BIODIVERSITY AND ECOSYSTEM HEALTH OF THE ALDABRA GROUP, SOUTHERN SEYCHELLES

SCIENTIFIC REPORT TO THE GOVERNMENT OF SEYCHELLES

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National Geographic Pristine Seas

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SUMMARY

The Aldabra Group (Aldabra Atoll, Assumption Island, Cosmoledo Atoll, Astove Atoll) lies in the remote southwest corner of the Seychelles Archipelago and harbors some of the least impacted coral reefs in the region. National Geographic's Pristine Seas project, in collaboration with the government of the Seychelles, the Island Conservation Society (ICS), the Seychelles Islands Foundation (SIF), and the Waitt Foundation, conducted an expedition to explore the poorly known marine environment around these islands. The goals were to assess the biodiversity of the nearshore marine environment and to survey the largely unknown deep sea realm. The data collected contribute to the marine spatial planning of the Seychelles, in particular the creation of large marine reserves.

We conducted *in situ* surveys of fishes, corals, and other components of the reef community at 39 locations, in more than 200 hours of scientific diving. We found a total of 165 species of hard corals, with seven new records for the region. Coral cover averaged 36% among all four islands, and was highest at Astove and lowest at Assumption, with the latter having suffered severe land degradation due to past guano mining activities. The reefs appeared to have recovered from the 1998 mass bleaching event and are in a healthy condition.

We recorded a total of 332 fish species during our expedition. Fish biomass averaged over 4 tonnes per hectare and was dominated by large groupers and trevally (jacks). Biomass of fishes in the Aldabra Group is the largest in the Seychelles and among the largest in the Indian Ocean. Two top predators, bluefin trevally *(Caranx melampygus)* and potato cod *(Epinephelus tukula),* comprised 7% and 5% of the total biomass in our surveys, respectively. However, sharks were rare and were only present

in any numbers at Aldabra, where we observed six different species (grey reef, nurse, blacktips, silvertips, lemon, and whitetips). The presence of SIF staff at Aldabra may help to dissuade potential poachers, although the remote eastern portion of the island is infrequently visited by the staff owing to weather and boat size.

Fishing vessels from Mahé and poaching from East African countries pose a serious threat to these reefs. Large groupers are an important component of this marine ecosystem but can be easily overfished due to their slow growth, longevity (> 30 years), and predictable timing and locations of spawning. Charismatic species like the Napoleon wrasse *(Cheilinus undulatus)* are listed as endangered by the International Union for the Conservation of Nature (IUCN), but are common in the Aldabra Group. Their high market value, however, also makes them highly susceptible to overfishing.

Our exploration of the deep sea around these islands down to 2,095 m revealed rich and diverse communities with 35 different fish taxa observed, including lantern sharks *(Etmopteridae),* false cat sharks *(Pseudotriakis microdon),* grenadiers *(Macrouridae),* dogtooth tuna *(Gymnosarda unicolor),* and deepwater snappers *(Lutjanidae).*

The reefs of the Seychelles Outer Atolls are some of the last pristine coral ecosystems in the Indian Ocean and appear to have been resilient to the global and local stressors that have plagued reefs elsewhere. Our results provide essential and difficult to obtain information that increases basic knowledge of the region, including detailed science support for the Seychelles Government debt for adaptation funding and related marine spatial planning, which is a cornerstone of the Blue Economy concept in the Seychelles.

INTRODUCTION

Set in the western Indian Ocean, 1,600 km from East Africa, the Republic of the Seychelles is situated between 4° and 10° south of the equator and consists of > 150 islands scattered across the 1,400,000 km^2 of its exclusive economic zone (Jennings et al. 2000). The northern, more populated islands are continental and granitic in origin. They are a fragment of the continental masses of India and Madagascar, but were isolated from the beginning of the Tertiary (67 million years ago) as India moved northwards opening up the Indian Ocean (Chatterjee et al. 2013). The granitic islands are considered to harbor the oldest and hardest granite in the world. The outer islands are comprised of geologically much younger low sand cays on sea-level platform reefs and atolls (Braithwaite 1971).

The Seychelles has a mixed, developing economy that is heavily dependent upon tourism and fisheries. While the northern, more populated islands have suffered from local threats (e.g., overfishing, runoff, coastal development) and global threats (climate change) (Jennings et al. 1995, Graham et al. 2007), the more remote areas are still relatively unimpacted by local stressors and offer important conservation hotspots that require immediate protection (Friedlander et al. 2013). The Aldabra Group (Aldabra Atoll, Assumption Island, Cosmoledo Atoll, Astove Atoll) is in the remote southwest corner of the Seychelles Archipelago and appears to be among the least impacted coral reefs in the region.

The Nature Conservancy (TNC) is acting to mobilize a $30 million (USD) debt-swap for the government of the Seychelles in exchange for the government's commitment to enhance marine conservation and for climate adaptation commitments. The effort will also establish a permanent endowment that generates sustainable financing for Seychelles' marine conservation efforts. This project will result in the Indian Ocean's second-largest marine reserve. With the support of Oceans 5, TNC is facilitating a marine spatial planning process that engages multiple stakeholders (fishing, energy tourism, government, and conservation) in the development of a sustainable use plan for the entire archipelago.

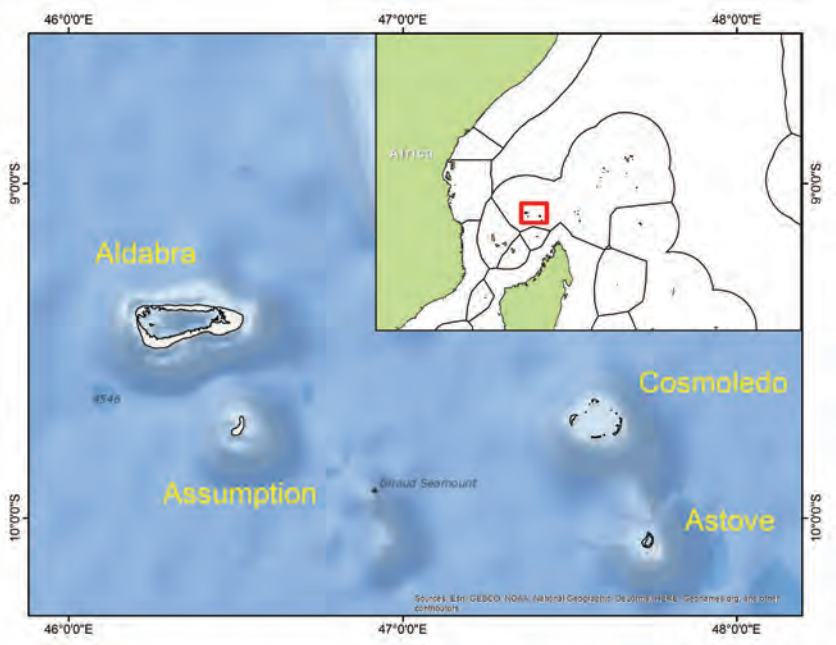
Owing to the Aldabra Group's distance from the capital, no comprehensive marine resource assessment has been conducted at these remote locations except Aldabra (Drew 1977, Downing et al. 2005, Stobart et al. 2005). Remote islands, like the Aldabra Group, with low human populations and limited fishing pressure offer ideal opportunities for understanding whether reefs can be resilient from global threats if local threats are reduced. National Geographic's Pristine Seas project, in collaboration with the government of the Seychelles, The Island Conservation Society (ICS), and the Seychelles Islands Foundation (SIF), conducted an expedition to the Aldabra Group in 2015 to explore the relatively unknown marine environment around these islands and produce a documentary to highlight this unique region (Appendix II).

Objectives:

The objectives of this research expedition were to quantify the biodiversity of the nearshore marine environment of the remote and nearly untouched islands of the Aldabra Group (Fig. 1), as well as explore and describe the deep sea realm surrounding these islands, to support marine spatial planning of the Seychelles Archipelago. Our integrated assessment will provide a much better understanding of how the entire ecosystem functions, thereby helping to inform ecosystem-based management and marine spatial planning. Our advanced technologies (e.g., drop cameras) will greatly improve our understanding of the largely unknown deep reefs and seamounts in the area.

FIGURE 1.

Islands in the Aldabra Group, southern Seychelles.



Environmental Setting

Aldabra - Aldabra is the world's second largest coral atoll (Stoddart et al. 1971) after Kiritimati, Line Islands, and was designated a World Heritage Site by UNESCO in 1982 as a prime example of a raised coral atoll (maximum elevation ~ 8 m). It is 34 km long (east to west) and 14.5 km wide, with a land area of 155 km^2 and a lagoon area of 196 km^2. The atoll is significantly less disturbed than most other atolls in the Indian Ocean and elsewhere in the world. It is classed under category Ia (Strict Nature Reserve) of the IUCN Management Category and designated as a Natural World Heritage Site under criteria ii, iii, and iv. Some of the outstanding features of Aldabra include the world's largest population (100,000) of giant tortoises *(Aldabrachelys gigantea),* one of the largest congregations of nesting green turtles *(Chelonia mydas)* in the Indian Ocean, the world's second-largest breeding population of greater and lesser frigate birds *(Fregata minor and F. ariel),* the last flightless bird species in the Indian Ocean — the white-throated rail *(Dryolimnas cuvieri aldabranus),* and a number of endemic taxa of plants and animals.

Assumption - Assumption is a raised reef-limestone island, similar in origin to Aldabra but without a central lagoon. It is 6 km long, northeast to southwest, and 0.6 to 1.6 km wide, with an area of 10.5 km^2. The limestone rises to a maximum height of ~ 6 m above sea level and forms cliffs along the northern half of the east coast (Stoddart et al. 1970). Between 1926 and 1945, 161,000 tons of guano were exported from Assumption, with an unknown amount from the settlement period in 1908 until 1926. Assumption has lost many of the faunal and floral elements that formerly characterized the elevated reef islands of the southwest Indian Ocean and represents an extreme example of ecological change brought about by human settlement and exploitation.

Astove - Astove is an elevated atoll with a nearly continuous land rim, located 35 km south of Cosmoledo Atoll and 145 km southeast of Aldabra (Bayne et al. 1970a). It has maximum surface dimensions of 4.6 x 2.8 km and a land area of 4.25 km^2. The shallow lagoon is 5 km^2, with most of the area < 0.5 m deep. Much of the west rim of Astove is formed of elevated reef-rock, which rises 4-5 m above sea level.

Cosmoledo – Cosmoledo Atoll is located 110 km east of Aldabra and consists of eight main islands and numerous islets on the atoll rim, surrounding a large and open lagoon (Bayne et al. 1970b). The atoll has maximum dimensions of 14.5 x 11.5 km, and a total area of 152 km^2. The peripheral reef flat varies in width from 1 to 2.5 km, averaging about 1.5 km, and encloses a shallow lagoon, opening to the south in two major channel systems. Cosmoledo comprises 19 islands with a total land area of 460 ha, surrounding a roughly circular lagoon of 14,500 ha. The three largest islands are Menai (c. 230 ha), Grand Ile (160 ha), and Ile du Sud-Ouest (35 ha) (Rocamora et al. 2003).

RESULTS

Coral Reef Community

We conducted in situ surveys of fishes, corals, and other benthic community components at 39 locations in more than 200 hours of scientific diving (Table 1).

TABLE 1.

Sampling locations and number of survey sites (N) among islands in the Aldabra Group.

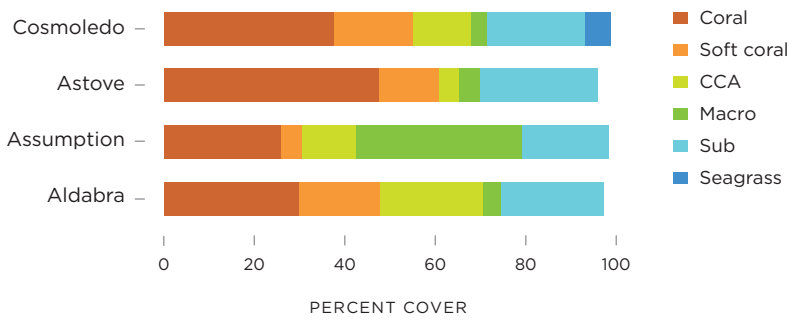
Island	Perimeter (km)	Reef type	N
Aldabra	85.6	Raised atoll	14
Assumption	16.7	Raised limestone island	6
Astove	16.3	Raised atoll	7
Cosmoledo	49.7	Raised atoll	12
Total			39

Benthic Community Structure

Coral cover averaged 36% among the four islands and was highest at Astove (48%) and lowest at Assumption (26%, Fig. 2). Macroalgae were uncommon, except at Assumption where they accounted for 37% of the benthic cover. Soft coral averaged 13% overall and was highest at Aldabra (23%). Seagrass was only found in any abundance at Cosmoledo, where is accounted for 6% of the bottom.

FIGURE 2.

Benthic cover of the major functional components at the four islands in the Aldabra Group. CCA – crustose coralline algae, Macro – macroalgae, Sub – substrate.



Benthic community structure differed among islands in ordination space based on Principal Coordinate Analysis (PCO, Fig. 3). The first two axes of the PCO explained 72.6% of the total variation in benthic functional groups among islands. Axis 1 was correlated with seagrass and soft corals towards Cosmoledo and Astove, and macroalgae towards Assumption. Axis 2 was correlated with coral towards Aldabra and Cosmoledo.

There was a significant difference in benthic community structure among islands based on the major functional components of the benthos (e.g., CCA – crustose coralline algae, corals, macroalgae, seagrass, soft corals, substrate, Table 2A). Assumption was the most different from the other three, while benthic community structure at Cosmoledo and Astove were most similar to one another (Table 2B).

Coral cover tended to be higher on the northern sides of all the islands, while CCA was more abundant on the more exposed south shores (Fig 4). Macroalgae were more abundant along the east side of Assumption, while soft corals were most common on the western sides of Aldabra and Cosmoledo.

FIGURE 3.

Principal Coordinate Analysis of major benthic functional groups among islands. Only vectors of major functional groups with > 0.5 correlation are overlaid on the plot.

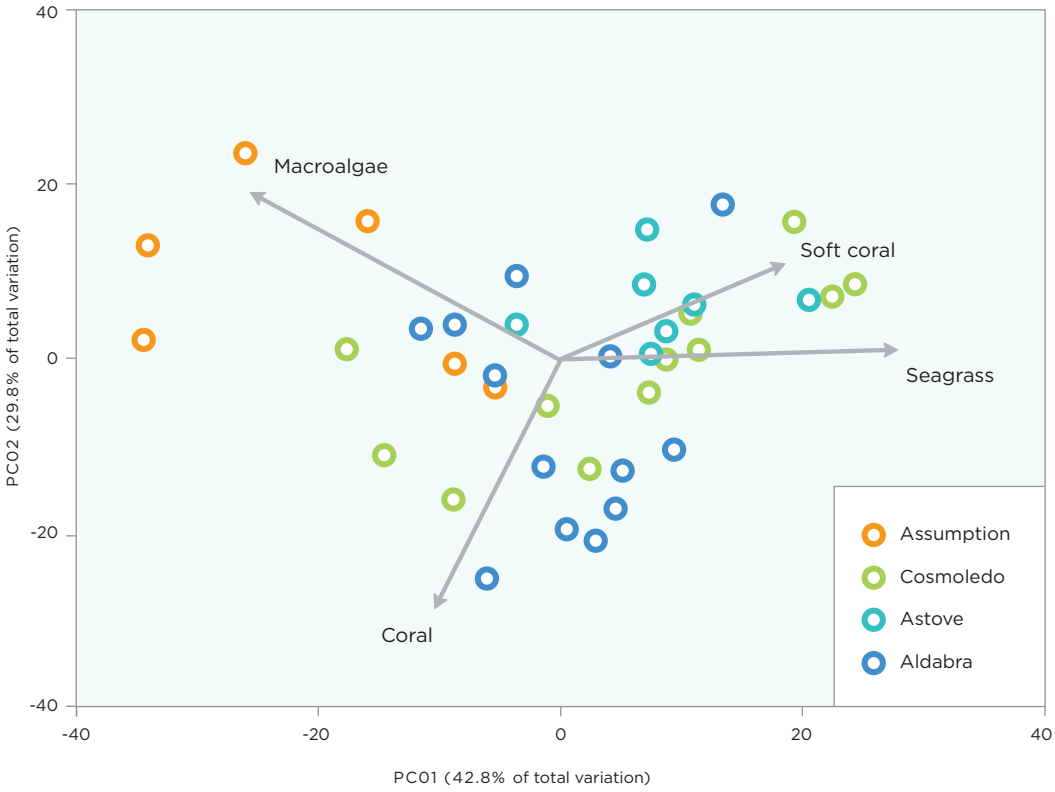


TABLE 2.

A. Permutation-Based Multivariable Analysis of Variance (PERMANOVA) of differences in benthic community structure among islands. B. Pair-wise comparisons of benthic community structure between islands.

A. Permanova of benthic community structure among islands.

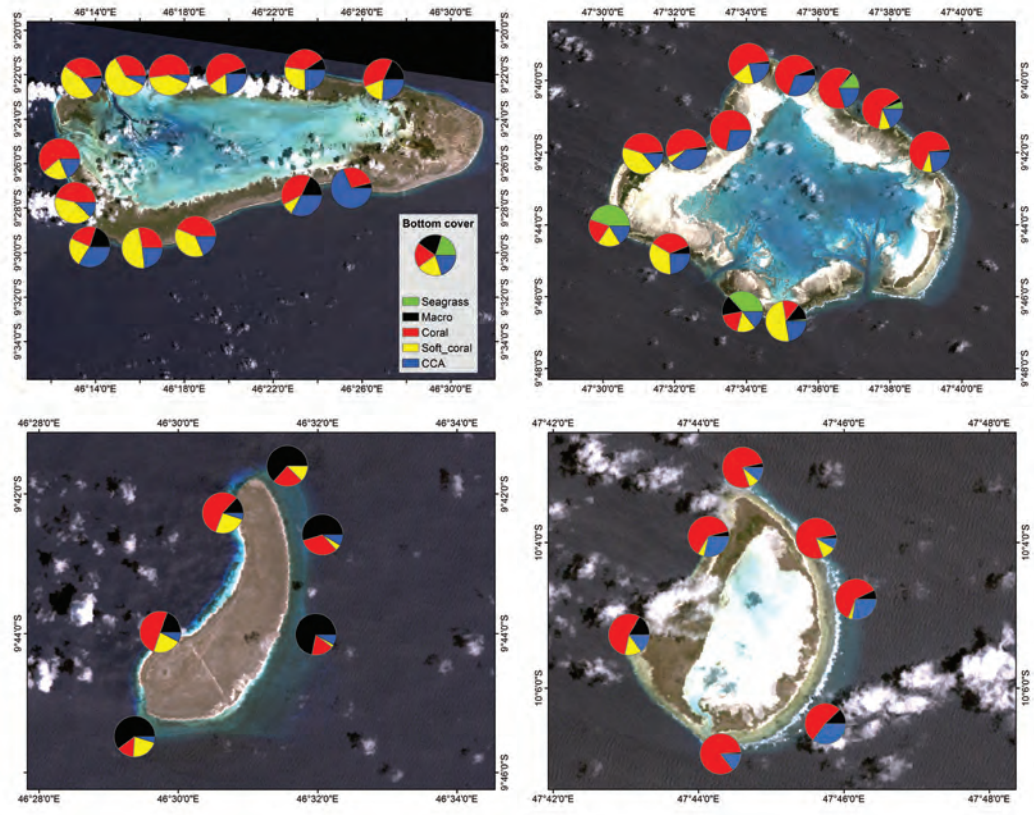
Source	df	MS	Pseudo-F	P(perm)
Island	3	2058	6.5	0.001
Residuals	34	315		
Total	37			

B. Pair-wise multiple comparisons of benthic community structure between islands.

Groups	t	P(perm)
Assumption, Cosmoledo	3.12	0.001
Assumption, Astove	3.73	0.001
Assumption, Aldabra	3.39	0.001
Cosmoledo, Astove	1.43	0.134
Cosmoledo, Aldabra	1.68	0.044
Astove, Aldabra	2.37	0.006

FIGURE 4.

Bottom cover of major functional groups within islands. Data are an average of surveys at 10 m and 20 m depths for each site.



Hard Corals

We found a total of 165 species of corals, from 54 genera and 16 families, with seven new records for the region (Table 3, Fig. 5, Appendix II). The family Acroporidae accounted for ~ 31% of the species, followed by Merulinidae (21%), and Poritidae (9%). *Porites lobata* was the dominant hard coral species at all islands, accounting for 15% of the cover at Astove, 7% at Cosmoledo, and 4% at both Aldabra and Assumption. Acroporid corals are recovering in many locations previously devastated by the 1998 mass bleaching event, and on some reefs they represented the dominant coral taxa (Fig. 6).

TABLE 3.

Coral families, genera, and species observed during the study with the percent total for each family.

Family	No. genera	No. species	Percent total
Acroporidae	4	50	30.7
Agariciidae	4	9	5.5
Astrocoeniidae	1	1	0.6
Coscinaraeidae	1	2	1.2
Dendrophylliidae	1	3	1.8
Euphylliidae	1	1	0.6
Faviidae	3	3	1.8
Fungiidae	9	10	6.1
Helioporidae	1	1	0.6
Incertae sedis	4	9	5.5
Lobophylliidae	5	11	6.7
Merulinidae	13	34	20.9
Mussidae	2	5	3.1
Pocilloporidae	2	6	3.7
Poritidae	2	15	9.2
Psammocoridae	1	3	1.8
Total	54	163	

FIGURE 5.

Zoopilus echinatus is a free-living mushroom coral, which was observed at Cosmoledo and is a new species record for this region.

FIGURE 6.

Acroporid corals are making a comeback in many locations, such as the shallow lagoon at Aldabra.

Algae

A total of 35 algal taxa were observed on quantitative surveys among the four islands (Table 4, Appendix III). Crustose corallines algae (CCA) comprised 13% of the total cover, followed by green algae (Chlorophyta, 12%). The seagrass *Thalassodendron ciliatum* was only present in any abundance at Cosmoledo, where it comprised nearly 6% of the total benthic cover (Fig. 7). The CCA *Hydrolithon onkodes* was the most abundant algae, comprising 7% overall. Four species of *Halimeda* made up > 34% of the total cover at Assumption, while this genus only accounted for 3% of the cover at Aldabra and < 2% at the other two islands (Fig. 8). Brown algae (Phaeophyceae) were rare and comprised <1% of the total cover. Green algae were the most specious group with 17 taxa represented, followed by red algae (12), with CCAs accounting for 75% of this group.

FIGURE 7.

Halimeda gracilis is an important sediment-producing green alga and was common around Assumption Island.

FIGURE 8.

The seagrass *Thalassodendron ciliatum* formed dense meadows at Cosmoledo Atoll.

TABLE 4.

Algal taxa observed on quantitative surveys in the Aldabra Group. Values are percentage of total benthic cover. Assump. – Assumption, Cosmo. – Cosmoledo.

Grouping	Taxa	Assump.	Cosmo.	Astove	Aldabra	Mean
Brown algae	*Dictyota* sp.	0.00	0.00	0.00	0.06	0.01
	Lobophora variegata	0.07	0.03	2.03	0.07	0.55
CCA	CCA unidentified	1.77	4.58	2.53	3.46	3.09
	Hydrolithon cf. *samoense*	0.03	0.07	0.50	0.00	0.15
	Hydrolithon craspedium	0.00	0.00	0.00	0.43	0.11
	Hydrolithon onkodes	1.70	10.25	9.83	7.67	7.36
	Hydrolithon "maërl"	0.00	0.00	0.00	3.54	0.89
	Mesophyllum erubescens-like	0.00	0.00	0.00	0.30	0.08
	Peyssonnelia calcea	0.00	0.02	0.03	0.00	0.01
	Peyssonnelia cf. *conchicola*	0.10	0.42	0.20	0.50	0.30
	Peyssonnelia sp. (yellowish)	1.10	2.03	1.67	1.09	1.47
Cyano.	Cyanobacteria	0.03	0.03	0.00	0.04	0.03
Green algae	*Avrainvillea amadelpha*	0.13	0.02	0.07	0.00	0.05
	Caulerpa cupressoides	0.07	0.02	0.00	0.00	0.02
	Caulerpa racemosa turbinata	0.90	0.00	0.00	0.00	0.23
	Caulerpa serrulata	0.00	0.10	0.03	0.03	0.04
	Caulerpa sp.	0.00	0.00	1.07	0.00	0.27
	Chlorodesmis fastigiata	0.00	0.03	0.00	0.00	0.01
	Cladophoropsis sundanensis	0.00	0.02	0.00	0.00	0.00
	Dictyosphaeria cavernosa	0.00	0.10	0.07	0.00	0.04
	Dictyosphaeria versluysii	1.40	0.62	0.00	0.04	0.51
	Halimeda cf. *lacunalis*	14.47	0.03	0.00	0.26	3.69
	Halimeda cf. *stuposa*	5.30	0.93	0.00	1.99	2.05
	Halimeda gracilis	11.63	1.02	1.60	0.79	3.76
	Halimeda micronesica	2.73	0.00	0.00	0.13	0.72
	Halimeda tuna	0.00	0.00	0.00	0.11	0.03
	Microdictyon okamurae	0.00	0.47	0.07	0.01	0.14
	Rhipilia tomentosa	0.00	0.00	0.10	0.00	0.03
	Valonia fastigiata	0.00	0.05	0.00	0.00	0.01
Red algae	*Dictyurus purpurascens*-like	0.00	0.02	0.00	0.24	0.06
	Galaxaura filamentosa	0.00	0.02	0.00	0.00	0.00
	Portieria hornemannii	0.10	0.07	0.00	0.00	0.04
Seagrass	*Thalassodendron ciliatum*	0.00	5.78	0.00	0.00	1.45
Turf algae	Filamentous algae	0.07	0.00	0.00	0.00	0.02
	Turf algae	0.07	0.68	1.30	1.07	0.78

Other Benthic Organisms

A total of 15 soft coral taxa were recorded during the expedition (Appendix IV). The genus *Rhytisma* accounted for 5.1% of the total benthic cover overall, and 15% of the total cover at Aldabra. There were nine sponge taxa observed, accounting for 2.4% of the total benthic cover (Appendix IV). The genus *Petrosia* was the most abundant sponge observed and was most common at Astove, where it comprised 1.7% of the benthic cover. The invasive sponge *Terpios hoshinota,* which engulfs huge areas of corals, has been noted from Aldabra and is being monitored by the Seychelles Islands Foundation (Fig. 9). Giant clams (*Tridacna* spp.) were rare, only being present at one station at Cosmoledo and one at Aldabra.

FIGURE 9.

The invasive sponge *Terpios hoshinota* overgrowing the left portion of a *Leptastrea* colony on Aldabra.

Fishes

We recorded a total of 332 fish species from 46 families among the four islands during our expedition (Appendix V). Wrasses (Labridae) were the most specious family with 54 species, followed by surgeonfishes (Acanthuridae – 26), groupers (Serranidae – 23), damselfishes (Pomacentridae – 21), and butterflyfishes (Chaetodontidae – 20).

Fish biomass averaged > 4 t ha^{-1} and was dominated by large groupers. Biomass was highest on Cosmoledo (4.9 t ha^{-1}) and lowest at Assumption (2.8 t ha^{-1}, Fig. 10). Despite this 75% difference, there was no significant difference in total biomass among the four islands ($F_{3,37}$ – 1.02, p = 0.30) and no difference in trophic structure (Table 5). Total biomass in the Aldabra Group was 94% higher than areas open to fishing in the northern Seychelles and 88% higher than in no-take reserves (NTRs, Fig. 11). Differences in top predators were even more striking, with biomass 98% higher in the Aldabra Group compared to areas open to fishing around the granitic islands and 96% higher than in NTRs.

Piscivores and planktivores were the most important trophic groups by weight, accounting for 32% and 33%, respectively, of total fish biomass. The percentage of piscivores was highest at Assumption (44%) and lowest at Astove (20%). Planktivores were most abundant at Cosmoledo, accounting for 38% of the biomass at that island.

FIGURE 10.

Fish biomass (t ha^{-1}) among islands. Error bars are ± 1 SE of the mean.

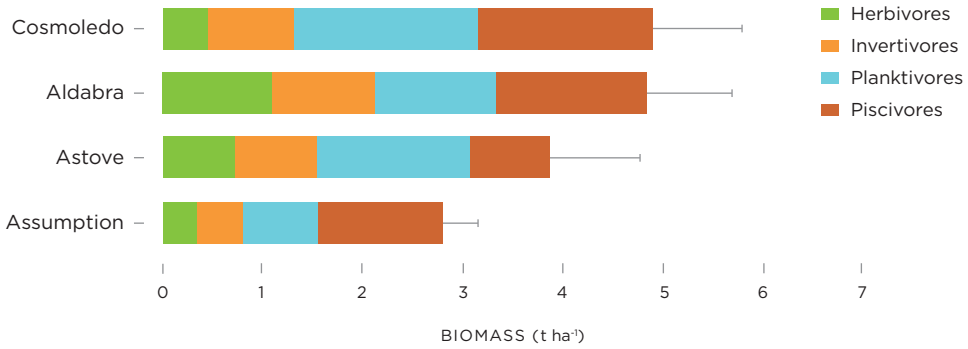


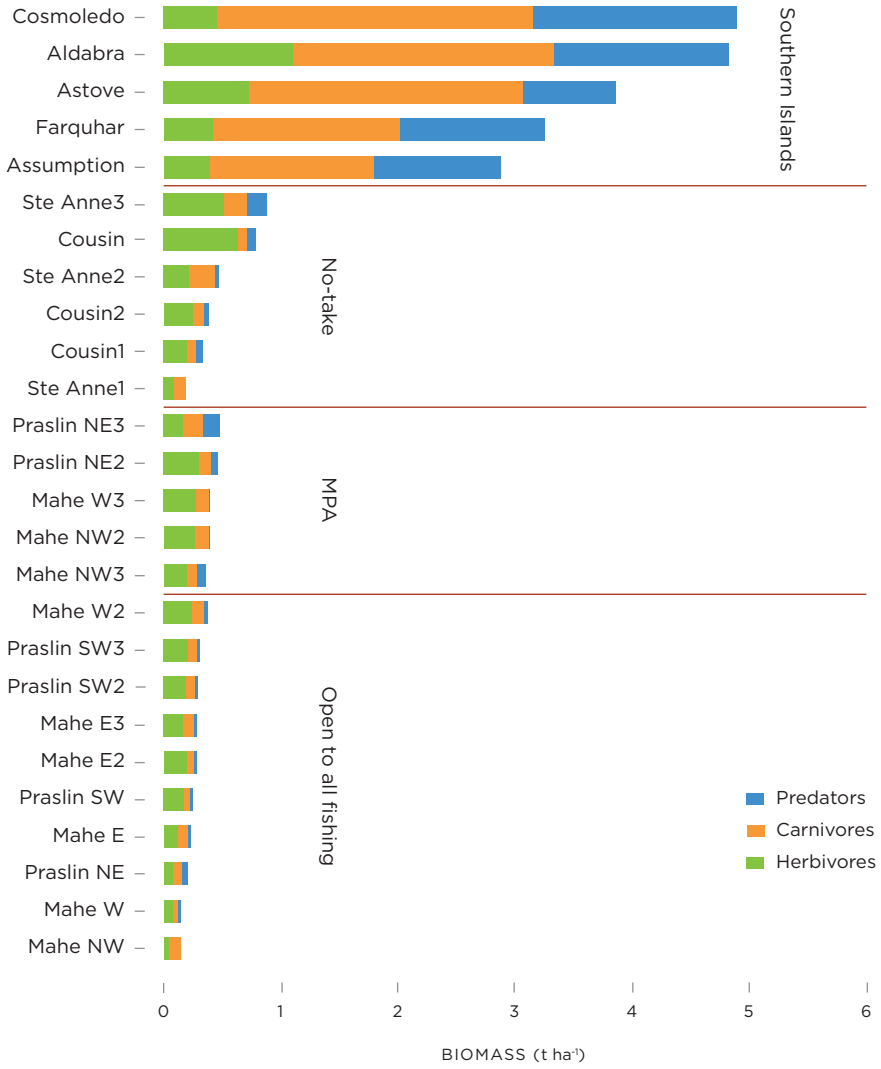
TABLE 5.

A. Permutation-Based Multivariable Analysis of Variance (PERMANOVA) of fish trophic biomass among islands.

Source	df	MS	Pseudo-F	P(perm)
Island	3	335	1.1	0.30
Residuals	34	296		
Total	37			

FIGURE 11.

Comparison of fish biomass among open areas, multi-use marine protected areas (MPAs), and no-take reserves in the northern Seychelles, and islands in the southern Seychelles.



The planktivorous blue-dash fusilier *(Pterocaesio tile)* was the most abundant species by weight, accounting for 8% of the total biomass overall, and was most abundant at Cosmoledo, where it comprised 14% of the total fish biomass (Table 6). This was followed by two top predators, bluefin trevally *(Caranx melampygus)* and potato cod *(Epinephelus tukula),* which comprised 7% and 5% of the total biomass, respectively (Figs. 12-13). Bluefin trevally accounted for >10% of the biomass at Cosmoledo and 14% at Assumption. The potato cod accounted for 9% of the biomass at Assumption and >4% at Aldabra. The herbivorous bluespine unicornfish *(Naso unicornis)* accounted for an additional 5% of the overall fish biomass observed among the four islands and was most abundant at Aldabra. The Napoleon wrasse *(Cheilinus undulatus)* is listed as endangered by IUCN, but is common at Aldabra and Cosmoledo (Fig. 14).

TABLE 6.

Top 30 fish species based on biomass, ordered by average overall biomass. Values are biomass (t ha^{-1}) with the rank of that species at each island in parentheses.

Species	Common name	Aldabra	Assump.	Astove	Cosm.
Pterocaesio tile	Blue-dash fusilier	0.15 (9)	0.19 (4)	0.29 (1)	0.71 (1)
Caranx melampygus	Bluefin trevally	0.19 (5)	0.39 (1)	0.09 (11)	0.53 (2)
Epinephelus tukula	Potato Cod	0.21 (3)	0.26 (2)	0.23 (4)	0.15 (9)
Naso unicornis	Bluespine unicornfish	0.41 (1)	<0.01 (77)	0.26 (2)	0.03 (28)
Lutjanus kasmira	Blue-lined snapper	0.25 (2)	0.06 (11)		0.21 (4)
Myripristis berndti	Myripristis berndti	0.1 (16)	0.06 (10)	0.19 (5)	0.16 (6)
Lutjanus bohar	Red snapper	0.09 (18)	0.19 (3)	0.05 (19)	0.15 (8)
Variola louti	Lunar-tail grouper	0.14 (11)	0.08 (7)	0.08 (13)	0.12 (14)
Myripristis kuntee	Epaulette soldierfish	0.05 (26)	0.03 (27)	0.11 (9)	0.22 (3)
Cheilinus undulatus	Napoleon wrasse	0.15 (10)		0.03 (34)	0.17 (5)
Acanthurus thompsoni	Thompson's surgeonfish	0.08 (20)	0.09 (6)	0.12 (7)	0.14 (11)
Chlorurus sordidus	Bullet-head parrotfish	0.16 (8)	0.03 (19)	0.01 (66)	0.14 (10)
Melichthys indicus	Indian triggerfish	0.19 (4)	0.04 (16)	0.05 (24)	0.07 (16)
Hemitaurichthys zoster	Black pyramid butterflyfish	0.03 (36)	0.12 (5)	0.07 (17)	0.16 (7)
Gnathodentex aureolineatus	Gold-spot emperor	0.06 (22)	0.04 (15)	0.05 (22)	0.12 (13)
Ctenochaetus truncatus	Indian gold-ring bristle-tooth	0.11 (14)	0.02 (29)	0.08 (14)	0.04 (25)
Odonus niger	Red-toothed triggerfish	0.17 (6)	0.03 (24)	0.01 (79)	0.02 (42)
Lutjanus gibbus	Paddletail snapper	0.1 (17)	0.01 (64)		0.09 (15)
Caesio xanthonota	Yellow-back fusilier	0.14 (12)	0.01 (67)	0.04 (26)	0.02 (45)
Carcharhinus amblyrhynchos	Blacktip reef shark	0.16 (7)			
Acanthurus leucosternon	Powderblue surgeonfish	0.03 (31)	0.03 (25)	0.12 (8)	0.05 (24)
Lepidozygus tapeinosoma	Fusilier damselfish	0.05 (24)	0.04 (17)	0.04 (25)	0.07 (18)
Naso hexacanthus	Sleek unicornfish	0.01 (88)	0.01 (54)	0.02 (40)	0.14 (12)
Scarus tricolor	Three-color parrotfish	0.11 (15)	0.03 (20)	0.04 (29)	0.01 (61)
Dermatolepis striolatus	Smooth grouper	0.01 (63)		0.18 (6)	0.03 (33)
Naso mcdadei	Hump-nose unicornfish	0 (148)		0.24 (3)	0 (200)
Naso brevirostris	Spotted unicornfish	0.08 (19)	0.01 (43)	0.07 (16)	0 (89)
Chlorurus strongylocephalus	Steephead parrotfish	0.03 (30)	0.02 (32)	0.04 (27)	0.07 (17)
Lutjanus ehrenbergii	Black-spot snapper	0.13 (13)			
Naso brachycentron	Humpback unicornfish	0.08 (21)		0.09 (10)	

FIGURE 12.

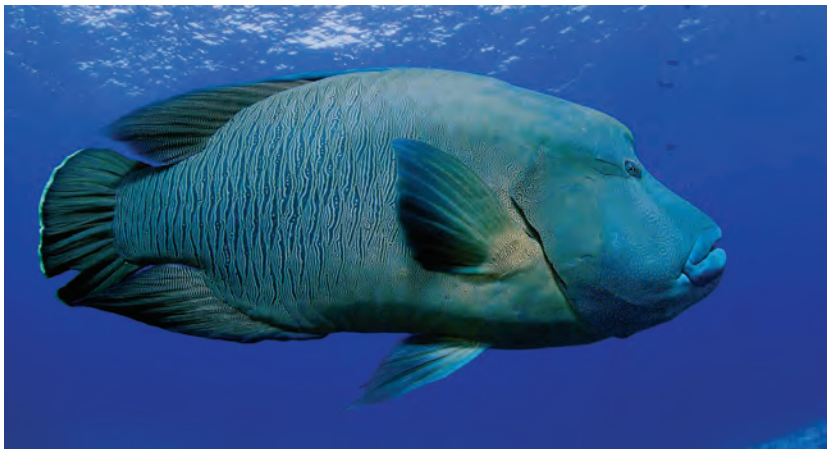
Potato cod *(Epinephelus tukula)* are large predators, which were common at the majority of the sites surveyed.

FIGURE 13.

Schools of giant trevally *(Caranx ignobilis)* were common at Aldabra and Cosmoledo. Cosmoledo is known for having some of the best giant trevally fisheries in the world, and has become the benchmark for anglers searching for the ultimate saltwater flats destination.

FIGURE 14.

Charismatic species like the Napoleon wrasse *(Cheilinus undulatus)* are listed as endangered by IUCN, but are common in the Aldabra Group.



Although biomass was higher than all other locations previously surveyed in the Seychelles, sharks were rare and only present in any numbers at Aldabra, where we observed six different species (grey reef, nurse, blacktips, silvertips, lemon, whitetips). We noted 24 observations of sharks from six different species at Aldabra, while at Astove and Cosmoledo we only observed one whitetip reef shark *(Triaenodon obesus)* at each island (Figs. 15-16). There is a long history of shark fishing in the Seychelles, and the high value of shark fins means that poaching is lucrative and common. The presence of SIF staff at Aldabra may help to dissuade would-be poachers, but the remote eastern portion of the island is infrequently visited by the staff owing to weather and boat size.

FIGURE 15.

Observations of sharks among islands in the Aldabra Group.

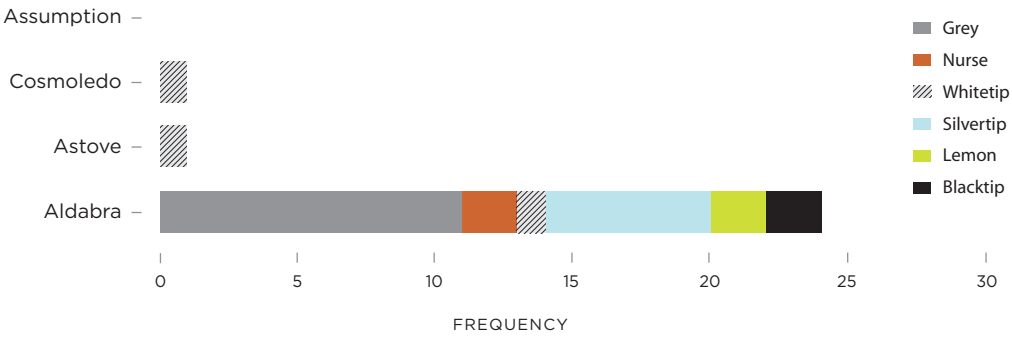


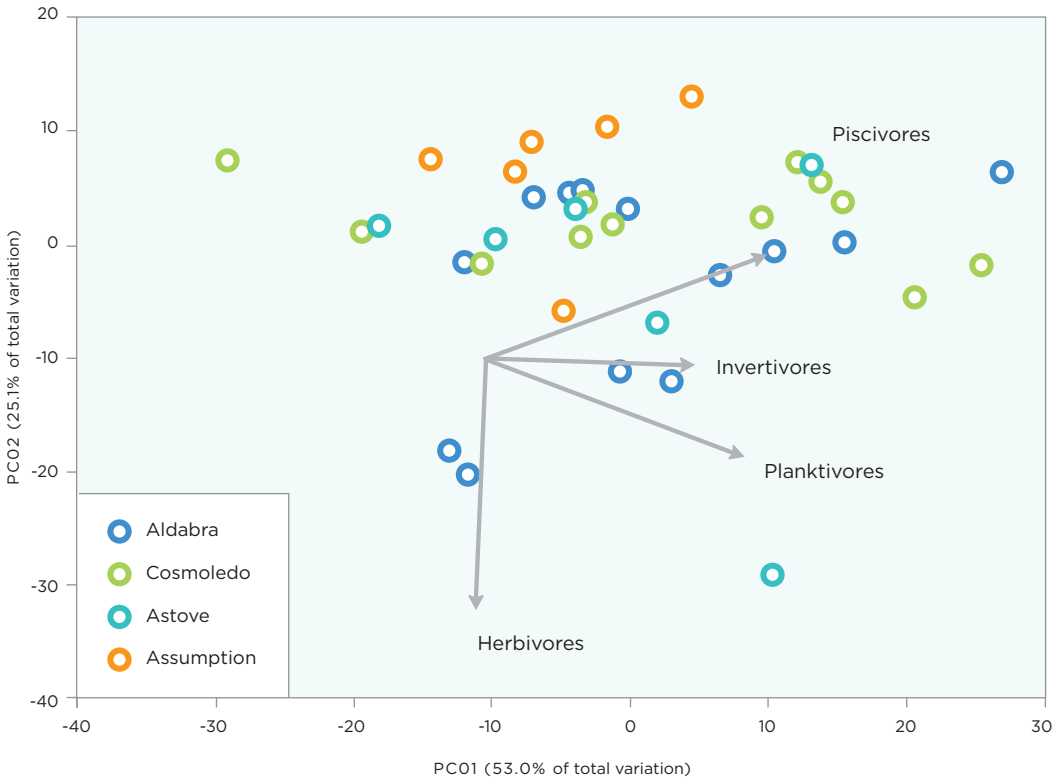
FIGURE 16.

Blacktip reefs sharks were common along the shallow sand flats of Aldabra, but uncommon elsewhere within the island group.

Fish assemblage structure among islands, based on trophic biomass, showed considerable overlap in ordination space (Fig. 17). The first two axes of the PCO explained 78.1% of the total variation among islands. Axis 1 was correlated with piscivores and planktivores towards Cosmoledo and Aldabra, and Axis 2 was correlated with herbivores away from Assumption and towards Aldabra.

FIGURE 17.

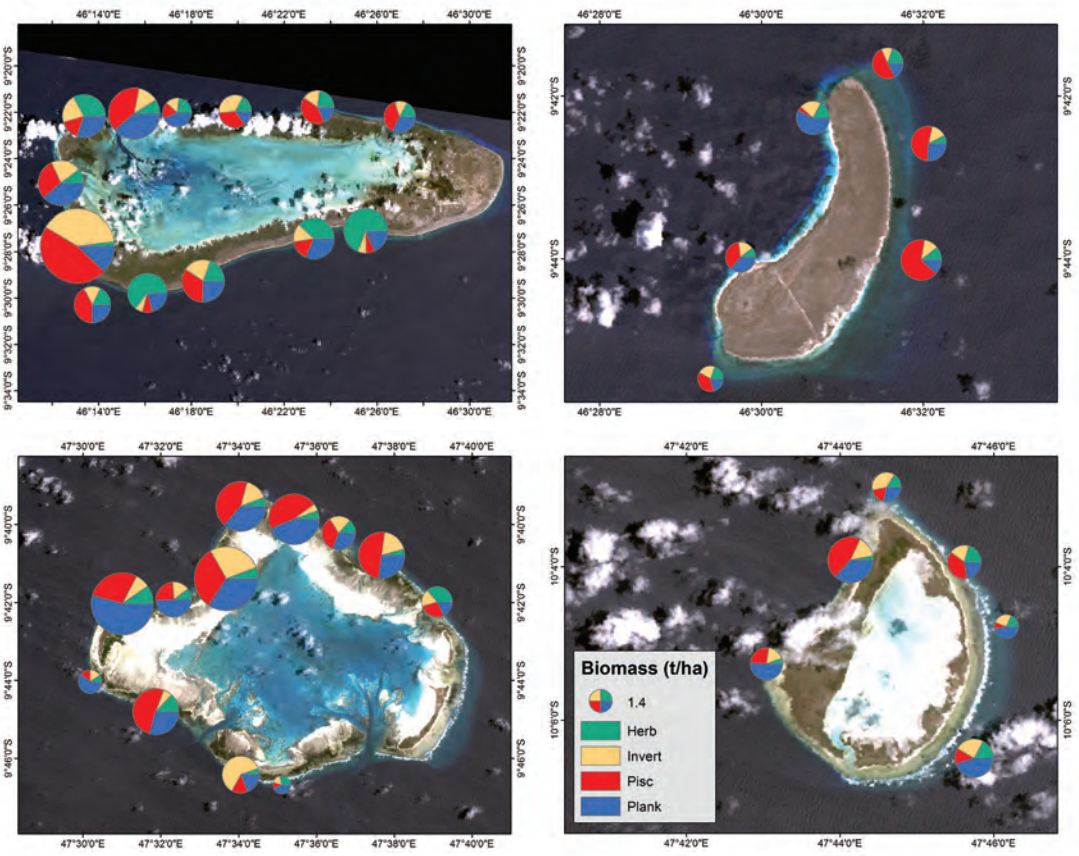
Principal Coordinate Analysis of fish trophic biomass among islands. Vectors of major functional groups are overlaid on the plot.



Fish biomass by trophic group varied by island and location within islands (Fig. 18). Piscivores and planktivores were most abundant along the northern shores of Cosmoledo and the western shores of Aldabra. Herbivores were most common along the southern coast of Aldabra.

FIGURE 18.

Fish biomass (t ha^{-1}) within islands. Herb = Herbivores, Invert = Invertivores, Pisc = Piscivores, Plank = Planktivores.



Deep Sea Community

Eight drop-cam deployments lasting from 2 to 10 hrs were conducted during the expedition between 56 m and 2,095 m (Table 7, Fig. 19). A wide range of species were observed on the deep drop-cameras, including lantern sharks, cusk eels, grenadiers, chimeras, and false cat sharks (Table 8, Figs. 20-21). Cutthroat eels (*Synaphobranchus* sp.) were the most frequently encountered taxa, occurring in five of the eight deployments.

TABLE 7.

Drop-cam deployment statistics.

Drop No.	Island	Date	Time	Lat.	Long.	Depth (m)	Duration (hrs)
1	Cosmoledo	2015/03/16	08:01	-9.6896	47.4803	1389	9
2	Cosmoledo	2015/03/17	08:05	-9.6453	47.5378	1873	9
3	Cosmoledo	2015/03/18	08:36	-9.7525	47.4841	1463	7.75
4	Astove	2015/03/19	09:00	-10.0475	47.7190	1271	7
5	Astove	2015/03/20	11:30	-10.0888	47.6984	1196	4.5
6	Aldabra	2015/03/22	07:25	-9.3816	46.1998	173	10
7	Aldabra	2015/03/23	07:15	-9.3830	46.1545	2095	10
8	Aldabra	2015/03/24	11:12	-9.3891	46.1969	56	2

FIGURE 19.

A drop-camera is deployed off the stern of the Waitt Foundation's research vessel.

TABLE 8.

Fish taxa observed on deep-sea drop-cams. Freq. – frequency of occurrence (N = 8).

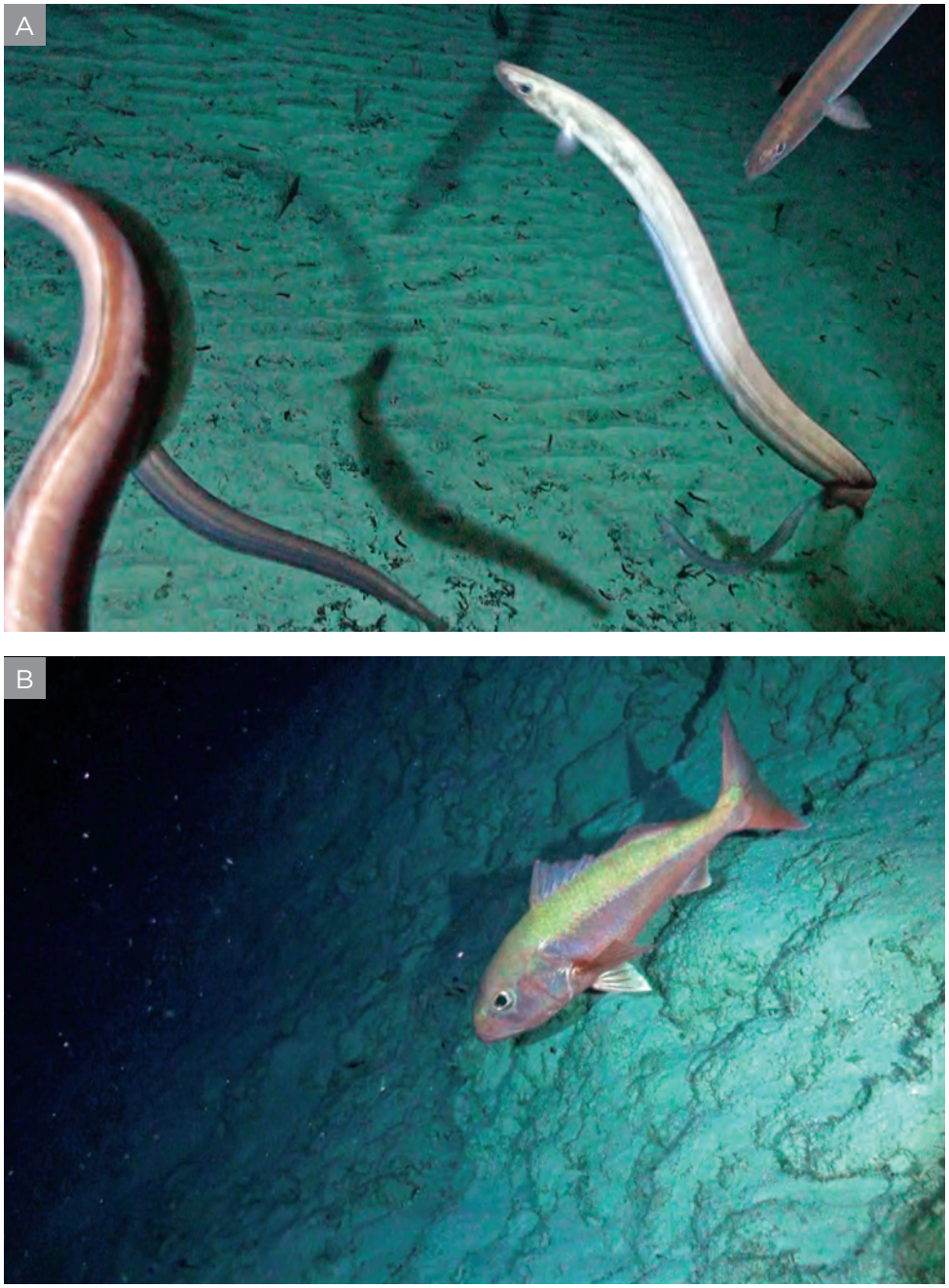
Family	Taxa	Common name	Freq	Depth range (m)
Acanthuridae	*Acanthurus xanthopterus*	Yellowfin Surgeonfish	0.125	56
Balistidae	*Sufflamen fraenatus*	Bridle triggerfish	0.125	56
Carangidae	*Carangoides ferdau*	Banded trevally	0.125	56
	Carangoides orthogrammus	Island trevally	0.125	56
	Caranx lugubris	Black trevally	0.125	173
	Caranx melampygus	Bluefin trevally	0.125	56
	Seriola dumerili	Amberjack	0.125	173
Carcharhinidae	*Carcharhinus albimarginatus*	Silvertip shark	0.125	173
Chimaeridae	*Hydrolagus* sp.	Chimera	0.375	1389-1973
Etmopteridae	*Etmopyerus* sp.	Lantern shark	0.125	1463
Haemulidae	*Plectorhinchus plagiodesmus*	Yellowmouth sweetlips	0.125	56
Labridae	*Suezichthys* sp.	Deepwater cleaner wrasse	0.125	173
Lethrinidae	*Gymnocranium grandoculis*	Bluelined large-eye emperor	0.125	56
	Lethrinus olivaceus	Longnosed emperor	0.125	56
	Lethrinus sp.	Emperor	0.125	56
Lutjanidae	Aprion virescens	Jobfish	0.25	56-173
	Etelis carbunculus	Ruby snapper	0.25	56-173
	Lutjanus bohar	Red snapper	0.125	56
	Pristipomoides auricilla	Goldflag Jobfish	0.125	173
Macrouridae	Bathygadinae	Grenadier	0.125	1196
	Coelorinchus sp.	Grenadier	0.375	1271-2095
	Macrourinae	Grenadiers	0.125	1873
Monacanthidae	*Aluterus scriptus*	Scrawled filefish	0.125	56
Myxinidae	*Eptatretus* sp.	Hagfish	0.125	2095
Ophidiidae		Cusk-eel	0.125	2095
Pseudotriakidae	*Pseudotriakis microdon*	False cat shark	0.25	1271-1389
Scaridae	*Chlorurus strongylocephalus*	Steephead parrotfish	0.125	56
Scombridae	*Gymnosarda unicolor*	Doogtooth tuna	0.25	56-173
Serranidae	*Epinephelus chlorostigma*	Smallspot grouper	0.125	173
	Epinephelus milliaris	Netfin grouper	0.125	173
	Epinephelus poecilonotus	Dot-dash grouper	0.125	173
	Epinephelus sp.	Grouper	0.125	173
	Epinephelus tukula	Potato cod	0.125	173
	Pseudanthias sp.	Anthias	0.125	173
Synaphobranchidae	*Synaphobranchus* sp.	Cutthroat eel	0.625	1196-1873

FIGURE 20.

Deepwater fishes observed on drop-cams. A. Hagfish (*Eptatretus* sp.) 2,095 m, B. Chimera (*Hydrolagus* sp.) 1,873 m. C. Silvertip shark *(Carcharhinus albimarginatus)* 173 m. D. Smallspot grouper *(Epinephelus chlorostigma)* 173 m. E. Lantern shark (*Etmopyerus* sp.) 1,463m. F. Potato cod *(Epinephelus tukula)* 173 m.

FIGURE 21.

A. Cutthroat eels (*Synaphobranchus* sp.) 1,196 m. B. Ruby snapper *(Etelis carbunculus)* 173 m.



Microplastics

Given the increasing levels of plastic pollution of the oceans, it is important to better understand the impact of microplastics in the ocean food web. We partnered with National Geographic Emerging Explorer Gregg Treinish from Adventurers and Scientists for Conservation (ASC, http://www.adventurescience.org/) to sample microplastics during our expedition. We collected samples of sea water in 1 liter bottles at 22 locations during the expedition. Samples were sent to ASC for analyses.

In total, 132 microplastics were counted, with an average of six pieces per liter, a maximum of 52 pieces per liter, and only one sample with no plastics (Fig. 23). 121 pieces were fibrous/filamentous. 50 were transparent/white, 37 were blue, 24 were black, 3 were red, and 18 were other colors, including several clear/blue particles. Only one sample—the 22nd—did not contain any plastic.

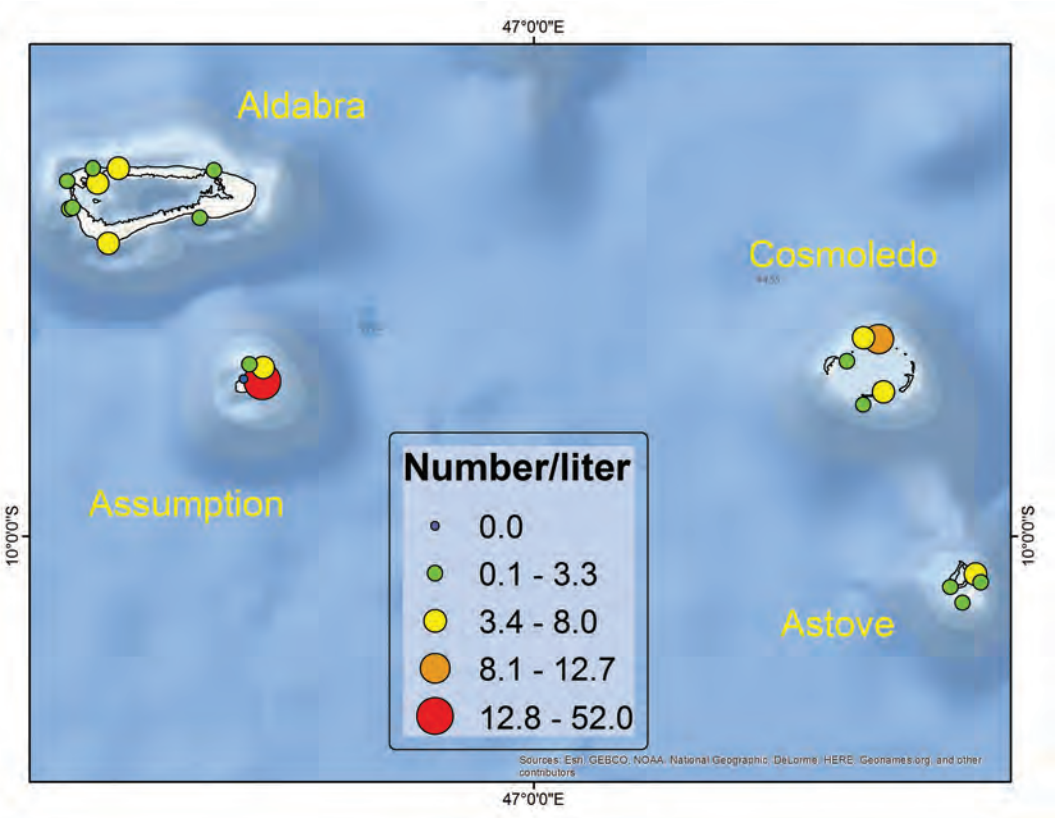


FIGURE 22.

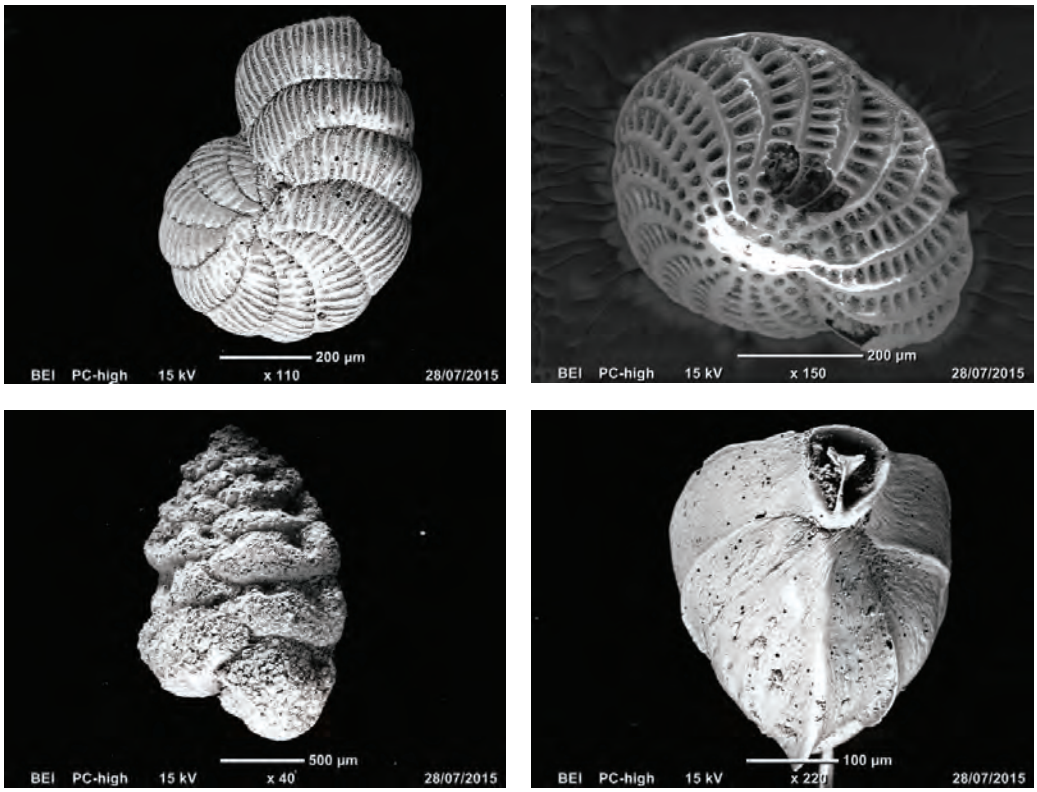
Density of microplastics observed in sampled collected around the Aldabra Group.

Micropaleontology Collections

Microfossils are excellent indicators of general environmental conditions such as temperature, salinity, organic enrichment, etc. We sampled at 26 locations for microfossils collected from the top 1 cm of sediment. Approximately 100 ml of sand was collected from the top 1 cm of the sediment at three different sites within a location. Samples were preserved in 100% isopropyl alcohol and are being analyzed by National Geographic Emerging Explorer Dr. Beverly Goodman at Haifa University in Israel (Fig. 23).

FIGURE 23.

Scanning Electron Microscope images of marine microfossils from the expedition.



Sea Turtles

During the 1980s when large numbers of green turtles were being killed legally for meat in the Seychelles, Cosmoledo was the site of the heaviest exploitation. Sea turtles, primarily green *(Chelonia mydus),* but also hawksbill *(Eretmochelys imbricata)* and loggerhead *(Caretta caretta),* were commonly observed during the expedition, with the greatest abundances at Aldabra (Figs. 24-25). Considering the status of sea turtles globally, this is an encouraging sign.

FIGURE 24.

Hawksbill sea turtle *(Eretmochelys imbricata)* at Aldabra.

FIGURE 25.

Turtle hatchlings emerge from their shells and make their way to the sea for the first time.

DISCUSSION & **CONCLUSIONS**

Intact Marine Ecosystem

Our integrated assessment of the reefs of the Aldabra Group found healthy marine communities that are significant for their abundance and size of fishes, the relatively high cover of live coral, the lack of large seaweed, and the abundance of protected species such as sea turtles. Fish biomass in the Aldabra Group is an order of magnitude larger than no-take reserves in the northern Seychelles, and the size and abundance of groupers and other large predators is indicative of an ecosystem that has experienced limited fishing pressure. Seaweed, which has overgrown many reefs around the world, is nearly absent in the Aldabra Group. This condition results from a lack of land-based nutrient inputs and a high biomass of herbivorous fishes. Coral cover was relatively high, and evidence of new recruits indicated that the reef system is resilient and has the capacity to recover from perturbations. Our investigation of the deep sea down to > 2,000 m showed a diverse community, with numerous top predators (e.g., eteline snappers, dogtooth tuna, groupers) present at the shallower end of this range (~ 175 m).

Coral Reefs and Climate Change

The 1998 warming of the Indian Ocean had devastating effects on the coral reefs of the region, and this was particularly true for the Seychelles (Sheppard et al. 2005, Graham et al. 2006). Following this event, coral cover around Aldabra and Cosmoledo previously exceeded 50%, but was massively reduced in shallow water and halved in deeper water (Teleki et al. 2000). In < 10 m of water, mortality exceeded 90% and even 99% in some areas (Sheppard and Obura 2005). Five years after the bleaching event there were signs of hard coral recovery at some locations, but in spite of several years of high coral recruitment recovery of hard coral has not occurred at a significant level (Stobart et al. 2005). No significant changes in total fish-species diversity were seen in the five years after the bleaching event, contrary to fish-diversity changes seen on coral bleaching-impacted reefs elsewhere in the region (Downing et al. 2005).

We found coral cover to average 36% among the four islands, and overall the reefs appeared to have recovered from the 1998 mass bleaching event with indications (e.g., new coral recruits, low macroalgae cover) that the reefs are in a relatively healthy condition (Figs. 26-27). However, the coral assemblage, once dominated by the genus *Acropora,* is now dominated by *Porites* spp., which are less sensitive to warming than other genera (Sheppard and Obura 2005). Soft corals have also appeared to have bounced back relative to the early 2000s (Teleki et al. 2000, Sheppard and Obura 2005). Climate change will likely bring about conditions that are less conducive to coral reef development in the region, and degradation of coral reefs in the Seychelles will have serious impacts on tourism, fisheries, and other services that depend on coral reefs (Payet and Agricole 2006).

FIGURE 26.

The shallow lagoon at Aldabra harbors a remarkable diversity of life.

FIGURE 27.

Reefs dominated by the coral genus *Acropora* were common around the Seychelles prior to the 1998 mass bleaching event. Areas in the southern Seychelles are recovering better than other reefs in the region.

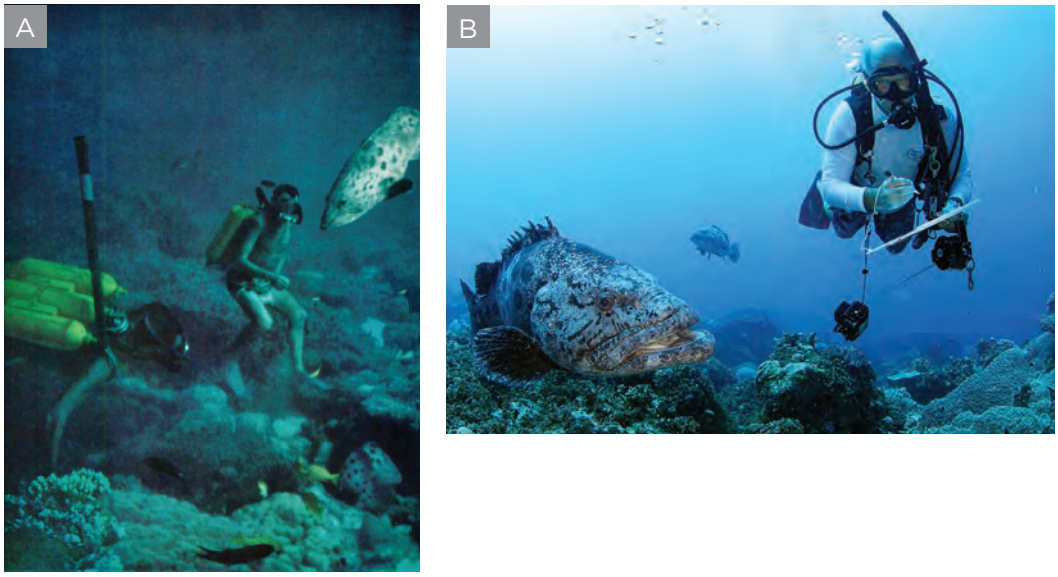
Early Underwater Exploration

Despite the limited scientific information from this region, some of the first underwater exploration using scuba was conducted in the Aldabra Group. Jacques-Yves Cousteau's 1953 book "The Silent World: A Story of Undersea Discovery and Adventure" and the subsequent 1956 film "Silent World" (the first of Cousteau's documentary films to win an Academy Award for Best Documentary Feature) describe the thriving reefs of Assumption and Aldabra.

Luis Marden's article in *National Geographic* magazine from 1956 (Marden 1956), titled "Camera under the Sea," details an expedition with Cousteau aboard the *Calypso* to Assumption Island, where he describes the fish as living in an underwater age of innocence, never having seen a man, with almost no fear. We had similar experiences of curious potato cod at Assumption Island to those of Cousteau and Marden, which is an encouraging sign that these reefs are still in a healthy state compared to 60 years ago (Fig. 28). Cousteau's "Life and Death in a Coral Sea" published in 1971 highlights the unspoiled reefs of Cosmoledo and Assumption (Cousteau 1971).

FIGURE 28.

A. 1956 Cousteau expedition from *National Geographic* magazine. B. 2015 Pristine Seas expedition.



Overfishing, Few Sharks

William Travis's book "Beyond the Reefs" documents the exploitation of green snails *(Turbo marmoratus)* in the southern Seychelles in the 1950, and in his account he describes the reefs of Cosmoledo and Aldabra as teeming with sharks, including tigers, nurse, hammerheads, blacktips, and whitetips (Travis 1959). In his sequel "Sharks for Sale" published in 1961, he describes his attempt to establish a shark fishery in the Seychelles and he laments that after just two years, he was forced further and further afield since the more accessible areas of sharks were depleted. The absence of sharks at these islands is a concern as these top predators are an essential component of a healthy reef (Bascompte et al. 2005, Robbins et al. 2006, Ruppert et al. 2013), but they have been extirpated from most of the world's oceans (Baum et al. 2003, Myers and Worm 2003, 2005).

Experimental handline fishing at Aldabra in 2000 yielded 3,288 kg of six grouper species (Grandcourt 2005). Age and growth estimates from potato cod revealed that it was a very slow-growing species (k = 0.13), with a low natural mortality (m = 0.16 yr^{-1}) and a maximum age of ~ 30 years. Many of these species are known to form spawning aggregations in the southern Seychelles at discrete locations and time, which are known to and targeted by commercial and artisanal fishers (Robinson et al. 2008, 2011). These results clearly highlight the susceptibility of these large groupers and other large long-lived species to even modest levels of exploitation, and should be a cautionary tale for the management of these islands as many of these species have been severely depleted throughout much of the world. We observed a 20 m boat from Mahé during our time at Cosmoledo that was actively fishing reef fishes on the west side of the island. It would take very little effort to remove these large carnivores from the reef, and the recovery rate would be extremely slow.

Sportfishing

In past years, Cosmoledo had become known as one of the best giant trevally fisheries in the world, with anglers from across the globe coming to cast their flies at these behemoths as well as other prized sportfish such as bonefish, permit, triggerfish, and barracuda, until it was closed four years ago due to piracy. With better security and reduced piracy, this fishery is once again open, and anglers pay > $14,000 for a week of fishing at Cosmoledo, Astove, and Assumption. If well managed, high-end catch-and-release sportfishing can provide sustainable revenue to the Seychelles without compromising the health of the ecosystem. However, a precautionary approach needs to be taken since these fisheries can also have negative impacts to these resources. Examples from other remote locations illustrate both correct and incorrect ways in which to manage these fisheries (Friedlander et al. 2008).

Enforcement

Island Development Corporation has announced plans to build a runway on Cosmoledo to have a presence in these islands that would deter poaching and other illegal activities. Boats from Madagascar have been reported visiting the Aldabra Group to catch turtles and collect sea cucumbers. Advances in satellite technology have made enforcement of remote areas much more achievable than in the past, and any marine spatial plan needs to consider the most effective and cost-efficient ways to prevent illegal fishing.

Microplastics

Plastic debris has become a serious problem, not just in coastal areas but throughout the world's oceans. Large plastic items slowly degenerate in microplastic particles (<5 mm) and spread across the ocean. Even in the remote islands of the southern Seychelles, 95% of our water samples contained microplastics. Public concern is growing regarding the impact on marine species that ingest this plastic and the accumulation of plastics along coastal and remote areas. The global environmental, economic, and health costs associated with microplastics require immediate international attention.

Outreach

Blog posts from the expedition helped carry our message to policy makers, partners, and a highly motivated general audience (http://voices.nationalgeographic.com/author/prose/). At the post-expedition conference in Mahé, initial results were provided and a short film from the expedition was presented. The finance minister and head of the Blue Economy, Jean-Paul Adam, delivered the keynote address. Key senior members of government and our NGO partners were in attendance. The event was well attended by senior leaders and influencers from across all Seychelles government, business, and private sectors.

Benefits to the Seychelles and Potential Users

These reefs are some of the last remaining intact coral reef ecosystems in the region and appear to have been resilient to the global and local stressors that have plagued reefs elsewhere. This expedition established a baseline for the marine ecosystems of the Aldabra Group, which can be used to gauge the effects of future activities and management measures. The results from our work provide valuable information in an area that is little known scientifically and is relatively pristine, with high global biodiversity value. The methodology is comparable with previous studies in the Seychelles and therefore presents a valuable baseline. Our integrated assessment provides a much better understanding of how the entire ecosystem functions, therefore helping to inform ecosystem-based management as well as support for the Seychelles government debt for adaptation funding and related marine spatial planning.

REFERENCES

Bascompte J, Melian CJ, Sala E (2005) Interaction strength combinations and the overfishing of a marine food web. Proceedings of the National Academy of Sciences 102, 5443–5447.

Baum JK, Myers RA, Kehle, DG, Worm B, Harley SJ, Doherty PA (2003) Collapse and conservation of shark populations in the northwest Atlantic. Science 299, 389–392.

Bayne CJ, Cogan BH, Diamond AW, Frazier J, Grubb P, Hutson A, et al. (1970a) Geography and ecology of Astove. Atoll Research Bulletin 136, 83-99.

Bayne CJ, Cogan BH, Diamond AW, Frazier J, Grubb P, Hutson A, et al. (1970b) Geography and ecology of Cosmoledo Atoll. Atoll Research Bulletin 136, 37-56.

Braithwaite C (1971) Seychelles Reefs: structure and development. Symposium of the Zoological Society of London 28, 39-64.

Chatterjee S, Goswami A, Scotese CR (2013) The longest voyage: tectonic, magmatic, and paleoclimatic evolution of the Indian plate during its northward flight from Gondwana to Asia. Gondwana Research 23, 238-267.

Cousteau JY (1953) Silent world. Hamish Hamilton, London.

Cousteau JY (1971) Life and death in a coral sea. Doubleday & Company, Inc., Garden City, New York.

Drew, E. A. (1977). A photographic survey down the seaward reef-front of Aldabra Atoll. Atoll Res. Bulletin. No. 193.

Downing, N., Buckley, R., Stobart, B., LeClair, L., & Teleki, K. (2005). Reef fish diversity at Aldabra Atoll, Seychelles, during the five years following the 1998 coral bleaching event. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, 363(1826), 257-261.

Friedlander AM, Caselle JE, Beets J, Lowe CG, Bowen BW, Ogawa TW, Kelley KM, Calitri T, Lange M, Anderson BS (2008) Biology and ecology of the recreational bonefish fishery at Palmyra Atoll National Wildlife Refuge with comparisons to other Pacific islands. Biology and management of the world tarpon and bonefish fisheries. CRC Press, Boca Raton. Pp 27-56.

Friedlander AM, Obura D, Aumeeruddy R, Ballesteros E, Church J, Cebrian E, Sala E (2014) Coexistence of low coral cover and high fish biomass at Farquhar Atoll, Seychelles. PLoS ONE 9(1), e87359. doi:10.1371/journal.pone.0087359

Graham NA, Wilson SK, Jennings S, Polunin NV, Bijoux JP, Robinson J (2006) Dynamic fragility of oceanic coral reef ecosystems. Proceedings of the National Academy of Sciences 103, 8425-8429.

Graham NAJ, Wilson SK, Jennings S, Polunin NVC, Robinson J, Bijoux JP, Daw TW (2007) Lag effects in the impacts of mass coral bleaching on coral reef fish, fisheries, and ecosystems. Conservation Biology 21, 1291-1300.

Grandcourt EM (2005) Demographic characteristics of selected epinepheline groupers (family Serranidae, subfamily Epinephelinae) from Aldabra Atoll, Seychelles. Atoll Research Bulletin 539, 200-216.

Jennings S, Grandcourt, EM, Polunin NVC (1995. The effects of fishing on the diversity, biomass and trophic structure of Seychelles' reef fish communities. Coral Reefs 14, 225-235.

Jennings S, Marshall SS, Cuet P, Naim O (2000) The Seychelles. In: McClanahan T, Sheppard CRC, Obura DO, editors. Coral reefs of the Indian Ocean: their ecology and conservation. Oxford University Press, Oxford UK. pp. 383-410.

Marden L (1956) Camera under the sea. *National Geographic* Magazine. 109, 162-200.

Myers RA, Worm B (2003) Rapid worldwide depletion of predatory fish communities. Nature 423, 280–283.

Myers RA, Worm B (2005) Extinction, survival or recovery of large predatory fishes. Philosophical Transactions of the Royal Society B 360, 13–20.

Payet R, Agricole W (2006) Climate change in the Seychelles: implications for water and coral reefs. AMBIO: A Journal of the Human Environment 35, 182-189.

Robbins WD, Hisano M, Connolly SR, Choat JH (2006) Ongoing collapse of coral-reef shark populations. Current Biology 16, 2314-2319.

Robinson J, Aumeeruddy R, Jörgensen TL, Öhman MC (2008) Dynamics of camouflage *(Epinephelus polyphekadion)* and brown marbled grouper *(Epinephelus fuscoguttatus)* spawning aggregations at a remote reef site, Seychelles. Bulletin of Marine Science 83, 415-431.

Robinson J, Samoilys MA, Grandcourt E, Julie D, Cedras M, Gerry C (2011) The importance of targeted spawning aggregation fishing to the management of Seychelles' trap fishery. Fisheries Research 112, 96-103.

Rocamora G, Feare CJ, Skerrett A, Athanase M, Greig E (2003) The breeding avifauna of Cosmoledo Atoll (Seychelles) with special reference to seabirds: conservation status and international importance. Bird Conservation International 13, 151-174.

Ruppert JLW, Travers MJ, Smith LL, Fortin M-J, Meekan MG (2013) Caught in the middle: combined impacts of shark removal and coral loss on the fish communities of coral reefs. PLoS ONE 8(9), e74648. doi:10.1371/journal.pone.0074648

Sheppard C, Obura D (2005) Corals and reefs of Cosmoledo and Aldabra atolls: extent of damage, assemblage shifts and recovery following the severe mortality of 1998. Journal of Natural History 39, 103-121.

Stobart, B., Teleki, K., Buckley, R., Downing, N., & Callow, M. (2005). Coral recovery at Aldabra Atoll, Seychelles: five years after the 1998 bleaching event. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences,* 363(1826), 251-255.

Stoddart DR, Taylor JD, Fosberg FR, Farrow GE (1971) Geomorphology of Aldabra atoll. Royal Society.

Stoddart DR, Benson CW, Peake JF (1970) Ecological change and effects of phosphate mining on Assumption Island. Atoll Research Bulletin 118, 121-146.

Stoddart DR (1971) Scientific studies at Aldabra and neighboring islands. Philosophical Transactions of the Royal Society B 260, 5-29.

Teleki KA, Spencer T, Bradshaw C, Spalding MD (2000) Coral bleaching in the southern Seychelles during the 1997–1998 Indian Ocean warming event. Marine Pollution Bulletin 40, 569–586.

Travis W (1959) Beyond the Reef. EP Dutton & Company, Inc. New York.

Travis W (1961) Sharks for Sale. Rand McNally & Company, Chicago. Printed in Great Britain.

APPENDICES

Appendix 1.

Expedition Participants

Name	Role	Institution
Paul Rose	Expedition leader	Pristine Seas-National Geographic/Royal Geographical Society
Alan Friedlander	Chief Scientist - fishes	Pristine Seas-National Geographic /University of Hawaii
Kike Ballesteros	Algae/benthos	Centre d'Estudis Avançats de Blanes (CSIC), Spain
Eric Brown	Corals	US National Park Service, Kalaupapa National Historical Park, Hawaii
Jim Beets	Fishes	University of Hawaii at Hilo
Philip Haupt	Fishes	Seychelles Islands Foundation
Daig Romain	Benthos	Seychelles Islands Foundation
Brad Henning	Drop-camera	National Geographic Remote Imaging
Neil Gelinas	Producer/camera	Pristine Seas-National Geographic Society
Manu San Felix	UW camera	Pristine Seas-National Geographic Society
Jose Arribas	UW assistant	Pristine Seas-National Geographic Society
Dave McAloney	Dive safety officer	Pristine Seas-National Geographic Society
Neil Gelinas	Producer/camera	Pristine Seas-National Geographic Society
Jesse Goldberg	Cameraman	National Geographic Society
Alan Turchik	Drop camera	National Geographic Remote Imaging

Appendix II.

Methods

In-water Biological Surveys:

Benthos - Characterization of the benthos was conducted along 50 m-long transects run parallel to the shoreline at each sampling depth strata. For algae, corals, and other sessile invertebrates, we used a line-point intercept methodology along each transect, recording the species or taxa found every 20 cm on the measuring tape.

Fishes - At each depth stratum within a site, divers counted and estimated lengths for all fishes encountered within fixed-length (25-m) belt transects whose widths differed depending on the direction of swim. All fish ≥ 20 cm total length (TL) were tallied within a 4 m-wide strip surveyed on an initial "swim-out" as the transect line was laid (transect area = 100 m^2). All fishes < 20 cm TL were tallied within a 2 m-wide strip surveyed on the return swim back along the laid transect line (transect area = 50 m^2).

Deep Drop-camera Surveys

National Geographic's Remote Imaging Team has developed deep ocean drop-cams, which are high-definition cameras encased in a borosilicate glass sphere that are rated to a depth of 10,000 m. Drop-cams have an onboard VHF transmitter that allows for recovery using locating antennae with back-up location achieved via communication with the ARGOS satellite system. Drop-cameras were deployed on seamounts and other unique geological features on an opportunistic basis, and relied on local expertise and bathymetric charts for optimal deployment locations.

Microplastic Sampling

Water samples were collected at 22 sites around the Aldabra Group. Samples were collected from a 1 liter Nalgene bottle that was rinsed three times prior to collection. At each site we recorded the date, time, time of high tide, and GPS coordinates. Samples were sent to ASC in Maine for processing. Once received, the water was vacuum pumped over a gridded 0.45 micron filter and dried for a minimum of 24 hours. Using a microscope at 40x magnification, pieces of microplastic (<5 mm) on the filter were systematically counted along the grid lines. Each plastic piece was categorized based on shape (round, filament/microfiber, other) and color (blue, red, green, black, transparent/white, other). The volume of water was recorded, and the final count for the sample was divided by the quantity of water to obtain a density estimate for each.

Micropaleo Sampling

We collected samples from the top 1 cm of sediment to determine the community of benthic microfossils present in different sub environments in these remote locations. Microfossils are excellent indicators of general environmental conditions such as temperature, salinity, organic enrichment, etc. While some species are cosmopolitan and found worldwide, others are unique to certain geographic locations. The sediment was characterized for its minerological and granulometric characteristics as well as elemental composition. An aliquot of sample was selected for microfossil characterization. The microfossils (foraminifera, in particular, but any ostracods, diatoms, or radiolarians will also be documented) will be isolated to produce a community assemblage and catalogue of the microfossil community for each sampling location. The aims of the project are to provide some insight into the state of the environment of the sites studied during the Pristine Seas expeditions, to document any new species, to create a baseline catalogue for sites that have no previous comparative samplings, and to provide an updated set for sites with a previous record. Three samples were collected at each site. Approximately 100 ml of sand was collected from the top 1 cm of the sediment. Samples were preserved in 100% isopropyl alcohol and shipped off to National Geographic Emerging Explorer Dr. Beverly Goodman at Haifa University in Israel. Results will be published separately.

Statistical Analysis

Comparisons of benthic functional groups were examined using Principal Coordinates Analysis on the Bray-Curtis dissimilarity matrix of percent cover of the major functional groups (coral, macroalgae, soft coral, CCA, substrate, seagrass). Eigenvectors with > 0.5 correlation were overlaid on the plot. Differences in benthic community structure and fish trophic biomass were analyzed using one-way permutational analysis of variance (PERMANOVA) on arcsin square root-transformed data and based on Bray-Curtis dissimilarity matrix. Fish biomass was compared among the four islands using a one-way Analysis of Variances (ANOVA).

Appendix III.

Scleractinian corals recorded during the expedition. Species are ordered by family. Species in bold are new records for the region. Assump. – Assumption, Cosm. – Cosmoledo, Sheppard & Obura 2005.

Family	Coral Species	Aldabra	Assump.	Astove	Cosm.	Sheppard & Obura
Acroporidae	*Acropora abrotanoides*	X				X
	Acropora anthoceris				X	X
	Acropora appressa	X		X	X	
	Acropora arabensis	X	X	X		X
	Acropora austera	X				X
	Acropora brueggemanni	X				X
	Acropora cerealis	X				X
	Acropora cf. polystoma	X	X		X	
	Acropora clathrata			X		X
	Acropora digitifera	X			X	X
	Acropora divaricata	X				X
	Acropora florida	X				X
	Acropora gemmifera	X				
	Acropora globiceps	X				X
	Acropora irregularis	X		X	X	
	Acropora latistella	X				X
	Acropora listeri			X		X
	Acropora massawensis	X				X
	Acropora microclados			X	X	X
	Acropora microphthalma				X	
	Acropora nana	X				X
	Acropora nobilis	X				
	Acropora pinguis	X		X		
	Acropora pulchra	X				
	Acropora retusa	X		X	X	X
	Acropora rosaria	X				X
	Acropora roseni		X		X	
	Acropora samoensis		X			X
	Acropora secale	X			X	X

Family	Coral Species	Aldabra	Assump.	Astove	Cosm.	Sheppard & Obura
	Acropora sp. 1 juvenile	X			X	X
	Acropora tenuis	X				X
	Acropora valida	X	X		X	X
	Astreopora listeri	X	X	X	X	X
	Astreopora myriophthalma	X	X	X	X	X
	Astreopora suggesta	**X**				
	Isopora palifera	X	X	X	X	X
	Montipora calcarea	X		X	X	X
	Montipora* cf. *caliculata	X		X	X	
	Montipora* cf. *meandrina		**X**		**X**	
	Montipora efflorescens	X		X		X
	Montipora effusa				X	
	Montipora floweri				X	
	Montipora grisea	X	X	X	X	X
	Montipora mollis	X		X	X	
	Montipora monasteriata	X		X	X	X
	Montipora sp. 1				X	X
	Montipora stilosa		X		X	X
	Montipora tuberculosa	X	X	X	X	X
	Montipora turgescens			X	X	X
	Montipora undata				X	X
	Montipora venosa			X		X
Agariciidae	*Gardineroseris planulata*	X	X	X	X	X
	Leptoseris mycetoseroides	X	X	X	X	X
	Pachyseris speciosa	X	X	X	X	X
	Pavona clavus	X	X		X	X
	Pavona diffluens	X		X	X	
	Pavona duerdeni	X		X	X	
	Pavona explanulata	X				X
	Pavona maldivensis				X	
	Pavona varians	X	X	X	X	X
	Pavona venosa	X			X	X
Astrocoeniidae	*Stylocoeniella armata*	X		X		X
Dendrophylliidae	*Turbinaria mesenterina*		X			X
	Turbinaria reniformis	X	X	X	X	X
	Turbinaria stellulata	X				X
Euphyllidae	*Physogyra lichtensteini*	X				X
Faviidae	*Cyphastrea agassizi*	X				
	Cyphastrea chalcidicum	**X**	**X**	**X**	**X**	**X**
	Cyphastrea microphthalma	X		X	X	X

APPENDIX III. CONTINUED.

Family	Coral Species	Aldabra	Assump.	Astove	Cosm.	Sheppard & Obura
Faviidae	*Cyphastrea serailia*	X		X		X
	Echinopora gemmacea	X	X		X	X
	Echinopora hirsutissima	X	X	X	X	X
	Favia matthaii	X	X	X	X	X
	Favia pallida		X	X	X	X
	Favia rotumana	X	X			X
	Favia speciosa	X				X
	Favia stelligera	X	X	X	X	X
	Favites abdita	X				X
	Favites flexuosa			X		X
	Favites halicora	X				X
	Favites micropentagona	X	X	X	X	X
	Favites pentagona	X	X			X
	Favites russelli		X	X		X
	Favites spinosa	X	X	X		X
	Favites stylifera	X		X	X	X
	Goniastrea aspera	X	X		X	
	Goniastrea edwardsi	X	X		X	X
	Goniastrea minuta			X		X
	Goniastrea palauensis	X	X	X	X	
	Goniastrea pectinata			X	X	X
	Goniastrea peresi	X	X	X	X	X
	Goniastrea retiformis	X	X		X	X
	Leptastrea aequalis		X			X
	Leptastrea bottae		X			X
	Leptastrea cf. bottae	X				X
	Leptastrea pruinosa	X	X	X	X	X
	Leptastrea purpurea	X	X	X	X	X
	Leptastrea transversa	X	X	X	X	X
	Leptoria phyrgia	X		X	X	X
	Montastrea colemani				X	X
	Montastrea curta	X	X	X	X	X
	Montastrea serageldini	X				
	Oulophyllia crispa		X	X	X	X
	Platygyra carnosus		X			X
	Platygyra crosslandi	X	X	X	X	X
	Platygyra daedalea	X	X	X	X	X
	Platygyra pini	X	X	X	X	X
	Platygyra ryukyuensis	X	X	X	X	X
	Platygyra sinensis	X				X
	Plesiastrea verispora	X				X

Family	Coral Species	Aldabra	Assump.	Astove	Cosm.	Sheppard & Obura
Fungiidae	*Cycloseris costulata*		X		X	X
	Fungia fungites				X	X
	Fungia klunzingeri		X			X
	Fungia scutaria	X	X		X	X
	Fungia seychellensis	X				X
	Halomitra pileus	X				
	Herpolitha limax	X				
	Podabacia crustacea				X	X
	Podabacia motuporensis	X			X	X
	Zoopilus echinatus				**X**	
Merulinidae	*Hydnophora exesa*	X	X	X	X	X
	Hydnophora microconos	X		X	X	X
	Merulina ampliata	X				X
Mussidae	*Acanthastrea brevis*	X	X	X	X	X
	Acanthastrea echinata	X	X		X	X
	Acanthastrea hemprichii	X				
	Acanthastrea ishigakiensis	X				X
	Blastomussa merleti	X				
	Lobophyllia corymbosa	X				
	Lobophyllia hemprichii	X	X		X	X
	Symphyllia radians	X	X		X	X
Oculinidae	*Galaxea fascicularis*	X			X	X
Pectiniidae	*Echinophyliia echinata*	X	X		X	X
	Echinophyllia echinoporoides			X		X
	Mycedium elephantotus	X	X	X	X	X
	Mycedium mancaoi				X	
	Oxypora crassispinosa	X			X	X
	Oxypora lacera		X		X	X
Pocilloporidae	*Pocillopora capitata*		X	X	X	X
	Pocillopora damicornis			X	X	X
	Pocillopora eydouxi	X	X	X	X	X
	Pocillopora indiania	X				X
	Pocillopora verrucosa	X	X	X	X	X
	Stylophora pistillata	X	X	X	X	X
Poritidae	***Goniopora burgosi***	**X**				
	Goniopora minor	X				X
	Goniopora planulata	X				
	Goniopora somaliensis		X			X
	Porites australiensis			X	X	X
	Porites cf. lichen	X				

APPENDIX III. CONTINUED.

Family	Coral Species	Aldabra	Assump.	Astove	Cosm.	Sheppard & Obura
Poritidae	*Porites cf.arnaudi*		X			
	Porites cylindrica	X		X	X	X
	Porites harrisoni	X		X		X
	Porites lobata	X	X	X	X	X
	Porites lutea	X	X	X	X	X
	Porites monticulosa	X			X	
	Porites profundus	X	X	X	X	X
	Porites rus	X			X	X
	Porites solida	X		X	X	X
Siderastreidae	*Coscinaraea columna*	X	X	X	X	X
	Coscinaraea monile	X	X	X	X	X
	Psammocora haimeana	X	X	X	X	X
	Psammocora nierstraszi			X	X	X
	Psammocora superficialis	X				
	165	124	71	75	100	130

Appendix IV.

Algae recorded on quantitative surveys in the Aldabra Group. Values are means of percent cover by island and overall mean percent cover.

Group	Taxa	Cosm.	Assump.	Astove	Aldabra	Mean
Turf algae	Turf algae	0.68	0.07	1.30	1.07	0.78
	Filamentous algae	0.00	0.07	0.00	0.00	0.02
Seagrass	*Thalassodendron ciliatum*	5.78	0.00	0.00	0.00	1.45
Red algae	*Hydrolithon onkodes*	10.25	1.70	9.83	7.67	7.36
	CCA unidentified	4.58	1.77	2.53	3.46	3.09
	Peyssonnelia sp.	2.03	1.10	1.67	1.09	1.47
	Hydrolithon "maërl"	0.00	0.00	0.00	3.54	0.89
	Peyssonnelia cf. *conchicola*	0.42	0.10	0.20	0.50	0.30
	Hydrolithon cf. *samoense*	0.07	0.03	0.50	0.00	0.15
	Hydrolithon craspedium	0.00	0.00	0.00	0.43	0.11
	Mesophyllum erubescens-like	0.00	0.00	0.00	0.30	0.08
	Peyssonnelia calcea	0.02	0.00	0.03	0.00	0.01
	Dictyurus purpurascens-like	0.02	0.00	0.00	0.24	0.06
	Portieria hornemannii	0.07	0.10	0.00	0.00	0.04
	Galaxaura filamentosa	0.02	0.00	0.00	0.00	0.00
Green algae	*Halimeda gracilis*	1.02	11.63	1.60	0.79	3.76
	Halimeda cf. *lacunalis*	0.03	14.47	0.00	0.26	3.69
	Halimeda cf. *stuposa*	0.93	5.30	0.00	1.99	2.05
	Halimeda micronesica	0.00	2.73	0.00	0.13	0.72
	Dictyosphaeria versluysii	0.62	1.40	0.00	0.04	0.51
	Caulerpa sp.	0.00	0.00	1.07	0.00	0.27
	Caulerpa racemosa turbinata	0.00	0.90	0.00	0.00	0.23
	Microdictyon okamurae	0.47	0.00	0.07	0.01	0.14
	Avrainvillea amadelpha	0.02	0.13	0.07	0.00	0.05
	Dictyosphaeria cavernosa	0.10	0.00	0.07	0.00	0.04
	Caulerpa serrulata	0.10	0.00	0.03	0.03	0.04
	Halimeda tuna	0.00	0.00	0.00	0.11	0.03
	Rhipilia tomentosa	0.00	0.00	0.10	0.00	0.03
	Caulerpa cupressoides	0.02	0.07	0.00	0.00	0.02
	Valonia fastigiata	0.05	0.00	0.00	0.00	0.01
	Chlorodesmis fastigiata	0.03	0.00	0.00	0.00	0.01
	Cladophoropsis sundanensis	0.02	0.00	0.00	0.00	0.00
Cyanobacteria	Cyanobacteria	0.03	0.03	0.00	0.04	0.03
Brown algae	*Lobophora variegata*	0.03	0.07	2.03	0.07	0.55
	Dictyota sp.	0.00	0.00	0.00	0.06	0.01

Appendix V.

Benthic taxa (excluding scleractinian corals) recorded on quantitative surveys in the Aldabra Group. Values are means of percent cover by island and overall mean percent cover.

Higher Grouping	Taxa	Aldabra	Assump.	Astove	Cosm.	Mean
Blue coral	*Heliopora coerula*	0.05	0.64	0.00	0.03	0.13
Fire coral	*Millepora* sp.	1.96	1.70	3.71	2.13	2.30
Hard coral	*Stylaster* sp.	0.00	0.03	0.00	0.00	0.01
Hydrarian	*Macrorhynchia philippina*	0.00	0.00	0.17	0.00	0.04
Mollusca	*Tridacna* sp.	0.01	0.00	0.00	0.03	0.01
Soft coral	*Dendronephthya* sp. 1 (spiny)	0.10	0.07	0.27	0.00	0.11
	Dendronepthya sp. 2 (simple)	0.39	0.00	1.33	2.83	1.14
	Dendronepthya sp. 3 (nice)	0.00	0.00	0.00	0.07	0.02
	Dendronepthya sp. 4	0.00	0.00	0.00	0.02	0.00
	Dendronepthya sp. 5(blue)	0.00	0.00	0.00	0.00	0.00
	Dendronepthya sp. 6 (alga-like)	0.00	0.00	0.00	0.58	0.15
	Gorgonian (asparagus-like)	0.21	0.00	0.00	0.00	0.05
	Gorgonian (deepwater fan, orange)	0.06	0.00	0.00	0.00	0.01
	Gorgonian (purple)	0.00	0.00	0.10	0.00	0.03
	Heteractis magnifica	0.00	0.03	0.10	0.02	0.04
	Palythoa sp.	0.53	0.00	1.23	0.07	0.46
	Rhytisma sp.	15.04	5.43	0.00	0.00	5.12
	Soft corals	4.71	6.00	0.30	8.98	5.00
	Stichodactylidae unidentified	0.00	0.10	0.00	0.00	0.03
	Zoanthus sp.	0.20	0.00	0.00	0.00	0.05
Sponge	Cliona sp. (black)	0.39	0.30	0.97	0.18	0.46
	Cliona sp. (plate-like, brown)	0.04	0.07	0.70	0.23	0.26
	Sponge (big, red-purple, tubular)	0.20	0.07	0.07	0.22	0.14
	Sponge 1 (Brown Petrosia)	0.30	0.37	1.67	0.00	0.58
	Sponge 2 (Crambe-like)	0.00	0.13	0.00	0.02	0.04
	Sponge 3 (red Crambe-like)	1.41	0.43	0.00	0.02	0.47
	Sponge sp. 4 (orange)	0.06	0.33	0.20	0.08	0.17
	Terpios hoshinota	0.07	0.00	0.00	0.00	0.02
	Unidentified sponges	0.20	0.03	0.60	0.33	0.29
Tunicate	*Didemnum molle*	0.09	0.00	0.00	0.00	0.02
	Tunicate (colonial)	0.33	0.00	0.00	0.20	0.13
	Tunicate (solitary)	0.00	0.13	0.47	0.03	0.16

Appendix VI.

Fish taxa observed during the expedition (listed in phylogenetic order).

Family	Species	Common name
Ginglymostomatidae	*Nebrius ferrugineus*	Tawny nurse shark
Carcharhinidae	*Carcharhinus albimarginatus*	Silvertip shark
	Triaenodon obesus	Whitetip reef shark
	Carcharhinus melanopterus	Blacktip reef shark
	Carcharhinus amblyrhynchos	Grey reef shark
Dasyatidae	*Himantura jenkinsii*	Jenkin's whipray
	Taeniurops meyeni	Round ribbontail ray
Myliobatidae	*Aetobatis narinari*	Spotted eagle ray
	Manta birostrios	Manta ray
Muraenidae	*Gymnothorax breedeni*	Black cheek moray
	Gymnothorax javanicus	Giant moray
	Gymnothorax meleasgris	Whitemouth moray
Congridae	*Heteroconger hassi*	Spotted garden eel
Chanidae	*Chanos chanos*	Milkfish
Synodontidae	*Synodus jaculum*	Tail-blotch lizardfish
	Synodus dermatogenys	Sand lizardfish
	Synodus variegatus	Variegated lizardfish
	Saurida nebulosa	Blotched saury
Holocentridae	*Sargocentron caudimaculatum*	White-tail squirrelfish
	Myripristis berndti	Yellow-fin soldierfish
	Sargocentron tiere	Blue lined squirrelfish
	Sargocentron spiniferum	Sabre squirrelfish
	Sargocentron microstomus	Smallmouth squirrelfish
	Neoniphon sammara	Spotfin squirrelfish
	Neoniphon opercularis	Mouthfin squirrelfish
	Myripristis vittata	Immaculate soldierfish
	Myripristis violacea	Violet squirrelfish
	Myripristis murdjan	Crimson soldierfish
	Myripristis kuntee	Epaulette soldierfish
	Sargocentron diadema	Crown squirrelfish
	Myripristis adusta	Shadowfin soldierfish
	Myripristis melanosticta	Splendid soldierfish

APPENDIX VI. CONTINUED.

Family	Species	Common name
Aulostomidae	*Aulostomus chinensis*	Trumpetfish
Fistulariidae	*Fistularia commersonii*	Smooth coronetfish
Scorpaenidae	*Scorpaenopsis diabola*	False stonefish
Serranidae	*Pseudanthias evansi*	Yellow-tail basslet
	Epinephelus polyphekadion	Camouflage grouper
	Epinephelus multinotatus	White-blotched grouper
	Epinephelus lanceolatus	Giant grouper
	Epinephelus fuscoguttatus	Flower grouper
	Epinephelus fasciatus	Blacktip grouper
	Epinephelus areolatus	Aerolate grouper
	Epinephelus tukula	Potato cod
	Gracila albomarginata	White-square grouper
	Luzonichthys microlepis	Slender splitfin
	Nemanthias carberryi	Threadfin basslet
	Epinephelus spilotoceps	Foursaddle grouper
	Plectropomus punctatus	Marbled coral trout
	Cephalopholis spiloparaea	Orange rock cod
	Pseudanthias squamipinnis	Orange basslet
	Variola louti	Lunar-tail grouper
	Dermatolepis striolatus	Smooth grouper
	Cephalopholis nigripinnis	Blackfin rock cod
	Aethaloperca rogaa	Red-flushed grouper
	Cephalopholis argus	Peacock grouper
	Cephalopholis leopardus	Leopard rock cod
	Cephalopholis miniata	Vermilion rock cod
	Plectropomus laevis	Black-saddle coral trout
Priacanthidae	*Priacanthus hamrur*	Moontail bigeye
Apogonidae	*Cheilodipterus quinquelineatus*	Five-lined cardinalfish
	Apogon angustatus	Narrow-striped cardinalfish
	Apogon apogonoides	Plain cardinalfish
	Apogon fraenatus	Tapered-line cardinalfish
	Apogon kallopterus	Iridescent cardinalfish
	Rhabdamia gracilis	Slender cardinalfish
	Cheilodipterus macrodon	Large toothed cardinalfish
	Apogon nigrofasciatus	Black-striped cardinalfish
Malacanthidae	*Malacanthus latovittatus*	Blue tilefish
	Malacanthus brevirostris	Flagtail tilefish
Carangidae	*Caranx melampygus*	Bluefin trevally
	Scomberoides lysan	Double-spotted queenfish
	Elagatis bipinnulata	Rainbow runner

Family	Species	Common name
Carangidae	*Caranx sexfasciatus*	Bigeye trevally
	Carangoides ferdau	Barred trevally
	Caranx ignobilis	Giant trevally
	Trachinotus blochii	Snub-nose pompano
Lutjanidae	*Lutjanus monostigma*	One-spot snapper
	Lutjanus kasmira	Blue-lined snapper
	Lutjanus gibbus	Paddletail snapper
	Lutjanus fulviflamma	Dory snapper
	Lutjanus ehrenbergii	Black-spot snapper
	Aphareus furca	Small-tooth jobfish
	Aprion virescens	Green jobfish
	Lutjanus bohar	Red snapper
	Lutjanus fulvus	Blacktail snapper
	Lutjanus bengalensis	Bengal snapper
	Macolor niger	Black snapper
	Lutjanus rivulatus	Blubberlip snapper
Caesionidae	*Pterocaesio tile*	Blue-dash fusilier
	Pterocaesio lativittata	Broad-stripe fusilier
	Caesio teres	Yellow-tail fusilier
	Caesio xanthonota	Yellow-back fusilier
	Pterocaesio chrysozona	Yellow-stripe fusilier
	Caesio lunaris	Moon fusilier
	Caesio sp.1	Two-lined fusilier
Haemulidae	*Plectorhinchus paulayi*	Zebra sweetlip
	Plectorhinchus vittatus	Indian Ocean oriental sweetlips
	Plectorhinchus picus	Spotted sweetlip
	Plectorhinchus albovittatus	Giant sweetlip
	Plectorhinchus plagiodesmus	Barred sweetlip
Lethrinidae	*Lethrinus obsoletus*	Orange-stripe emperor
	Monotaxis grandoculis	Large-eye bream
	Gnathodentex aureolineatus	Gold-spot emperor
	Lethrinus erythracanthus	Yellowfin emperor
	Lethrinus lentjan	Red-spot emperor
	Lethrinus mahsena	Mahsena emperor
	Lethrinus microdon	Small-tooth emperor
	Lethrinus nebulosus	Spangled emperor
	Lethrinus olivaceus	Longnosed emperor
	Lethrinus variegatus	Slender emperor
	Lethrinus xanthochilus	Yellow-lip emperor

APPENDIX VI. CONTINUED.

Family	Species	Common name
Mullidae	*Parupeneus pleurostigma*	Round-spot goatfish
	Parupeneus rubescens	Redstripe goatfish
	Mulloidichthys flavolineatus	Yellow-stripe goatfish
	Mulloidichthys vanicolensis	Yellowfin goatfish
	Parupeneus barberinus	Dot-and-dash goatfish
	Parupeneus ciliatus	Whitesaddle goatfish
	Parupeneus cyclostomus	Yellow-saddle goatfish
	Parupeneus macronema	Long-barbel goatfish
	Parupeneus trifasciatus	Double-bar goatfish
Pempheridae	*Pempheris tominagai*	Indian Ocean sweeper
	Pempheris vanicolensis	Greenback sweeper
Kyphosidae	*Kyphosus cinerascens*	Highfin chub
Chaetodontidae	*Chaetodon xanthocephalus*	Yellow-head butterflyfish
	Heniochus monoceros	Masked bannerfish
	Hemitaurichthys zoster	Black pyramid butterflyfish
	Chaetodon bennetti	Bluelashed butterflyfish
	Chaetodon falcula	Double-saddle butterflyfish
	Forcipiger longirostris	Very long-nose butterflyfish
	Chaetodon guttatissimus	Spotted butterflyfish
	Chaetodon kleinii	Brown butterflyfish
	Chaetodon interruptus	Yellow teardrop butterflyfish
	Chaetodon auriga	Threadfin butterflyfish
	Heniochus acuminatus	Reef bannerfish
	Chaetodon trifasciatus	Pinstriped butterflyfish
	Chaetodon lineolatus	Lined butterflyfish
	Chaetodon lunula	Raccoon butterflyfish
	Chaetodon madagaskariensis	Madagascar butterflyfish
	Chaetodon melannotus	Black-back butterflyfish
	Chaetodon meyeri	Meyer's butterflyfish
	Chaetodon mitratus	Indian butterflyfish
	Chaetodon trifascialis	Chevron butterflyfish
	Forcipiger flavissimus	Long-nose butterflyfish
Pomacanthidae	*Pomacanthus imperator*	Emperor angelfish
	Centropyge bispinosa	Two-spined angelfish
	Pomacanthus chrysurus	Goldtail angelfish
	Centropyge acanthops	Orangeback angelfish
	Pygoplites diacanthus	Regal angelfish
	Centropyge multispinis	Dusky angelfish
	Pomacanthus semicirculatus	Semi-circular angelfish
	Apolemichthys trimaculatus	Three-spot angelfish

Family	Species	Common name
Cirrhitidae	*Paracirrhites arcatus*	Arc-eye hawkfish
	Paracirrhites forsteri	Forster's hawkfish
	Cirrhitichthys oxycephalus	Spotted hawkfish
Pomacentridae	*Abudefduf vaigiensis*	Sergeant major
	Dascyllus trimaculatus	Three-spot dascyllus
	Stegastes insularis	Island gregory
	Pomacentrus sulfureus	Sulfur damselfish
	Pomacentrus caeruleus	Blue-yellow damselfish
	Plectroglyphidodon lacrymatus	Jewel damselfish
	Plectroglyphidodon johnstonianus	Johnson's damselfish
	Plectroglyphidodon dickii	Narrowbar damselfish
	Lepidozygus tapeinosoma	Fusilier damselfish
	Amphiprion akallopisos	Skunk clownfish
	Amphiprion allardi	Twobar clownfish
	Dascyllus carneus	Indian dascyllus
	Abudefduf sparoides	False-eye sergeant
	Amphiprion clarkii	Yellow-tail clownfish
	Chromis dimidiata	Chocolate-dip chromis
	Chromis nigrura	Black-tail chromis
	Chromis opercularis	Double-bar chromis
	Chromis ternatensis	Ternate chromis
	Chromis weberi	Weber's chromis
	Chromis xutha	Buff chromis
	Abudefduf sexfasciatus	Siccortail sergeant
Labridae	*Hologymnosus semidiscus*	Ringed wrasse
	Anampses twistii	Yellow-breasted wrasse
	Bodianus axillaris	Axil-spot hogfish
	Bodianus anthioides	Lyre-tail hogfish
	Biochoeres leucoxanthus	Canarttop wrasse
	Biochoeres cosmetus	Adorned wrasse
	Anampses meleagrides	Spotted wrasse
	Anampses lineatus	Lined wrasse
	Anampses caeruleopunctatus	Blue-spotted wrasse
	Allocoris formosa	Queen rainbow wrasse
	Bodianus bilunulatus	Saddle-back hogfish
	Allocoris cuvieri	African rainbow wrasse
	Pseudocheilinus octotaenia	Eight-lined wrasse
	Labroides bicolor	Bicolor cleaner wrasse
	Labroides dimidiatus	Blue-streak cleaner wrasse

APPENDIX VI. CONTINUED.

Family	Species	Common name
Labridae	*Labropsis xanthonota*	Yellow-back tubelip wrasse
	Labridae	Unknown wrasse
	Macropharyngodon bipartitus	Splendid leopard wrasse
	Novaculoides macrolepidotus	Seagrass wrasse
	Pseudocheilinus evanidus	Striated wrasse
	Pseudocheilinus hexataenia	Six-line wrasse
	Iniistius pavo	Peacock wrasse
	Pseudodax moluccanus	Chiseltooth wrasse
	Novaculichthys taeniourus	Rockmover wrasse
	Pseudocoris heteroptera	Torpedo wrasse
	Pseudojuloides species	wrasse
	Pteragogus sp.	Cryptic wrasse
	Stethojulis albovittata	Blue-lined wrasse
	Thalassoma amblycephalum	Blunt-headed wrasse
	Thalassoma herbraicum	Goldbar wrasse
	Thalassoma janseni	Jansen's wrasse
	Thalassoma lunare	Moon wrasse
	Bodianus diana	Diana's hogfish
	Hemitautoga scapularis	Zigzag wrasse
	Halichoeres iridis	Rainbow wrasse
	Cheilinus bimaculatus	Two-spot wrasse
	Cheilinus chlorourus	Floral wrasse
	Cheilinus digrammus	Cheek-line Maori wrasse
	Cheilinus fasciatus	Banded Maori wrasse
	Cheilio inermis	Cigar wrasse
	Cheilinus trilobatus	Triple-tail wrasse
	Cheilinus undulatus	Napoleon wrasse
	Cirrhilabrus exquisitus	Exquisite wrasse
	Coris aygula	Clown coris
	Coris caudimacula	Spot-tail coris
	Diproctacanthus xanthurus	Yellowtail tubelip
	Epibulus insidiator	Slingjaw wrasse
	Oxycheilinus digrammus	Cheek-lined wrasse
	Gomphosus caeruleus	Green bird wrasse
	Hemicoris batuensis	Batu rainbow wrasse
	Hologymnosus doliatus	Narrow-banded wrasse
	Hemigymnus melapterus	Blackeye thicklip wrasse
	Hemitautoga hortulanus	Checkerboard wrasse
	Hemigymnus fasciatus	Barred thicklip wrasse

Family	Species	Common name
Scaridae	*Calotomus carolinus*	Carolines parrotfish
	Cetoscarus bicolor	Bicolour parrotfish
	Chlorurus capistratoides	Black-tip parrotfish
	Scarus tricolor	Three-color parrotfish
	Leptoscarus vaigensis	Marbled parrotfish
	Bolbometopon muricatum	Bumphead parrotfish
	Scarus caudofasciatus	Bartail parrotfish
	Scarus rubroviolaceus	Redlip parrotfish
	Scarus psittacus	Palenose parrotfish
	Scarus prasiognathos	Greenthroat parrotfish
	Chlorurus strongylocephalus	Steaphead parrotfish
	Scarus niger	Dusky parrotfish
	Scarus frenatus	Bridled parrotfish
	Scarus festivus	Festive parrotfish
	Scarus scaber	Five-saddle parrotfish
	Scarus capistratoides	Indian parrotfish
	Chlorurus sordidus	Bullet-head parrotfish
	Hipposcarus harid	Longnose parrotfish
Pinguipedidae	*Parapercis signata*	Maldives sandperch
Blenniidae	*Ecsenius midas*	Lyre-tail combtooth blenny
	Ecsenius minutus	Little combtooth blenny
	Exallias brevis	Shortbodied blenny
	Plagiotremus rhinorhynchos	Blue-stripe fangblenny
	Plagiotremus tapeinosoma	Mimic blenny
	Cirripectes castaneus	Chestnut eyelash-blenny
	Cirripectes auritus	Black-flap blenny
	Blenniidae	Unknown blenny
Callionymidae	Dragonet	Dragonet
Gobiidae	*Fusigobius duospilus*	Barenape goby
	Eviota sebreei	Sebree's dwarfgoby
	Valenciennea strigata	Blueband goby
	Gnatholepis species	Sand-goby
	Gnatholepis anjerensis	Eye-bar goby
	Fusigobius maximus	Large sandgoby
	Amblyeleotris wheeleri	Barred shrimpgoby
	Amblyeleotris sp.	Shrimp goby
	Fusigobius neophytus	Neophyte sandgoby
Microdesmidae	*Nemateleotris magnifica*	Fire goby
	Ptereleotris evides	Blackfin dartfish

APPENDIX VI. CONTINUED.

Family	Species	Common name
Microdesmidae	*Ptereleotris heteroptera*	Blacktail goby
Ephippidae	*Platax orbicularis*	Orbicular batfish
Siganidae	*Siganus argenteus*	Schooling rabbitfish
	Siganus stellatus	Brown-spotted rabbitfish
Acanthuridae	*Naso annulatus*	Whitemargin unicornfish
	Naso vlamingii	Bignose unicornfish
	Naso unicornis	Bluespine unicornfish
	Naso thynnoides	One-spine unicornfish
	Naso Mcdadei	Hump-nose unicornfish
	Naso hexacanthus	Sleek unicornfish
	Naso elegans	Elegant unicornfish
	Naso brevirostris	Spotted unicornfish
	Ctenochaetus truncatus	Indian gold-ring bristle-tooth
	Naso brachycentron	Humpback unicornfish
	Ctenochaetus binotatus	Twospot surgeonfish
	Ctenochaetus striatus	Striated surgeonfish
	Zebrasoma scopas	Twotone tang
	Zanclus cornutus	Moorish idol
	Paracanthurus hepatus	Palette surgeonfish
	Acanthurus auranticavus	Orange-socket surgeonfish
	Acanthurus xanthopterus	Yellowfin surgeonfish
	Acanthurus thompsoni	Thompson's surgeonfish
	Acanthurus tennenti	Doubleband surgeonfish
	Acanthurus nigrofuscus	Brown surgeonfish
	Acanthurus nigricauda	Epaulette surgeonfish
	Acanthurus lineatus	Lined surgeonfish
	Acanthurus leucocheilus	Pale-lipped surgeonfish
	Acanthurus leucosternon	Powderblue surgeonfish
	Acanthurus dussumieri	Eyestripe surgeonfish
	Zebrasoma desjardinii	Indian sail-fin surgeonfish
Sphyraenidae	*Sphyraena barracuda*	Great barracuda
Scombridae	*Gymnosarda unicolor*	Dogtooth tuna
	Scomberomorus commerson	Narrowbanded Spanish mackerel
Balistidae	*Sufflamen bursa*	Boomerang triggerfish
	Rhinecanthus cinereus	Strickland's triggerfish
	Xanthichthys auromarginatus	Gilded triggerfish
	Sufflamen fraenatus	Masked triggerfish
	Pseudobalistes flavimarginatus	Yellow-margin triggerfish
	Sufflamen chrysopterus	Halfmoon triggerfish

Family	Species	Common name
Balistidae	*Odonus niger*	Red-toothed triggerfish
	Melichthys niger	Black triggerfish
	Melichthys indicus	Indian triggerfish
	Balistoides viridescens	Titan triggerfish
	Balistoides conspicillum	Clown triggerfish
	Balistapus undulatus	Orange-lined triggerfish
Monacanthidae	*Cantherines pardalis*	Honeycomb filefish
	Paraluteres arqat	Indian Ocean mimic filefish
	Paraluteres prionurus	False puffer
	Pervagor aspricaudus	Orange filefish
	Pervagor janthinosoma	Blackbar filefish
	Amanses scopas	Broom filefish
	Aluterus scriptus	Scrawled filefish
	Cantherines dumerilii	Barred filefish
Ostraciidae	*Ostracion meleagris*	Whitespotted boxfish
Tetraodontidae	*Canthigaster smithae*	Bicolored toby
	Canthigaster smithae	Smith's toby
	Canthigaster tyleri	Tyler's toby
	Canthigaster valentini	Valentin's sharpnose puffer
	Arothron stellatus	Stellate puffer
	Canthigaster janthinoptera	Honeycomb toby
	Arothron nigropunctatus	Blackspotted puffer
	Arothron meleagris	Guineafowl puffer
	Arothron mappa	Map puffer
Diodontidae	*Diodon liturosus*	Black-blotched porcupinefish

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