21 Fiji

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Abstract

The nearly 1000 islands, islets, atolls, and reefs of Fiji are located in the southwestern tropical Pacific Ocean, east of Vanuatu and New Caledonia, and west of Samoa and Tonga. The Fiji islands include a rich variety of habitats and consistently clear, calm, and warm offshore waters. Shallow coral reefs in Fiji have been subject to a great deal of research, but research on mesophotic coral ecosystems (MCEs) has been limited primarily to fishes. A series of expeditions from 2001 to 2010 using mixed-gas, closed-circuit rebreathers resulted in the discovery of many new species. Data downloaded from the Global Biodiversity Information Facility (GBIF) reveal a clear pattern of undersampling on MCEs for all taxonomic groups. Patterns of diversity and species richness among fishes are similar to those for reef fishes in general. A series of controlled rotenone stations at depths of 0–120 m at one particular site suggest that fish diversity on MCEs may approximate that of shallow reefs and that as many as 30% of the total ichthyofauna may consist of undescribed (and undiscovered) species. Very little is known about the ecology of MCEs in Fiji. Fijian MCEs face the same general threats as adjacent shallow reefs, in addition to global-scale threats facing reefs worldwide (i.e., climate change, ocean acidification, and overfishing of food fishes). The geographic location, variety of habitats, excellent diving conditions, and logistical infrastructure suggest that Fiji is an excellent location to conduct additional MCE research in the Pacific.

Keywords

Mesophotic coral ecosystems · Fiji · Coral reef · Fish · Technical diving

21.1 Introduction

Fiji is located in the southwestern tropical Pacific Ocean, east of Vanuatu and New Caledonia, and west of Samoa and Tonga. Nearly 1000 islands, islets, and atolls make up the Fiji Archipelago (including Rotuma in the north, Ceva-I-Ra to the southwest, and Ona-I-Lau to the southeast), ranging from approximately 11 to 21.75° S latitude and 174.6° E to 169° W longitude (Fig. 21.1). The archipelago consists of two large islands (Viti Levu and Vanua Levu), over 330 smaller islands (over 100 of which are inhabited), and more than 500 islets and atolls. The Lau Group in the east consists of mostly small islands, islets, and atolls, extending to Ona-I-Lau in the southeast corner. The Great Astrolabe Reef surrounding Kadavu Island south of Viti Levu is considered one of the largest barrier reefs in the world. Cakaulevu Reef (Great Sea Reef), north of Vanua Levu and stretching to the Yasawa Group, is likewise considered one of the world's longest barrier reefs. Rotuma, an isolated island 460 km to the northwest of the main Fijian islands, and tiny Ceva-I-Ra (Conway Reef), 450 km to the southwest, are both part of the nation of Fiji but are not geographically or geologically part of the Fiji Archipelago.

Shallow coral reefs in Fiji have been subject to a great deal of research, but research on mesophotic coral ecosystems (MCEs; 30–150 m; Hinderstein et al. 2010) has been limited primarily to fishes. Due to the high overall marine diversity, and the robust support for marine research provided by the School of Marine Studies at the University of the South Pacific (USP) in Suva (Viti Levu) (USP 2017), Fiji is an ideal location to study coral reef biodiversity, which is reflected in the large number of publications involving Fijian coral reefs (15,000+).[1] This chapter summarizes what is known about Fijian MCEs.

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[1]A search on Google Scholar for publications since 1950 with the search term "Fiji coral reef" yields over 15,000 results. Almost all of this research is focused on shallow-reef habitats.

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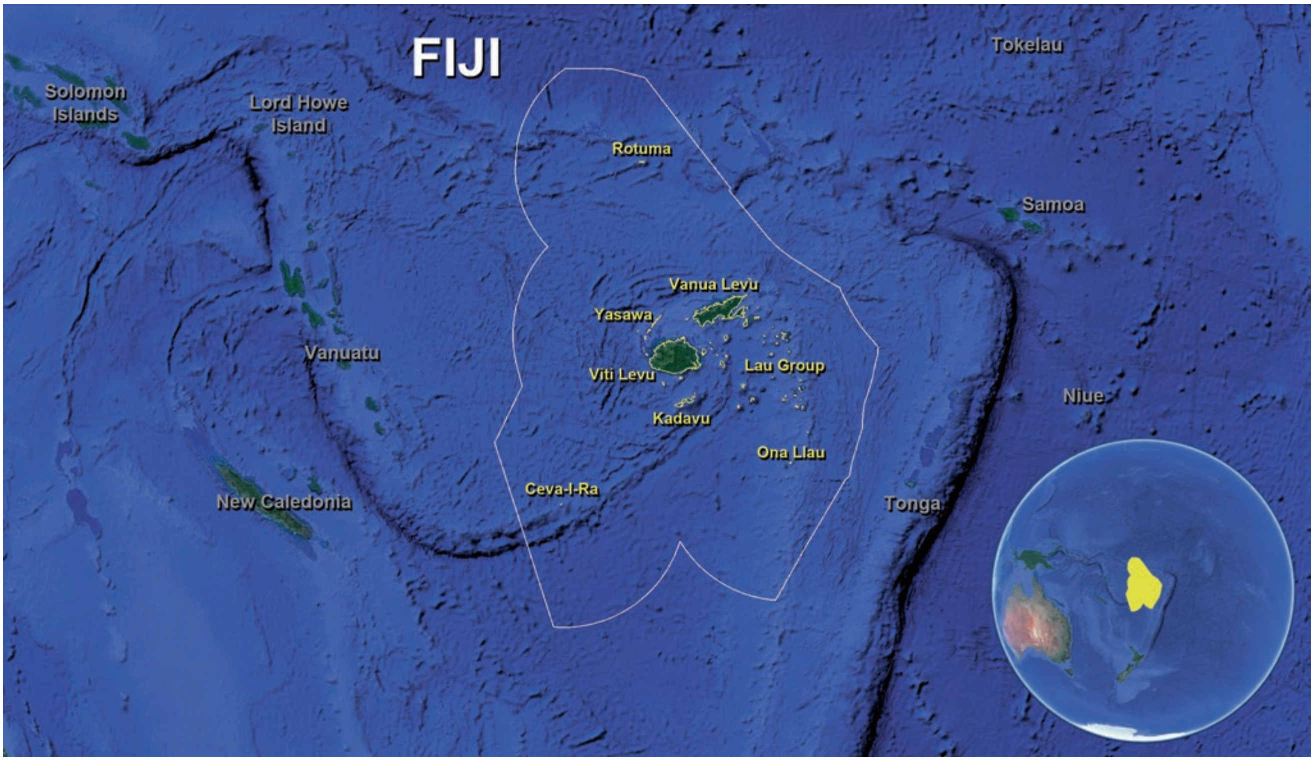

Fig. 21.1 Map of Fiji, showing the extent of the exclusive economic zone (EEZ) and main islands. (Base layer and inset courtesy Google Earth; EEZ modified from GML file obtained from Flanders Marine Institute; composite image assembled by R.L. Pyle)

21.1.1 Research History

Fiji has a long history of scientific research, including marine organismal specimens collected at least 250 years ago. The earliest scientific expeditions to Fiji were made by the French (Quoy and Gaimard 1824; Duperrey 1825–1830; Dumont d'Urville 1830–1834; Eydoux and Souleyet 1841). In 1838–1842, the US Exploring Expedition visited Fiji and collected specimens from marine environments, which are deposited at the US National Museum of Natural History. A brief summary (primarily focused on fishes) of expeditions to Fiji, from the Challenger Expedition (Günther 1889) through expeditions in the early twentieth century (Kendall and Goldsborough 1911; Nutting 1924; Borodin 1932; Herre 1935; Seale 1935; Fowler 1940), was published by Seeto and Baldwin (2010).

In contrast to shallow reefs, research focused on MCEs in Fiji is comparatively limited. Among the first to explore the MCEs of Fiji was Anthony Nahacky, who conducted many conventional SCUBA dives to MCE depths in search of rare fishes starting in the 1980s. This research included the first discovery of *Pseudanthias flavicauda* Randall and Pyle 2001. Two expeditions incorporating technical diving (see Pyle 2019) using mixed-gas, closed-circuit rebreathers were conducted as part of the production for the IMAX® feature film *Coral Reef Adventure* in 2001 (MFF 2003). These expeditions, lasting a month each, involved the use of rebreathers to enable access to depths of up to 120 m and included the collection of specimens and filming using large-format film and digital video. During the second of these expeditions, in March 2001, several specimens were collected and hours of video taken within MCE habitats in several locations in Fiji (Pyle, pers. obs.). In 2002, a team of rebreather divers participated in a project funded by the US National Science Foundation to document Fijian reef fishes (Pyle, pers. obs.). The project, led by David W. Greenfield, enabled additional exploration, as well as controlled fish collection stations from 0 to 120 m depth (Fig. 21.2; Pence and Pyle 2002). Additional video images of MCEs were captured during rebreather dives on MCEs in 2004 (Pyle, pers. obs.). Although no specimens were collected in 2004, the video included recordings of likely new species, including one in the genus *Symphysanodon* (Anderson and Springer 2005).

Preliminary data from these expeditions have allowed a direct comparison of fish diversity across different depths at a single site, using controlled fish sampling techniques (see *Fishes* Sect. 21.4.1). In addition, at least seven new deep-dwelling species of fishes have been described (Randall and Pyle 2001; Smith-Vaniz 2005; Randall 2006; Walsh and Tanaka 2012; Fukui and Motomura 2015; Winterbottom 2017), and many more are awaiting formal description (Fig. 21.3).

Fig. 21.2 The island of Viti Levu, showing sites where most rebreather dives have been conducted within MCEs. (Base layer courtesy Google Earth; composite image assembled by R.L. Pyle)

Several more recent projects have documented MCEs in Fiji. From 2008 to 2010, three separate expeditions conducted by John L. Earle and Robert K. Whitton with support from Mike Neumann of Beqa Adventure Divers focused on compiling a comprehensive list of fishes found at Shark Reef, off Pacific Harbor, Viti Levu (Fig. 21.2; Beqa Adventure Divers 2010). Although most of those surveys focused on shallow reefs at depths of 0–30 m, the 2010 expedition involved the use of closed-circuit rebreathers for extended time at depths of 30–50 m. A 2013 study examined video obtained by remotely operated vehicles (ROVs) to characterize changes in community assemblages of various taxonomic groups across depths of 10–130 m (Ayroza 2016). In May 2017, Project Baseline conducted an expedition to Fiji in collaboration with researchers at USP, using both divers (for shallow-reef habitats) and a submersible (down to 362 m), and obtained both specimens and video that are currently being analyzed (Project Baseline 2017a, b).

The potential for further research on MCEs in Fiji is very high. A variety of shallow and MCE environments exist in close proximity to robust and reliable ground-based logistical support. These include the facilities at USP, a major international airport, many boats set up to support diving activities, and other important resources being available locally (e.g., helium). The habitats are ideal for exploration using technical diving techniques, with warm clear water supporting rich MCE communities, and many vertical reef drop-offs to facilitate decompression. Given the geographic location of Fiji within the Pacific, and its rich and well-studied shallow-reef ecosystems, the opportunity exists not only for discovering new species but also for conducting future controlled quantitative research comparing coral reef diversity and ecology across all depths, including both shallow reefs and MCEs.

21.2 Environmental Setting

The Fiji Archipelago is located in the southwestern tropical Pacific, south of the South Equatorial Current and at the northwest edge of the South Pacific Gyre. Surface water temperatures vary from an average low of about 25 °C during the winter (June to July) to an average high of about 28 °C during the summer, with maximum water temperatures occurring in January to March (Reynolds and Smith 1994).

21.3 Habitat Description

Fiji includes about 35% of all coral reef area in the southwestern Pacific (Jupiter et al. 2012). The bathymetric and geologic characteristics of Fiji are complex (Dickinson

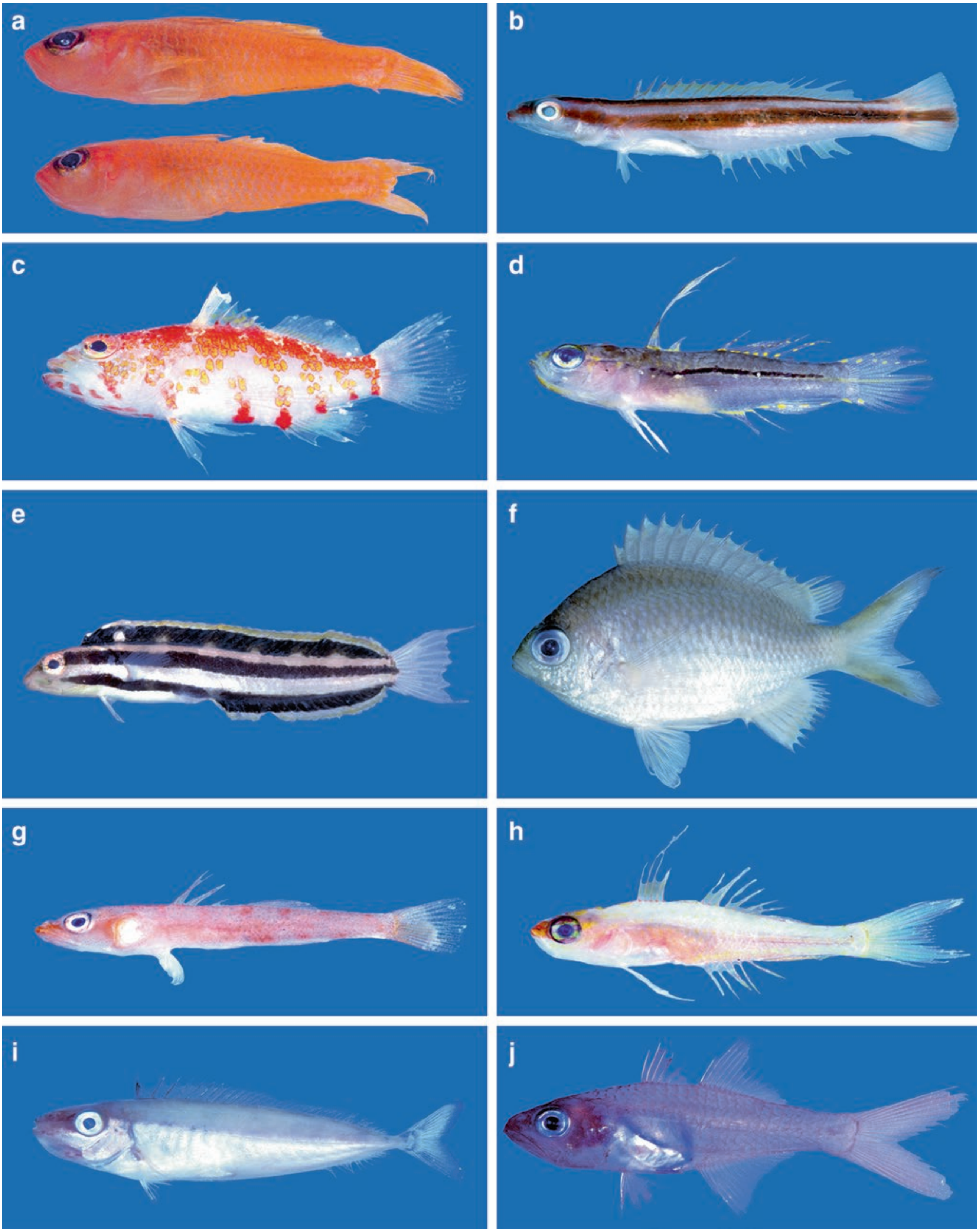

Fig. 21.3 Sample of new species discovered during deep dives in Fiji: (**a**) *Trimma bathum* Winterbottom 2017, (**b**) *Terelabrus dewapyle* Fukui and Motomura 2015, (**c**) *Plectranthias* n. sp., (**d**) *Tryssogobius nigrolineatus* Randall 2006, (**e**) *Petroscirtes pylei* Smith-Vaniz 2005, (**f**) *Chromis* n. sp., (**g**) Percophididae n. sp., (**h**) Gobiidae n. sp., (**i**) Acanthuridae? n. sp., and (**j**) Apogonidae n. sp. Background color of images have been altered. (Photo credits: R.L. Pyle, can be reused under the CC BY license)

1967) and result in many geologic features and different reef profiles between 0 and 200 m depth. Most outer reef areas include steep slopes and drop-offs extending from shallow reefs to well below MCE depths. Krüger and Kumar (2008) provide detailed bathymetric data for the southern coast of Viti Levu at depths ranging from approximately 20 to 2000 m.

MCEs in Fiji are similar in general structure and appearance to those found elsewhere throughout Oceania (except Hawai'i) and the tropical western Pacific (Bridge et al. 2019; Cabaitan et al. 2019; Colin and Lindfield 2019; Heyward and Radford 2019; Longenecker et al. 2019; Montgomery et al. 2019; Pichon 2019; Pyle and Copus 2019; Pyle et al. 2019; Rowley et al. 2019). MCEs in Fiji (and elsewhere in the tropical insular Pacific) are typically along vertical limestone drop-offs or steeply sloping bathymetry, and the primary habitat-forming corals are gorgonians and antipatharians, rather than scleractinians or sponges (Fig. 21.4). In contrast, the MCEs in Hawai'i consist of undercut limestone ledges representing ancient shorelines along otherwise gently sloping flat sandy bottoms and expansive beds of *Leptoseris* corals and *Halimeda* algae (Spalding et al. 2019).

21.4 Biodiversity

General patterns of biodiversity on Fijian MCEs, as compared with the shallow reefs, were assessed using occurrence records (i.e., records representing the occurrence of a particular species at a particular place and time) from two separate databases: the Explorer's Log (explorers-log.com) and the Global Biodiversity Information Facility (GBIF; gbif.org). The Explorer's Log is very robust in terms of accuracy but limited in total content. GBIF is extremely comprehensive but includes errors both in terms of taxonomic identification and associated data (see Robertson 2008). Nevertheless, it does include the most complete representation of biodiversity inhabiting both shallow reefs and MCEs across all taxa (see Pyle et al. 2019 for a discussion of how these data were obtained and analyzed, as well as inherent limitations). A search for records in the GBIF database at depths between 0 and 200 m in Fiji (11° S, 174.5° E and 22.5° S, 178° W) resulted in 11,944 occurrence records representing 2155 species among 16 phyla (12 animals, 3 algae, and 1 Foraminifera; GBIF 2017). Using the same filter criteria, the Explorer's Log database yielded 3026 occurrence records representing a total of 532 species among 73 families in five phyla (corals, crustaceans, mollusks, echinoderms, and fishes; Explorer's Log 2017). Contents of both databases were combined, and a summary of the phyla and their depth ranges is presented in Table 21.1.

The combined databases include occurrence records from a total of 2324 unique species among 1024 genera and 403 families. All phyla have at least one representative species recorded from shallow reefs. Conversely, 4 animal phyla (Cephalorhyncha, Gnathostomulida, Nematoda, and Platyhelminthes), with a combined 9 species and 39 occurrence records, did not include any species recorded from MCEs. Likewise, none of the 3 algae divisions (Chlorophyta, Rhodophyta, and Tracheophyta), with a combined 5 species and 42 occurrence records, were from MCE depths. A total of 181 species were recorded from depths in excess of 150 m, half of which (91) did not occur at shallower depths.

Species depth distributions were analyzed by depth zones (Fig. 21.5). A total of 1573 species from 762 genera among 324 families are recorded only from shallow reefs. By comparison, 407 species from 244 genera among 131 families are known only from MCE depths or greater (>30 m). An additional 362 species from 63 genera and 41 families have been recorded from both shallow and MCE depths. At least 160 of the 407 species (39%) that are restricted to depths below 30 m also occur at depths below MCEs (>150 m), and 91 of these are restricted to depths in excess of 150 m (i.e., do not occur on MCEs as currently defined). Only 22 species (<1%) have been recorded from both shallow reefs and depths in excess of 150 m.

Many of the species recorded from only shallow reefs may also occur on MCEs, but may not have been recorded due to sampling bias. However, it is highly unlikely that many of the species recorded only from MCEs also occur on shallow reefs. Thus, part of the disparity in number of shallow-only species compared with MCE-only species is due to sampling bias. Another consideration is that the MCE depth zone (30–150 m) is four times broader than the shallow depth zone (0–30 m). Even accounting for sampling bias, it is very unlikely that four times as many species occur on MCEs than on shallow reefs. Therefore, it is very likely that diversity per available habitat area is higher on shallow reefs than on MCEs. This finding is consistent with results from other studies that control for sampling bias.

To examine the extent of sampling bias, records were clustered into 10-m depth zones. In addition to the number of occurrence records and the number of distinct species within each depth zone, a count of the number of observation/collection days across each zone was used as a very rough approximation of effort (Table 21.2 and Fig. 21.6). The approximate effort varied considerably across depths as predicted, with far more effort concentrated in the shallower depth zones. Species per unit effort (SPUE; number of species per observation per collection day) varied widely, but not in a consistent way. The number of species recorded per day of collecting effort ranged from about 3 to 10 species per day of collecting time for most depth ranges to as many as 15–25 species per collecting day at 140–160 m. Whether these variations reflect actual trends or just noise in the data is unclear. However, given that nearly 80% of the total collecting days were concentrated in the shallowest 20% of the total depth range of coral ecosystems, there is no question

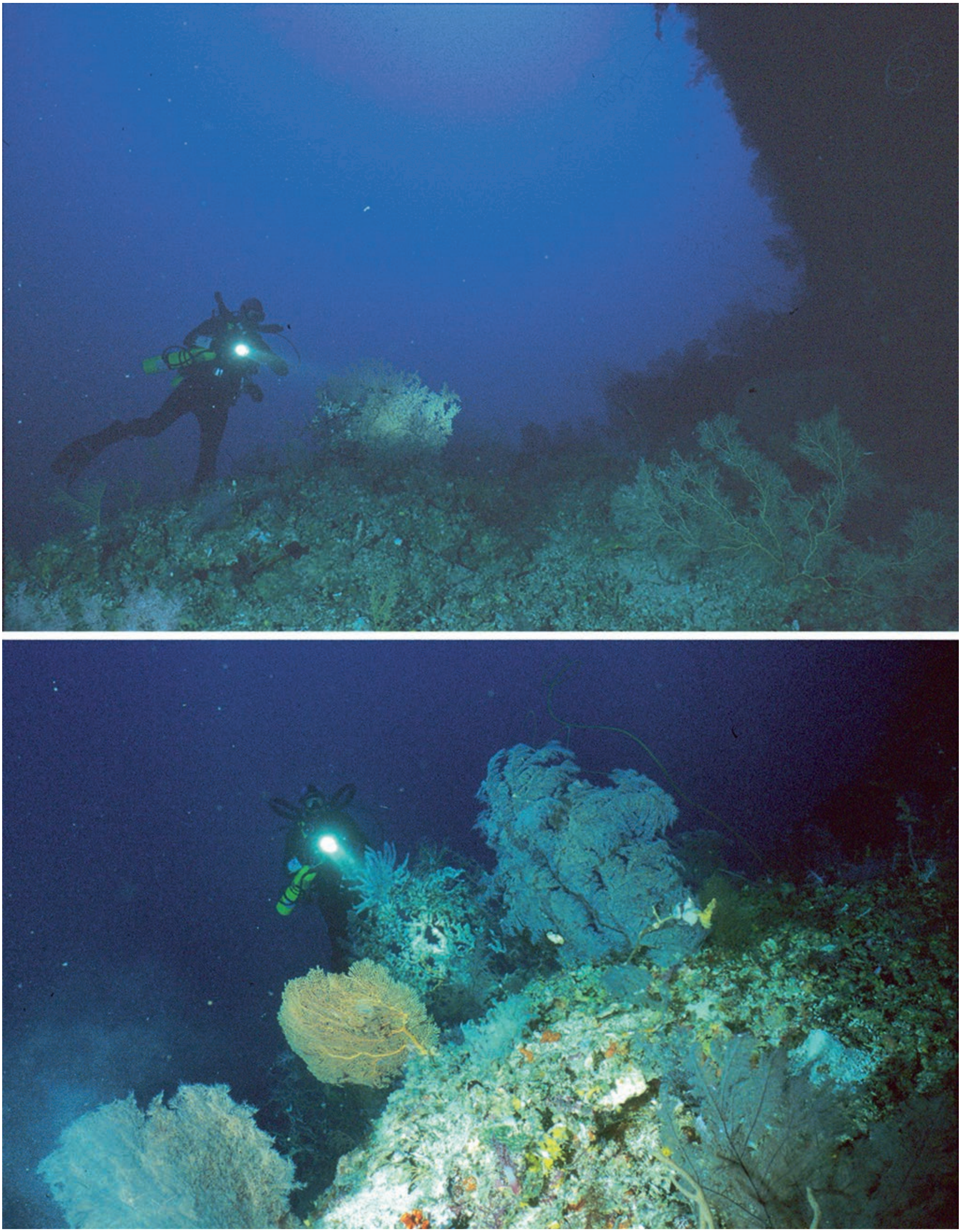

Fig. 21.4 Typical MCE habitat in Fiji, characterized by vertical limestone drop-offs interspersed with small caves and ledges and dominated by octocorals and encrusting invertebrates. (Photo credits: R.L. Pyle, can be reused under the CC BY license)

Table 21.1 A summary of occurrence records for 16 phyla of organisms, combined from the GBIF (2017) and Explorer's Log (2017) databases

Kingdom	Phylum	Species	Records	Min Depth	Max Depth
Animalia	Annelida	12	87	0.3	182.9
Animalia	Arthropoda	154	643	0	199
Animalia	Brachiopoda	1	6	27	70
Animalia	Cephalorhyncha	1	22	0.5	0.5
Animalia	Chordata	1179	10,091	0	195
Animalia	Cnidaria	137	389	0	198.5
Animalia	Echinodermata	86	303	0.1	195
Animalia	Gnathostomulida	5	5	4	15
Animalia	Mollusca	695	2903	0.1	199
Animalia	Nematoda	1	3	12	12
Animalia	Platyhelminthes	2	9	1	25.9
Animalia	Porifera	41	302	10.5	54.9
Chromista	Foraminifera	4	12	5	82
"Plantae"[a]	Chlorophyta	1	1	10	10
"Plantae"[a]	Rhodophyta	1	4	0.5	30
"Plantae"[a]	Tracheophyta	4	37	1	20
Totals		2324	14,817[b]		

[a]Provisionally assigned to this kingdom, though some modern classifications have changed this
[b]An additional 153 occurrence records could not be placed to phylum

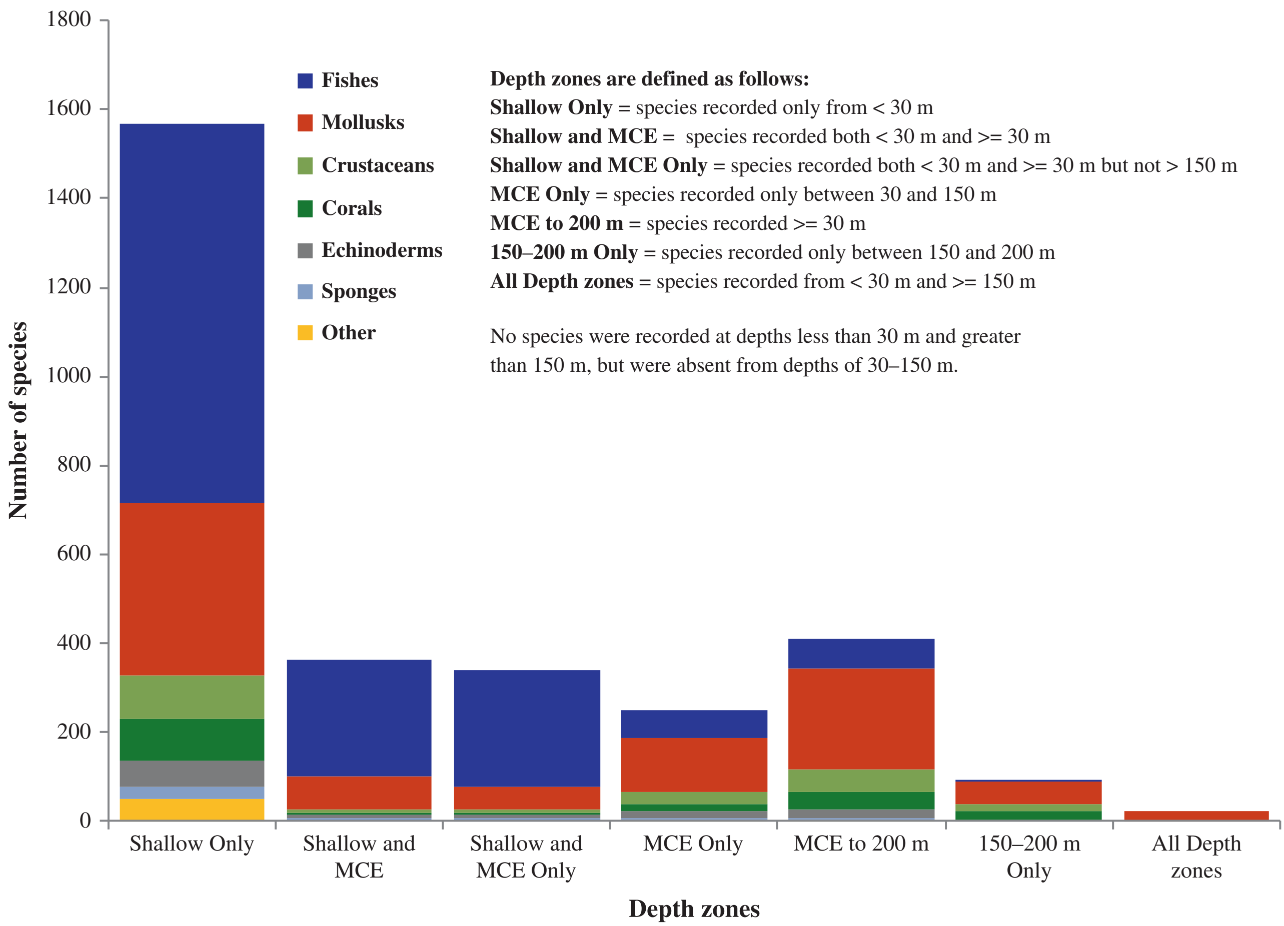

Fig. 21.5 Numbers of species within different phyla recorded from different depth zones. (Data from GBIF 2017; Explorer's Log 2017)

that the number of species occurring within MCEs (both restricted to MCEs and shared with shallow reefs) will increase with further sampling efforts.

Data were analyzed for the chronology of species documentation within 30-m wide depth zones in Fiji going back to the 1760s, both to examine which decades yielded the most new records (Fig. 21.7a) and the accumulation of species over time (Fig. 21.7b). Figure 21.7a, b does not necessarily represent the pattern of newly discovered species but rather the pattern of when and how many species were first documented in different depth zones in Fiji over ten decades. Records from shallow reefs in Fiji date back 250 years to 1767, and the first records from MCEs were sampled in the 1880s and 1890s. However, the vast majority of species sampled from shallow reefs (97%) began in the 1960s and from MCEs (96%) in the 1980s (Fig. 21.7a). The most productive decades for documenting shallow-reef organisms were the 1960s, 1980s, and 2000s and for documenting MCEs the 1980s, 1990s, and to a lesser extent the 2000s. Whereas the reduced number of species with increasing depth (Fig. 21.7b) likely reflects decreasing diversity with increasing depth to some extent, the pattern is also attributable to the reduction in sampling effort at greater depths (Fig. 21.6). Additionally, none of the species accumulation curves appear to be approaching an asymptote, although the shallowest two depth zones do appear to be shifting somewhat over the last 20 years (Fig. 21.7b). These findings demonstrate that much work remains to be done to document coral reef biodiversity in Fiji across all depths.

Table 21.2 A summary of approximate sampling effort as represented by number of days sampled and as % total sampling effort, as well as the total number of species and the calculated number of species per sampling day (SPUE or species per unit effort)

Depth (m)	Days	%	Species	SPUE
0–10	496	46.3%	1529	3.1
10–20	225	21.0%	879	3.9
20–30	123	11.5%	536	4.4
30–40	89	8.3%	382	4.3
40–50	34	3.2%	101	3.0
50–60	18	1.7%	69	3.8
60–70	11	1.0%	51	4.6
70–80	6	0.6%	34	5.7
80–90	10	0.9%	68	6.8
90–100	7	0.7%	32	4.6
100–110	9	0.8%	71	7.9
110–120	6	0.6%	60	10.0
120–130	5	0.5%	15	3.00
130–140	2	0.2%	15	7.50
140–150	3	0.3%	76	25.33
150–160	7	0.7%	110	15.71
160–170	2	0.2%	5	2.50
170–180	3	0.3%	18	6.00
180–190	10	0.9%	71	7.10
190–200	5	0.5%	30	6.00

21.4.1 Fishes

Fishes, in general, are comparatively well-documented for shallow reefs of Fiji. Although data available for fishes on

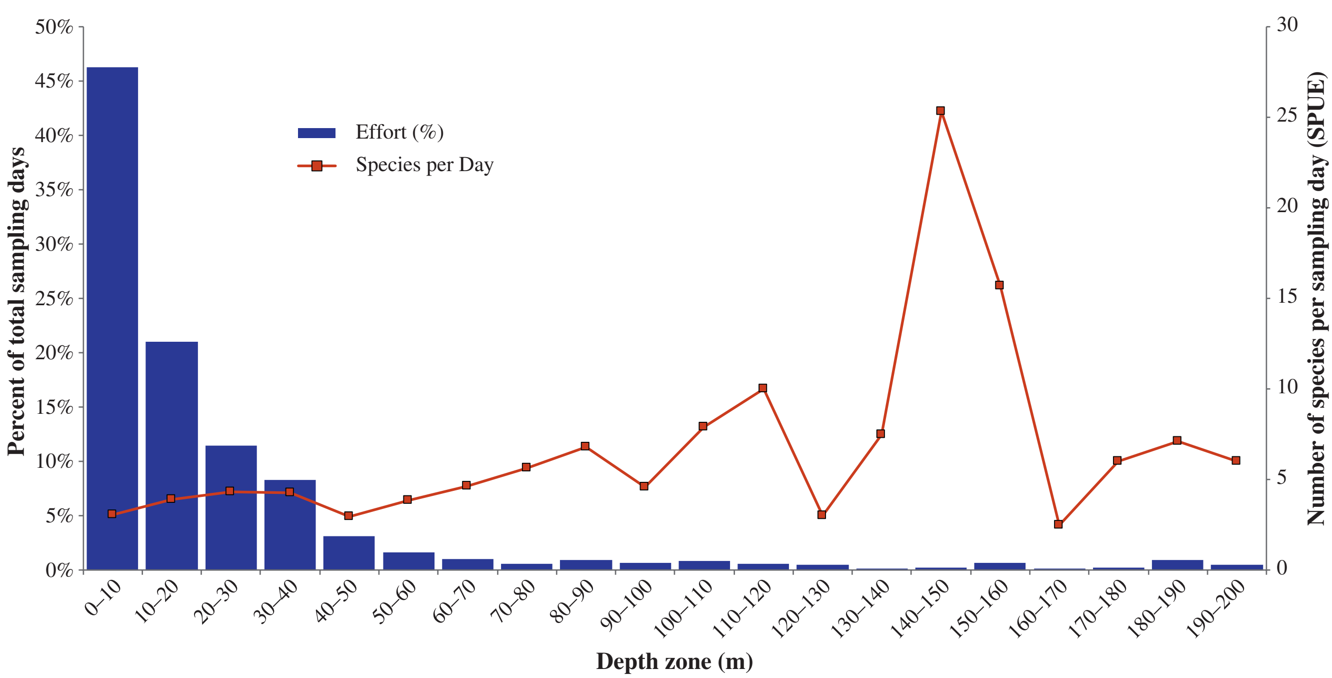

Fig. 21.6 Distribution of sampling effort across 10-m depth zones. Bars represent percent of total sampling days within each depth zone, and the line represents the species per unit effort (SPUE), defined as the total number of species divided by the total number of sampling days within each depth zone

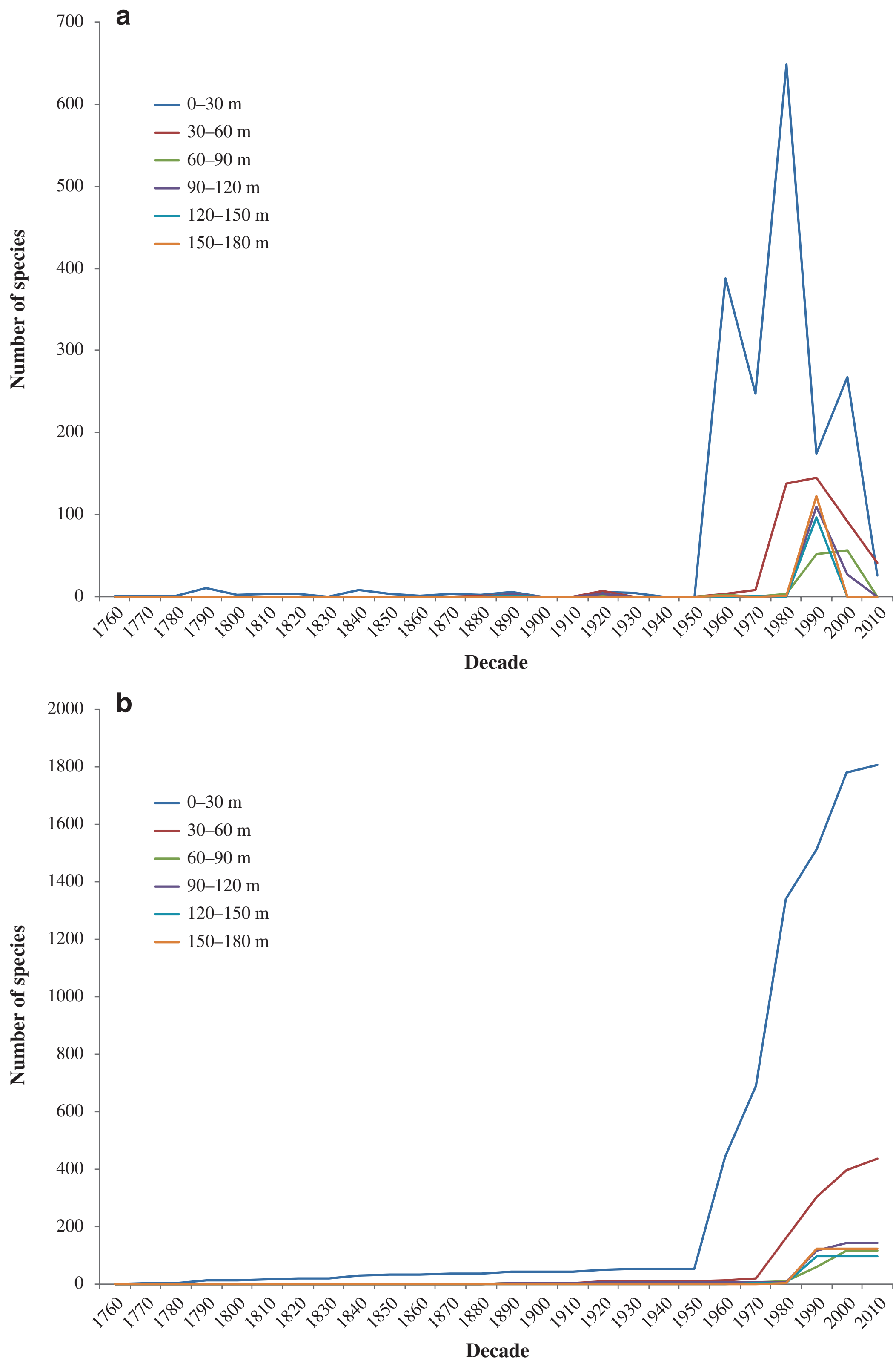

Fig. 21.7 Number of species recorded for the first time (**a**) and cumulative number of species (**b**) recorded within 30-m depth zones over ten decades. (Data from GBIF 2017; Explorer's Log 2017)

Fijian MCEs are extremely limited, it is considerably more substantial than what is known for other groups of organisms. Whitley (1927) made the first attempt to generate a checklist of fishes from Fiji, which included 439 species, though he noted that the list was incomplete. Fowler (1959) expanded Whitley's checklist to 560 species, and Carlson (1975) revised the list again to include 575 species. Starting in 1983, an effort to compile a more comprehensive list of fish species occurring in Fiji was begun by Wayne J. Baldwin, joined by Johnson Seeto. This effort culminated in the publication of Seeto and Baldwin (2010), which recorded over 2000 species they regarded as "confirmed" and an additional 275 species they regarded as doubtful because of potential misidentification or identification to genus level only. In addition to these published lists, Gerald R. Allen, David W. Greenfield, and Robert F. Myers have each been compiling separate lists of fish species from Fiji (Allen et al. pers. comm.), and there are general plans to produce a comprehensive, "evidence-based" checklist for Fijian fishes across all coral ecosystem depths that incorporates many sources of information.

As described in the *Research History* Sect. 21.1.1, four separate expeditions to Fiji using rebreathers have been conducted to document fishes and other organisms inhabiting depths of up to 125 m. These expeditions have led to the discovery of dozens of new fish species, at least seven of which have already been described (*Pseudanthias flavicauda* Randall and Pyle 2001, *Pseudanthias carlsoni* Randall and Pyle 2001, *Petroscirtes pylei* Smith-Vaniz 2005, *Tryssogobius nigrolineatus* Randall 2006, *Cirrhilabrus nahackyi* Walsh and Tanaka 2012, *Terelabrus dewapyle* Fukui and Motomura 2015, and *Trimma bathum* Winterbottom 2017). Many more fish species from MCEs in Fiji have been discovered and are awaiting formal description, a small sample of which is included in Fig. 21.3. Data from these expeditions are represented as specimen records in the Bernice P. Bishop Museum fish collection (available in the GBIF database) and video-based observation records captured in the Explorer's Log database and are therefore included in the analyses presented herein. Additional data related to shallow-reef fishes are available through the California Academy of Sciences Ichthyology Collection Database website (CAS 2017).

In addition to contributing to both the general diversity and fish data analyses, a subset of these data obtained during the 2002 rebreather expedition to Fiji have been used to quantitatively compare fish diversity across a depth range of 0–120 m at a single site (Fish Patch: 18.16° S, 178.40° E) in Fiji (Pyle 2005; Sinniger et al. 2016). This site, located just outside of Suva Harbor (Fig. 21.2), includes a full complement of habitats (ranging from shallow reefs less than a meter deep adjacent to a steep drop-off plummeting to >120 m) and has been the subject of intensive collections of fishes on shallow reefs by David W. Greenfield and his team (e.g., Greenfield and Longenecker 2005; Greenfield et al. 2005; Greenfield 2009; Greenfield and Randall 2010; Greenfield, unpubl. data). A total of 18 collecting stations were conducted by the same team of divers using rebreathers and the same volume and mixture of rotenone (consisting of liquid rotenone fortified with powdered rotenone and dishwashing soap as an emulsifier) during a 2-week period from near the surface to 120 m. Stations were biased in favor of shallow-reef habitats, both because of the increased time spent collecting specimens and because the fishes reacted to the rotenone more rapidly in the shallow, warm water compared with the deeper, cooler MCE stations. The first bias was compensated for by tracking the total amount of time spent at each station, normalizing for the number of hours spent collecting. The second bias was unable to be compensated for as there was no way to objectively quantify the bias from slower response to rotenone on the deeper stations. The number of stations, total number of species, total number of new species, and time spent collecting are summarized in Table 21.3.

More species were collected on the shallowest two stations than on any of the deeper stations. However, when controlling for total collecting time as a measure of effort, there was some degree of variability in SPUE at different depths, but no obvious pattern in relation to depth (e.g., the highest rate of SPUE was at 30–45 m and the lowest was at 45–60 m, with moderate values both shallower and deeper than these

Table 21.3 Results of rebreather diver collecting activity at different depths near Fish Patch, Fiji

Depth (m)	Stations	Spp.	N. sp.	%New	Hr	SPUE	NSPUE
0–15	2	74	0	0%	1.5	48.4	0
15–30	2	75	0	0%	1.6	46.3	0
30–45	1	28	0	0%	0.3	84.8	0
45–60	3	54	6	11%	1.7	32.3	3.6
60–75	2	31	9	29%	0.7	46.3	13.4
75–90	3	48	13	27%	1.3	36.9	10.0
90–105	4	55	21	38%	1.6	34.0	13.0
105–120	1	14	9	64%	0.3	42.4	27.0

Spp. total species, *N. Sp.* new species, *Hr* hours collecting time, *SPUE* total species per unit effort (Spp./Hr), *NSPUE* new species per unit effort (N.Sp./Hr) two depth zones). Among the 144 species collected from the 13 stations at depths in excess of 45 m, more than 40 species (>28%) were undescribed. Both the proportion of new species (as high as 64%) and the rate of discovery (as high as 27 new species per hour) increased with increasing depth.

The accumulation curve for the MCE species documented during the 2002 rebreather expedition in Fiji (Fig. 21.8) closely tracks the identified species from Greenfield's shallow-water surveys at the same site. This is remarkable, given that collection effort was much greater for the shallow stations in terms of number of divers, duration of stations, and relative effectiveness of the rotenone. The accumulation of new species from MCEs suggests a similarly increasing trend. The extrapolation of new species discoveries does not consider the unidentified material, an estimated half of which is likely new, and is therefore overly conservative. The proportion of new species on deep reefs is likely 30% of the total species from this site (deep and shallow combined).

The combined GBIF and Explorer's Log databases includes a total of 9098 occurrence records representing 1019 distinct species from 57 of the 74 families of coral reef fishes (Pyle et al. 2019). Fourteen families (Caracanthidae, Carapidae, Creediidae, Diodontidae, Ephippidae, Fistulariidae, Gobiesocidae, Kuhliidae, Kyphosidae, Ostraciidae, Pempheridae, Samaridae, Soleidae, Zanclidae) were present on shallow reefs, but not recorded from MCEs. Some of these families (e.g., Caracanthidae, Creediidae, Diodontidae, Ephippidae, Kuhliidae, Kyphosidae, and Pempheridae) are likely limited to shallow reefs based on their ecological characteristics and habitat preferences, whereas in other cases (particularly Carapidae, Gobiesocidae, Ostraciidae, Samaridae, and Soleidae), it is more likely a result of sampling bias. By contrast, Symphysanodontidae was the only family recorded from MCEs, but not present on shallow reefs.

The relative representation of the 20 most speciose families in Fiji, comparing total species, the number of species inhabiting shallow depths, and the number of species inhabiting MCEs, is included in Table 21.4 and shown in Fig. 21.9. The pattern of species richness is generally consistent with that of coral reef fish families overall (Pyle et al. 2019). The five most species-rich families are the same for Fiji and glob-

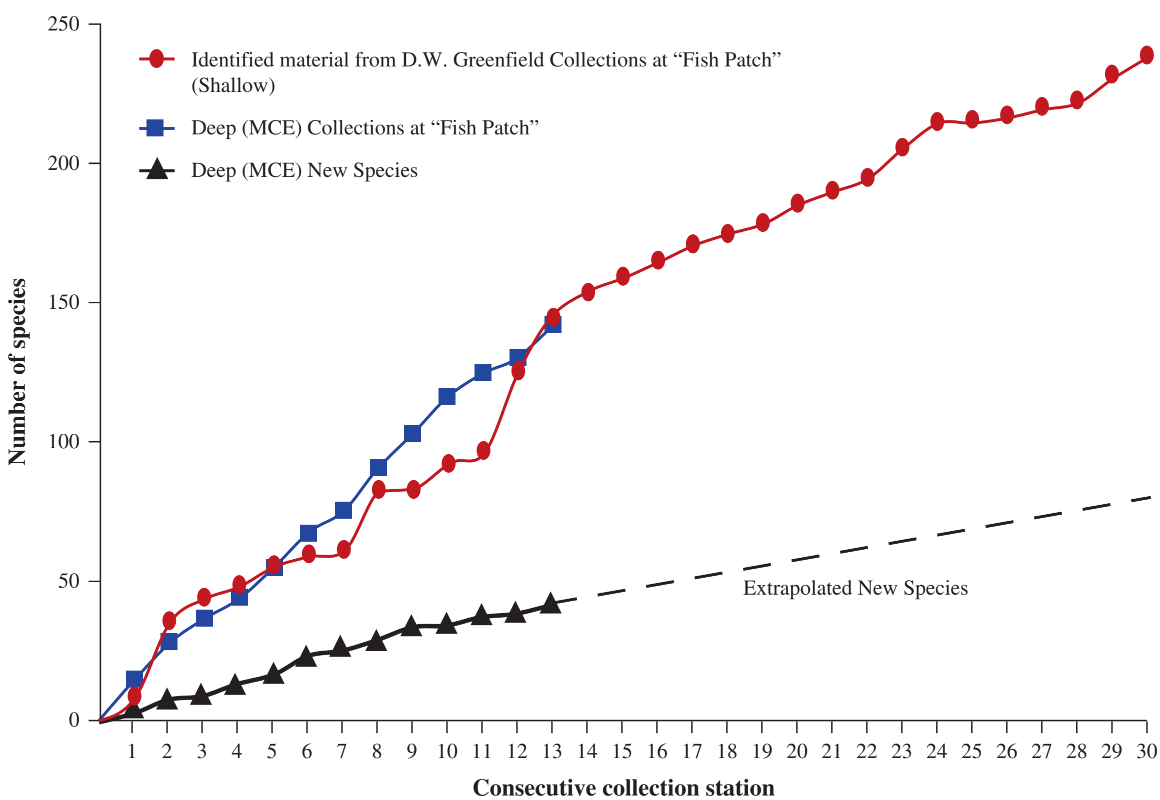

Fig. 21.8 Accumulation curves over the course of consecutive rotenone collection stations at Fish Patch, Fiji, for D.W. Greenfield's shallow stations (red circles), rebreather diver stations at MCE depths (blue squares), and new species discoveries on MCEs (black triangles). Dashed line represents extrapolated new species discovery. (Greenfield and Pyle, unpub. data)

Table 21.4 Top 20 most species-rich coral reef fish families in Fiji, comparing total number of species, number of species from shallow reefs, and number of species from MCEs represented in the GBIF (2017) and Explorer's Log (2017) databases. Values for both shallow and MCE habitats also include species occurring in both habitats

Taxon	Total	Shallow	MCE
Gobiidae	149	143	49
Labridae	90	84	27
Pomacentridae	85	81	22
Apogonidae	70	64	33
Serranidae	59	49	35
Blenniidae	52	51	4
Muraenidae	43	43	2
Chaetodontidae	33	33	7
Acanthuridae	32	31	8
Scorpaenidae	26	26	4
Holocentridae	25	24	12
Scaridae	25	24	2
Lutjanidae	21	21	5
Syngnathidae	21	20	3
Tripterygiidae	20	19	3
Pomacanthidae	19	17	10
Tetraodontidae	17	16	6
Ophichthidae	16	15	2
Microdesmidae	14	14	6
Mullidae	14	14	2
Total	831	749	242

ally, and all but 7 of the top 20 most species-rich families in Fiji (Acanthuridae, Holocentridae, Scaridae, Lutjanidae, Pomacanthidae, Microdesmidae, and Mulidae) are also on the global top 20 list (Pyle et al. 2019).

In all cases, more species are recorded from shallow habitats than from MCEs. The most conspicuous discrepancies are with the families Blenniidae, Muraenidae, and Scaridae, where there are far fewer species recorded from MCEs than for shallow reefs. In two of these cases (Blenniidae and Scaridae), the discrepancy may represent actual differences due to the ecological characteristics and habitat preferences of species in these two families. In the case of Muraenidae, the difference is more likely due to sampling bias, particularly as these eels tend to be among the last affected by rotenone (Pyle, pers. obs.), and fishes not only seemed to respond more slowly to rotenone on deep stations but also divers were not able to stay down long enough for the eels to emerge. For the same reasons, Ophichthidae is likely underrepresented among MCE samples. Sampling bias likely also plays a part in explaining the discrepancy for Syngnathidae, which includes a large number of cryptic species. For Tripterygiidae, the difference could either be due to sampling bias, genuine habitat differences, or a mixture of both.

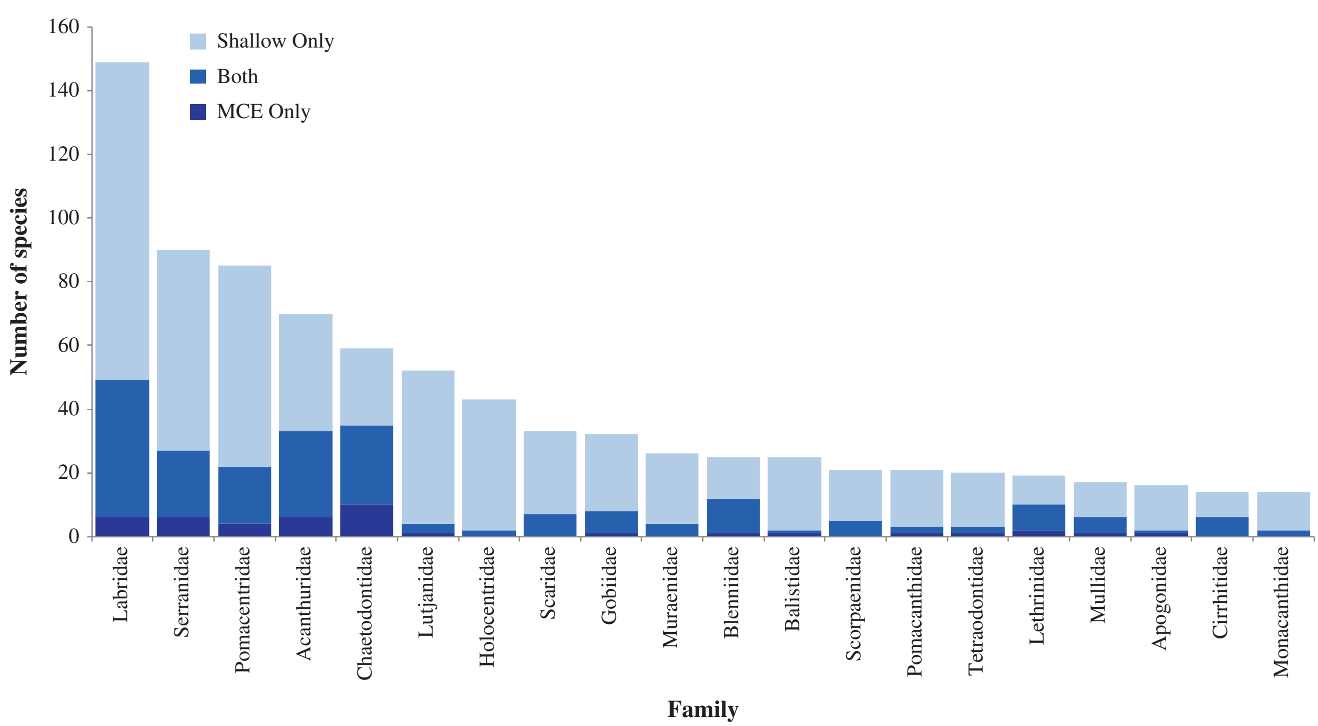

Fig. 21.9 The 20 most speciose families of coral reef fishes in Fiji, comparing data for total species (green bars), species inhabiting shallow depths (red bars), and species inhabiting MCEs (blue bars) from GBIF (2017) and Explorer's Log (2017). Values for both shallow and MCE habitats also include species occurring in both habitats

21.4.2 Other Biotic Components

Although much has been published concerning the algae and marine invertebrate fauna of shallow Fijian reefs (e.g., Bruce 1981; Brodie and Brodie 1990; N'Yeurt and South 1996; Wörheide and Reitner 1996; N'Yeurt 2001; Pohler 2004; Lovell 2005; Houart and Héros 2008; Schwabe et al. 2008; Suratissa and Rathnayake 2016, 2017; López et al. 2017), very little has been reported on these taxonomic groups within MCEs. Littler et al. (1997) described an unusual coral formation in 31 m. Moolenbeek et al. (2008) reported on new records and new species of cone snails collected at depths below 100 m in Fiji, but most of these were collected from depths in excess of 150 m. Another study documented the distribution of invertebrate taxa on MCEs in Fiji using video images from an ROV to assess changes in epibenthic community composition across depths from 10 to 130 m off Vatu-i-Ra (Ayroza 2016). It found invertebrates to be abundant down to 130 m, with a decrease in stony coral abundance and corresponding increase in octocorals and macroalgae with increasing depth up to 40–50 m, below which the octocorals and macroalgae decreased (see *Ecology* Sect. 21.5). The 2001–2010 rebreather expeditions recorded on video the presence of rich algal and invertebrate diversity across the entire MCE depth range (Pyle, pers. obs.). However, these expeditions did not collect voucher specimens, which are required for reliable identifications.

Among the combined GBIF and Explorer's Log databases, the most well-represented invertebrate phyla across both shallow reefs and MCEs in Fiji are Mollusca (2903 occurrence records representing 695 species), Arthropoda (Crustaceans: 643 records, 154 species), Cnidaria (389 records, 137 species), Echinodermata (303 records, 86 species), and Porifera (302 records, 41 species) (Table 21.1). All of these phyla also included representatives from MCEs. The three algae divisions and six animal phyla were only found on shallow reefs, with no occurrences on MCEs. The lack of documented algae on MCEs is likely due to sampling bias. Foraminifera are represented by only 12 records representing 4 species, with only 1 specimen from MCE depths (82 m). The five phyla with meaningful MCE representation in the database are listed in Table 21.5.

Although these data are necessarily limited by the general biases represented in the underlying databases, there are some noteworthy patterns. More species either occurred in (67–83%) or were exclusive to (57–71%) shallow reefs than MCEs (18–37% and 12–18%, respectively) (Fig. 21.5). The extent to which this may simply represent undersampling of MCEs is evident from the similar disparity in total number of records from each depth zone (65–67% of records from shallow habitats, 13–35% from MCEs). Comparable sampling effort within MCEs may reveal similar levels of overall diversity within each zone. However, even if this holds true, it is offset by the fact that MCE habitat spans four times the total depth range of shallow reefs, and therefore the total diversity per habitat area may be lower.

The extent of MCE representation is not consistent among all phyla. For example, among the phyla Arthropoda, Cnidaria, and Echinodermata, more than 90% of species (94%, 95%, and 91%, respectively) are recorded exclusively from shallow reefs. Similarly, more than 60% (63%, 68%, and 67%, respectively) of the MCE species are exclusive to MCEs, suggesting that species in these phyla exhibit relatively narrow depth ranges. By contrast, Mollusca and Porifera appear to have less depth zone specificity, with 84% and 76%, respectively, of shallow species restricted to shallow depths, and 51% and 47%, respectively, of MCE species restricted to MCEs. While this may certainly reflect sampling bias to some extent, the general trend does suggest variability among different phyla in terms of species depth ranges. This variability may perhaps be related to specific ecological factors that change with depth.

These results should be regarded as preliminary, as even the best available data is limited by strong sampling biases. Until more controlled and quantitative surveys can be performed across all depths both within Fiji and on MCEs in general, our understanding of true MCE biodiversity is necessarily limited.

Table 21.5 A summary of species and occurrence records for five phyla of invertebrates recorded from MCEs in Fiji, based on combined data from GBIF and Explorer's Log databases. For both shallow reefs (columns 2–4) and MCE environments (columns 5–7), within each environment, the total number of species, the number of species found exclusively within MCEs and shallow reefs, and the total number of occurrence records are shown for each phylum

Phylum	Species	Shallow exclusive	Records	Species	MCE exclusive	Records
Mollusca	467 (67%)	393 (57%)	1957 (67%)	245 (35%)	124 (18%)	705 (24%)
Arthropoda	104 (68%)	98 (64%)	425 (66%)	41 (27%)	26 (17%)	168 (26%)
Cnidaria	99 (72%)	94 (69%)	294 (76%)	25 (18%)	17 (12%)	49 (13%)
Echinodermata	67 (78%)	61 (71%)	234 (77%)	21 (24%)	14 (16%)	47 (16%)
Porifera	34 (83%)	26 (63%)	196 (65%)	15 (37%)	7 (17%)	106 (35%)
Total	771	672	3106	347	188	1075

Values in parentheses are percentage of total species and records, respectively, within each phylum

21.5 Ecology

Although much has been written regarding the general ecology on shallow-reef species in Fiji, almost nothing has been reported concerning the ecology of MCEs. Ayroza (2016) used a hierarchical classification of frame grabs from video collected by an ROV at depths of 10–130 m at four sites in Fiji and found that percent cover of stony corals, macroalgae, and macroinvertebrates was correlated with depth. In particular, stony coral abundance decreased with depth, whereas octocorals and macroalgae increased with depth up to 40–50 m and then decreased at greater depths. Other invertebrates were relatively abundant across all depths.

21.6 Threats and Conservation Issues

Fiji has been the focus of many studies related to potential threats and conservation issues among shallow-reef organisms (e.g., Lees and Forascu 2016; Tyson 2017). In general, the main threats to coral reefs in Fiji (both shallow and MCEs) are the same threats faced by coral reef ecosystems worldwide. Coral bleaching on shallow reefs in Fiji was well-documented by Cumming et al. (2002), who reported that corals were largely unaffected during the intense El Niño of 1998 but experienced mass bleaching in 2000 during the subsequent strong La Niña event. They found that mass bleaching occurred in all surveyed regions except north of Vanua Levu and that 64% of all scleractinian coral colonies surveyed were bleached. They estimated that 10–40% of coral colonies had died from bleaching within 4 months of the onset of bleaching.

Pollution is another issue that has received significant attention among shallow-reef habitats, particularly mangrove areas. For example, Suratissa and Rathnayake (2017) found lower diversity and abundance among 85 species of gastropods in 3 polluted shallow sites compared with 1 unpolluted site. Many different reports have also focused on the value of protected areas in Fiji for allowing population replenishment and recovery (e.g., Bao and Drew 2017; Bonaldo et al. 2017; Jupiter et al. 2017). All of these threat assessments were based on shallow-reef habitats, and the extent to which they apply to MCEs is not well established.

Goetze et al. (2011) examined the effect of depth on artisanal fishing in Fiji using baited remote underwater video systems (BRUVS), comparing shallow (5–8 m) and deep (25–30 m) sites. Although this study did not technically examine MCEs, their results suggest a possible depth-related refuge effect and highlighted the importance of incorporating multiple depth strata in studies of marine reserves, which likely apply to MCEs as well.

Another specific potential threat that may directly involve MCEs is aquarium fish collecting, as some collectors have access to advanced diving technology. However, the overwhelming majority of investigations on the impacts of the aquarium fish trade have almost universally concluded that the impacts from this fishery in general are very small relative to other fisheries (DLNR 2015). This issue has been specifically addressed in Fiji (Pyle 1993; Lovell and Tumuri 1999; Teitelbaum et al. 2010). Lovell and Tumuri (1999) reviewed the aquarium fish industry in Fiji and reported that six different companies were collecting and exporting live coral, live rock, and curio coral. They concluded that "… collection of live coral products appears to be sustainable based on the limited size classes required and the extensive reef area available for collection." Teitelbaum et al. (2010) noted that aquarium fish collectors, who tend to dive on the reef every day, "are the eyes and ears of the reef and can monitor the environment as it fluctuates." Indeed, collectors have contributed extensively to the understanding of coral reef fishes, including the discovery of new species within MCEs. Teitelbaum et al. (2010) concluded that "[a] well trained diver, collecting the right-sized specimens, focusing on species that are known to do well in aquaria, and spreading his efforts around a vast area, will cause only minimum impacts on reef fish populations." For species collected on MCEs in particular, the threat is trivial due to limited time for collecting and high values (maintained by deliberately limiting the number of fishes collected) of MCE species resulting in very few specimens being collected.

Overall, very few (if any) conclusions can be drawn concerning the threats and conservation issues related to MCEs in Fiji, over and above the very general concerns expressed for MCEs in general (Andradi-Brown et al. 2016; Smith et al. 2019; Weil 2019).

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References

Anderson WD, Springer VG (2005) Review of the perciform fish genus *Symphysanodon* Bleeker (Symphysanodontidae), with descriptions of three new species, *S. mona*, *S. parini*, and *S. rhax*. Zootaxa 996(1):1–44

Andradi-Brown D, Laverick J, Bejarano I, Bridge T, Colin PL, Eyal G, Jones R, Kahng S, Reed J, Smith T (2016) Threats to mesophotic coral ecosystems and management options. In: Baker EK, Puglise KA, Harris PT (eds) Mesophotic coral ecosystems—a lifeboat for coral reefs? The United Nations Environment Programme and GRID-Arendal, Nairobi, pp 67–82

Ayroza CR (2016) Caracterização da comunidade epibentônica em recifes de corais das ilhas Fiji por vídeo-imagem. BS Degree, Universidade Federal de Santa Catarina, Santa Catarina

Bao K, Drew J (2017) Traditional ecological knowledge, shifting baselines, and conservation of Fijian molluscs. Pac Conserv Biol 23(1):81–87

Beqa Adventure Divers (2010) Shark reef fish list website. http://fijisharkdive.com/conservation/shark-reef-fish-list/. Accessed 17 Aug 2017

Bonaldo RM, Pires MM, Junior PR, Hoey AS, Hay ME (2017) Small marine protected areas in Fiji provide refuge for reef fish assemblages, feeding groups, and corals. PLoS ONE 12(1):e0170638

Borodin NA (1932) Scientific results of the yacht 'Alva' world cruise, July, 1931 to March, 1932, in command of William K. Vanderbilt. Bull Vanderbilt Mar Mus 1(3):65–101

Bridge TCL, Beaman RJ, Bongaerts P, Muir PR, Ekins M, Sih T (2019) The Great Barrier Reef and Coral Sea. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 351–367

Brodie GD, Brodie JE (1990) A checklist of the opisthobranch molluscs of Fiji. J Malacol Soc Aust 11(1):53–63

Bruce AJ (1981) Pontoniine shrimps from Viti Levu, Fijian Islands. Micronesica 17(1–2):77–95

Cabaitan PC, Quimpo TJR, Dumalagan EE Jr, Munar J, Calleja MA, Olavides RDD, Go K, Albelda R, Cabactulan D, Tinacba EJC, Doctor MAA, Villanoy C, Siringan FP (2019) The Philippines. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 265–284

California Academy of Sciences [CAS] (2017) California Academy of Sciences Ichthyology Collection Database website. http://researcharchive.calacademy.org/research/Ichthyology/collection/index.asp. Accessed 1 Aug 2017

Carlson BA (1975) A preliminary check-list of the fishes of Fiji (based on specimens in the marine reference collection of the University of the South Pacific, Suva, Fiji). University of the South Pacific, Suva

Colin PL, Lindfield SJ (2019) Palau. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 285–299

Cumming RL, Toscano MA, Lovell ER, Carlson BA, Dulvy NK, Hughes A, Koven JF, Quinn NJ, Sykes HR, Taylor OJ, Vaughan D (2002) Mass coral bleaching in the Fiji Islands, 2000. In: Proceedings of the Ninth International Coral Reef Symposium, Bali, 23–27 October 2000, vol 2. pp 1161–1167

Department of Land and Natural Resources, State of Hawai'i [DLNR] (2015) Report on the findings and recommendations of effectiveness of the West Hawai'i Regional Fishery Management Area. Report to the Thirtieth Legislature 2015 Regular Session, Honolulu

Dickinson WR (1967) Tectonic development of Fiji. Tectonophysics 4(4–6):543–553

Dumont D'Urville JSC (1830–1834) Voyage de la corvette 'l'Astrolabe: exécuté par ordre du roi, pendant les années 1826, 1827, 1828, 1829. J Tastu, Paris

Duperrey LI (1825–1830) Voyage autour du monde: exécuté par ordre du roi, sur la corvette de Sa Majesté, la Coquille, pendant les années 1822, 1823, 1824, et 1825. Arthus Bertrand, Paris

Explorer's Log (2017) Explorer's Log website. http://explorers-log.com. Accessed 1 Jul 2017

Eydoux F, Souleyet LFA (1841) Zoologie, Tome Premier. In: Vaillant M (ed) Voyage autour du monde exécuté pendant les années 1836 et 1837 sur la corvette la Bonite. Arthus Bertrand, Paris, pp 1–132

Fowler HW (1940) The fishes obtained by the Wilkes expedition. Proc Am Philos Soc 82(5):733–800

Fowler HW (1959) Fishes of Fiji. Government of Fiji, Suva

Fukui Y, Motomura H (2015) A new species of deep water wrasse (Labridae: *Terelabrus*) from the western Pacific Ocean. Zootaxa 4040(5):559–568

Global Biodiversity Information Facility [GBIF] (2017) GBIF occurrence. http://www.gbif.org/occurrence. Accessed 1 July 2017

Goetze JS, Langlois TJ, Egli DP, Harvey ES (2011) Evidence of artisanal fishing impacts and depth refuge in assemblages of Fijian reef fish. Coral Reefs 30:507–517

Greenfield DW (2009) *Eviota randalli*, a new gobiid fish from Oceania. Proc Calif Acad Sci 60(15):683–687

Greenfield DW, Longenecker KR (2005) *Vanderhorstia bella*, a new goby from Fiji (Teleostei: Gobiidae). Proc Calif Acad Sci 56(27/37):619–623

Greenfield DW, Randall JE (2010) *Eviota karaspila*, a new gobiid fish from Fiji (Teleostei: Gobiidae). Zootaxa 2672(1):61–68

Greenfield DW, Langston RC, Randall JE (2005) Two new cardinalfishes of the indo-Pacific fish genus *Zoramia* (Apogonidae). Proc Calif Acad Sci 56(27/37):625–637

Günther A (1889) Report on the pelagic fishes collected by H.M.S. Challenger during the years 1873–76. In: Report on the scientific results of the Voyage of H.M.S. 'Challenger' during the Years 1873–76 under the Command of Captain George S. Nares, RN, FRS and the Late Captain Frank Tourle Thomson, RN, vol 31(78). pp 1–47, pls 1–23

Herre AWCT (1935) New fishes obtained by the Crane Pacific expedition. Field Mus Nat Hist Zool Ser 18(12):383–438

Heyward A, Radford B (2019) Northwest Australia. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 337–349

Hinderstein LM, Marr JCA, Martinez FA, Dowgiallo MJ, Puglise KA, Pyle RL, Zawada DG, Appeldoorn R (2010) Theme section on "Mesophotic coral ecosystems: characterization, ecology, and management." Coral Reefs 29(2):247–251

Houart R, Héros V (2008) Muricidae (Mollusca: Gastropoda) from Fiji and Tonga. Trop Deep-Sea Benthos 25:437–480

Jupiter S, McClennen C, Matthews E (2012) Vatu-i-Ra Seascape, Fiji. In: Hilty JA, Chester CC, Cross MS (eds) Climate and conservation: landscape and seascape science, planning and action. Island Press, Washington, DC, pp 148–161

Jupiter SD, Epstein G, Ban NC, Mangubhai S, Fox M, Cox M (2017) A social–ecological systems approach to assessing conservation and fisheries outcomes in Fijian locally managed marine areas. Soc Nat Res 9:1–6

Kendall WC, Goldsborough EL (1911) The shore fishes. In: Reports on the scientific results of the expedition to the tropical Pacific, in charge of Alexander Agassiz, by the U.S. Fish Commission steamer 'Albatross' from August, 1899, to March, 1900, vol 26(7). Mem Mus Compar Zool, Harvard College. pp 241–337

Krüger J, Kumar S (2008) High-resolution bathymetric survey of south Viti Levu, Fiji. EU EDF 8–SOPAC project report 109. Pacific Islands Applied Geoscience Commission, Suva

Lees K, Forascu T (2016) Fiji marine conservation and diving. Frontier, London

Littler MM, Littler DS, Brooks BL, Koven JF (1997) A unique coral reef formation discovered on the Great Astrolabe Reef, Fiji. Coral Reefs 16(1):51–54

Longenecker K, Roberts TE, Colin PL (2019) Papua New Guinea. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 321–336

López EH, Eastwood E, Drew J (2017) Genetic connectivity among populations of lollyfish (*Holothuria atra*). In: Mangubhai S, Lalavanua W, Purcell SW (eds) Fiji's sea cucumber fishery: advances in science for improved management. Report No 01/17. Wildlife Conservation Society, pp 62–70

Lovell ER (2005) Records of Scleractinia from Fiji. In: WWF (ed) Marine biodiversity survey of Cakaulevu (Great Sea Reef) and associated coastal habitats. Vanua Levu, Fiji, 5–16 December 2004. WWF-South Pacific Programme, Fiji

Lovell ER, Tumuri M (1999) Provisional environmental impact assessment for the extraction of coral reef products for the marine aquarium and curio trade in Fiji. A report prepared for the Fisheries Division, Government of Fiji, Suva

MacGillivray Freeman Films [MFF] (2003) Coral reef adventure website. http://www.coralfilm.com/. Accessed 1 July 2017

Montgomery AD, Fenner D, Kosaki RK, Pyle RL, Wagner D, Toonen RJ (2019) American Samoa. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 387–407

Moolenbeek RG, Röckel D, Bouchet P (2008) New records and new species of cones from deeper water off Fiji (Mollusca, Gastropoda, Conidae). Vita Malacol 6:35–49

N'Yeurt ADR (2001) Marine algae from the Suva Lagoon and reef, Fiji. Aust Syst Bot 14(5):689–869

N'Yeurt ADR, South GR (1996) A revised checklist of benthic marine algae of the Fiji Islands, South Pacific (including the island of Rotuma). Micronesica 29:49–98

Nutting CC (1924) The fishes in the Fiji: New Zealand expedition. Univ Iowa Stud Nat Hist 10(5):57–67

Pence DF, Pyle RL (2002) University of Hawaii dive team completes Fiji deep reef fish surveys using mixed-gas rebreathers. SLATE, April 1–3

Pichon M (2019) French Polynesia. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 425–443

Pohler SM (2004) The sabellariid worm colonies of Suva Lagoon, Fiji. S Pac J Nat Appl Sci 22(1):36–42

Project Baseline (2017a) Project baseline database website. http://www.projectbaseline.org/database/. Accessed 12 July 2017

Project Baseline (2017b) Project baseline YouTube channel website. http://tiny.cc/2a0oly. Accessed 12 July 2017

Pyle RL (1993) Marine aquarium fish. In: Wright A, Hill L (eds) Nearshore marine resources of the South Pacific: Information for fisheries development and management. Institute of Pacific Studies, Forum Fisheries Agency, Honiara; and International Centre for Ocean Development, Canada, Suva, pp 135–176

Pyle RL (2005) Recent discoveries of new fishes inhabiting deep Pacific coral reefs, with biogeographic implications. 7th Indo-Pacific Fish Conference, Taipei

Pyle RL (2019) Advanced technical diving. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 959–972

Pyle RL, Copus JM (2019) Mesophotic coral ecosystems: introduction and overview. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 3–27

Pyle RL, Kosaki RK, Pinheiro HT, Rocha LA, Whitton RK, Copus JM (2019) Fishes: biodiversity. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 749–777

Quoy JR, Gaimard P (1824) Zoologie. In: Freycinet L de (ed) Voyage autour du Monde, entrepris par Ordre du Roi, sous le ministère et conformément aux instructions de S. Exc. M. le Vicomte du Bouchage, secrétaire d'état au département de la Marine, exécuté sur les corvettes de SM l'Uranie et la Physicienne, pendant les années, Paris, pp 1–712

Randall JE (2006) Three new species of the gobiid fish genus *Tryssogobius* from the western and South Pacific. Aqua J Ichthyol Aquat Biol 11(3):105–116

Randall JE, Pyle RL (2001) Four new serranid fishes of the anthiine genus *Pseudanthias* from the South Pacific. Raffles Bull Zool 49(1):19–34

Reynolds RW, Smith TM (1994) Improved global sea surface temperature analyses using optimum interpolation. J Clim 7(6):929–948

Robertson DR (2008) Global biogeographical data bases on marine fishes: caveat emptor. Divers Distrib 14(6):891–892

Rowley SJ, Roberts TE, Coleman RR, Spalding HL, Joseph E, Dorricott MKI (2019) Pohnpei, Federated States of Micronesia. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 301–320

Schwabe E, Sirenko BI, Seeto J (2008) A checklist of Polyplacophora (Mollusca) from the Fiji islands. Zootaxa 1777(1):1–52

Seale A (1935) The Templeton Crocker Expedition to western Polynesia and Melanesian islands, 1933. Fishes. Proc Cal Acad Sci, Ser 4 21(27):337–378

Seeto J, Baldwin WJ (2010) A checklist of the fishes of Fiji and a bibliography of Fijian fish, Technical Report. University of the South Pacific, Suva

Sinniger F, Ballantine DL, Bejarano I, Colin PL, Pochon X, Pomponi SA, Puglise KA, Pyle RL, Reaka ML, Spalding HL, Weil E (2016) Biodiversity of mesophotic coral ecosystems. In: Baker EK, Puglise KA, Harris PT (eds) Mesophotic coral ecosystems—a lifeboat for coral reefs? The United Nations Environment Programme and GRID-Arendal, Nairobi, pp 50–62

Smith TB, Holstein DM, Ennis RS (2019) Disturbance in mesophotic coral ecosystems and linkages to conservation and management. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 911–929

Smith-Vaniz WF (2005) *Petroscirtes pylei*, a new saber-toothed blenny from the Fiji Islands (Teleostei: Blenniidae). Zootaxa 1046(1):29–36

Spalding HL, Copus JM, Bowen BW, Kosaki RK, Longenecker K, Montgomery AD, Padilla-Gamiño JL, Parrish FA, Roth MS, Rowley SJ, Toonen RJ, Pyle RL (2019) The Hawaiian Archipelago. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 445–464

Suratissa DM, Rathnayake US (2016) Diversity and distribution of fauna of the Nasese Shore, Suva, Fiji Islands with reference to existing threats to the biota. J Asia-Pac Biodivers 9(1):11–16

Suratissa DM, Rathnayake U (2017) Effect of pollution on diversity of marine gastropods and its role in trophic structure at Nasese Shore, Suva, Fiji Islands. J Asia-Pac Biodivers 10(2):192–198

Teitelbaum A, Yeeting B, Kinch J, Ponia B (2010) Aquarium trade in the Pacific. SPC Live Reef Fish Inf Bull 19:3–6

Tyson C (2017) Marine conservation in Fiji. iUniverse, Bloomington

University of the South Pacific [USP] (2017) USP School of Marine studies website. http://www.usp.ac.fj/index.php?id=4248. Accessed 1 July 2017

Walsh F, Tanaka H (2012) *Cirrhilabrus nahackyi*, a new wrasse (Perciformes; Labridae) from the South Pacific. Aqua 18(1):1–9

Weil E (2019) Disease problems. In: Loya Y, Puglise KA, Bridge TCL (eds) Mesophotic coral ecosystems. Springer, New York, pp 779–800

Whitley GPA (1927) A check-list of fishes recorded form Fijian waters. Pan-Pac Res Inst J 2(1):3–8

Winterbottom R (2017) Two new species of *Trimma* (Pisces; Gobiidae) from Fiji, southwestern Pacific Ocean. Zootaxa 4269(4):559–570

Wörheide G, Reitner J (1996) "Living fossil" sphinctozoan coralline sponge colonies in shallow water caves of the Osprey Reef (Coral Sea) and the Astrolabe Reefs (Fiji Islands). In: Reitner J, Neuweiler F (eds) Göttinger Arbeiten zur Geologie und Palaeontologie. Göttingen, pp 145–148