, expansion of trade volume and market values. Understanding the marine aquariumtrade is a complex process and lack of well-equipped tracking protocols, issues related to taxonomic distinctness (in particular for marine invertebrates) as well as poor reporting has resulted in data deficiency within the industry [5,48]. Our results show that the marine ornamental trade in India continues to be at infancy and contributes to < 5% of the global marine aquarium trade (in comparison to results of Wabnitz et al. [1] and Rhyne et al. [5]) with the majority of the species harvested utilized for the domestic trade.

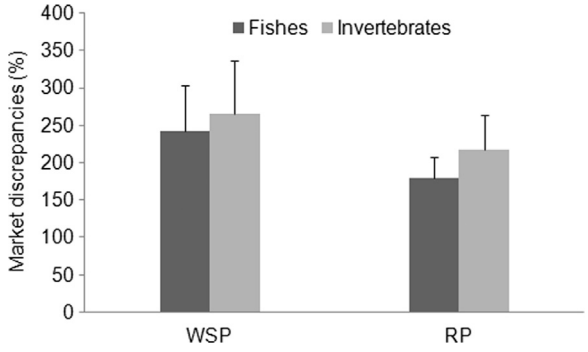

Fig. 7. Market discrepancies of profits (%) between wholesalers (WSP) and retailers (RP) with respect to the landing cost.

Previous studies on diversity of ornamental fishes in the GOMMBR have been published as either institutional reports and/or field guides [32,38,49–51], with no focus on either their abundance and/or exploitation for the aquarium trade. Among 87 species reported in the trade, five species within the family Pomacentridae (*Amphiprion sebae, A. clarkii, Pomacentrus caeruleus, Dascyllus trimaculatus, and Neopomacentrus nemurus*) together contributes half of the total marine ornamental trade in India. A recent study [52] recorded 40 species of marine ornamental fishes in the aquarium trade from the neighboring state of Kerala, of which ten were pomacentrids (clowns and damsels); however no information on whether these are targeted for the domestic or international trade was provided by the authors.

Compared to India, neighboring nations such as Sri Lanka and Maldives contribute significantly to the global marine aquarium trade. Around 445 species with 2,61,789 individuals of ornamental taxa were exported to US from Sri Lanka in the year 2005 [5], which increased further to 633 species and 6,38,606 individuals between the years 2008–2011 [6]. Furthermore, Rhyne et al. [6] listed 174 species of fishes (81,275 individuals) (powder blue tang *Acanthurus leucosternon* being the most common) and 4 species of invertebrates (1671 individuals) (red sea star *Echinaster sepositus* and bumble bee snail *Pusiostoma mendicaria* being the most common) that are imported to the USA from the Republic of Maldives. Though the export of corals is banned from the Maldives, the only exception is with the organ pipe coral *Tubipora musica*, which is exported to cater the pharmaceutical industry in India [53].

While fishes comprise one of the most heavily traded ornamental groups, invertebrates such as sea anemones, shrimps and sea stars are also becoming increasingly popular among hobbyists due to their distinct colors, unusual shape and hardiness in reef-aquaria [7,8]. This trend was observed in the data were anenomes were the primary species of export. *Stichodactyla haddoni*, *Heteractis magnifica* and *Entacmaea quadricolor* are heavily traded sea anemones from India. Intense unmanaged harvest of these organisms will not only decrease wild stocks, but also impair the distribution of associated fishes and shrimps [1,54–56] and therefore strict regulation of harvest is urgently required [24].

Around 128 marine ornamental decapod crustaceans are known to be present in the international aquarium trade [10], most of which display associative behavior with fishes and invertebrates [8]. In our study, *Lysmata* and *Stenopus*, (two of the world's most heavily traded

groups of shrimps, see [1,10]) contributed 14.3% (2496 individuals) of the trade while other shrimp species occupied 30.8% of the trade. *Lysmata* (L. *amboinensis* and *L. debelius*) and *Stenopus* (*Stenopus hispidus*) mostly possess fish cleaning behavior, whereas *Periclimenes brevicarpalis* tends to live in association with invertebrates, especially sea anemones [10]. The exploitation of large numbers of fish cleaner shrimps may affect the health condition of several reef fish species, although detailed knowledge on target species' population, growth, recruitment and reproductive biology is still lacking [10,57]. Of nearly 24 species of hermit crabs that occur in the international aquarium trade [10], only one species (*Dardanus* sp.; 53 individuals) was recorded in our study.

All the scleractinian corals are listed under the Schedule I of the Indian Wildlife Protection Act, 1972 that provides absolute protection for the species and illegal exploitation is prescribed with high penalties (www.moef.nic.in/sites/default/files/wildlife1l.pdf). The present study revealed that 22 species of corals that are illegally exploited from the GOM for the aquarium trade. Thus, proper monitoring and regulation of live coral collection will make way for the protection of resources thereby enhancing the natural habitats for associated organisms. Furthermore, the Gulf of Mannar Marine Biosphere Reserve Trust (GOMMBRT), a registered trust of Government of Tamil Nadu also assessed the marine ornamental fishery resources of GOM and provided recommendations for their sustainable use [58].

4.1. Priorities for existing policy and scientific research

In order to ensure sustainability in the Indian marine aquarium trade, the existing legal mechanisms [WLPA, 1972; Environment (Protection) Act, 1986 and Coastal Regulation Zone, (CRZ) 1991, Biological Diversity Act (BDA) 2002] and fisheries management policies needs to be upgraded or modified in acceptance with the stakeholder's consultation to minimize the significant threat on marine ornamental resources. As the Government of India lacks data on marine taxa exploited for the aquarium trade, basic understanding on the species harvested, domestic market demand and export potential needs to be evaluated. The Indian marine ornamental trade should be regulated under the Convention on International Trade of Endangered Species (CITES) that are subjected under licensing and certification to ensure that the trade does not threaten the survival of marine resources. Likewise, the UNEP has the established World Conservation Monitoring Centre (WCMC) is also a valuable source to track the extent of trade on marine ornamentals from coral reefs (http://www.unep-wcmc.org/). Research on species taxonomy would be considered as most significant baseline for future scientific research, as they help bridge knowledge gaps to inform biodiversity conservation [59]. In India, more effort has been focused hitherto on producing field guides for coral reef fishes [37,38] compared to invertebrates (shrimps, crabs, sea anemones and sea stars). Among invertebrates, coral reef dwelling ornamental shrimps have however received some attention with regard to their taxonomy and distribution [60–62]. Currently prevailing taxonomic uncertainities on other marine ornamental taxa are mainly due to the unavailability of specific keys to help species delimitation.

Obtaining the traditional knowledge of fishers and aquarium fish collectors will be the primary source of ecological inputs in understanding habitats, population distribution and extinction risk of the targeted species. However, there are possibilities that over dependence on fisher knowledge may also exaggerate fishing rates and capture less variability than log books [63]. Hence, the attitude and perceptions of coastal fishers on ornamental diversity of the GOM region could be obtained through questionnaire surveys, and this could then be supplemented with ecological and biological data through rigorous underwater surveys so as to sustainably manage diversity of habitats and species in the region. Likewise, stock assessment of prioritized (based on intensively exploited species) ornamental fishes and invertebrates needs to be estimated for a minimum span of two to three years (or at least one generation) to inform conservation and management strategies. Though, few climate change events has resulted in the mass coral bleaching in GOM [64–66], India is yet to address the impact of fluctuating climatic parameters on the ecology and physiology of coral reef associated organisms. To date, no specific policy also exists in India to address these issues; hence, there is a need to collect scientific information that helps to develop various policies and legal instruments to protect these vulnerable ecosystems and associated organisms.

4.2. Opportunities for management and conservation

Enforcing of licensing policy should be initiated with the help of local fishers who solely depend on collection of marine ornamental taxa for their livelihood. This would ensure that only trained and conscientious collectors take part in the trade. The licensing can be also extended to wholesalers and retailers, so that they can receive ornamental species only from the trained/licensed collectors and confirms that the supplied organisms are not harvested illegally and in any unsustainable manner. The hobbyists should also be encouraged to buy organisms only from a certified wholesaler or retailer, so that it would prevent illegal trading in the markets. Though, all ornamental taxa have to pass through a small number of wholesalers or retailers in India, licensing policy would act as an excellent source for monitoring the diversity and abundance of ornamental species that are supplied through the trade, leading to the potential establishment of species based quotas for effective management.

The main reason behind establishing size-based limitations for ornamental organisms is to ensure that the stocks should not be wasted without cause [67]. Collections of small juveniles are mostly encouraged by the exporters because they occupy less space and are easy to export [67]. For example, the Philippines have created a policy that restricts the harvest and exports of fishes < 2 cm [68]. The size -based limit could be extended to prevent the catch of large size fishes to ensure that adequate numbers of brooders are left on the reef [67]. The population estimation of sedentary organisms such as corals, sea anemones and tube worms is more accurate and easily accessed [69] for creating species based limits. Furthermore, labeling of species based on wild caught, captive bred or captive raised can be adopted and utilized in a reliable way based on the CITES protocol for corals [70,71]. As the corals are not allowed to be collected from the Indian waters for trade, the same protocol can be adopted for fishes that are extensively cultured in captivity.

Aquaculture of marine ornamental taxa is considered as an alternative to wild collection so as to meet the demand of highly desirable and targeted species for the aquarium trade. Technologies for marine ornamental fish culture are now available in India, especially of high in-demand groups such as clowns and damsels [72], while recent studies have also been initiated to improve our understanding on the natural history of marine ornamental shrimps [73]. Training on culture of marine ornamental species can be imparted to the local fishers and their family members in order to create employment opportunities and income generation, and reduce dependence on wild-collection.

Creation of self-help groups among the collectors would help them achieve better income distribution in the chain of stakeholders involved in the trade, and also involve in formal monitoring of populations, licensing and species quotas. SHG's can act as a tool for wider management strategies for long-term responsible ornamental fishery.

Lastly, participatory approach of stakeholders such as those in the public sector [Ministry of Commerce through the Marine Product Export and Development Authority (MPEDA) and Ministry of Environment Forests and Climate Change (MoEFCC)], state government departments (Forests and Wildlife) and agencies and NGO's along with fishers are warranted to establish an integrated management plans for the conservation of marine ornamental resources.

Fig. 8. A model representing different stakeholders from fishermen to government agencies (NBA-National Biodiversity Authority, MPEDA-Marine Product Export Development Authority and MoEFCC-Ministry of Environment Forest and Climate Change) to highlight the integrated management approach for sustainable ornamental trade.

Involvement of citizen scientists or fishers will not only improve livelihood generation but also allow establishment continuous monitoring programs for coral reefs. GOM being the major hotspot for the collection of coral reef organisms for aquarium trade from India, documentation of species diversity, population trend, harvest potential are prerequisite for effective monitoring on export trends and endangered species management for sustainable trade in the country.

5. Conclusions

Though, India's contribution to the global marine ornamental trade is meager; our study has provided a baseline on the species status, market demand and export potential of marine ornamental taxa. In order to improve the management of resources exploited for the marine aquarium trade, complete understanding on the individual species' life history (breeding, growth, recruitment etc.), and ecology is necessary. In addition to understanding the threats from overharvest, response of marine ornamental taxa to climate change need to be addressed with priority. Research on breeding and grow-out culture of coral reef organisms will not only provide the details on natural history of species but also helps to meet the ever increasing market demand. In addition, it could also facilitate the recovery of populations of conservation-concern species through ranching and stock enhancement. A holistic bottom-up approach involving various stakeholders (collectors, wholesalers, retailers, exporters, researchers and government officials) is necessary to establish management action plans to ensure the sustainability of ornamental resources (Fig. 8) as well as develop the livelihood opportunities of local fishers for employment and income generation.

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