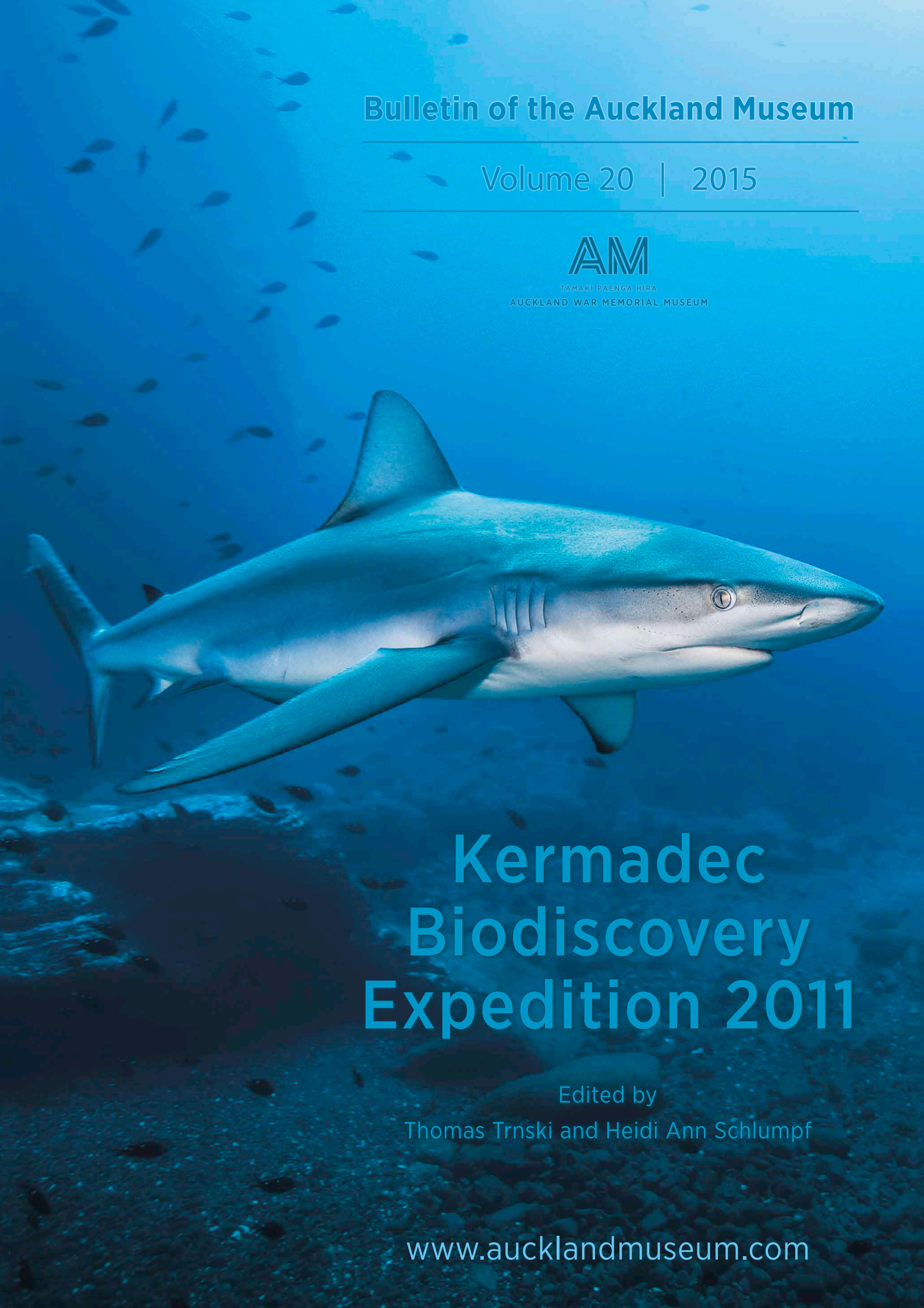




Bulletin of the Auckland Museum

Volume 20 | 2015

AM

TAMAKI PAENGA HIRA
AUCKLAND WAR MEMORIAL MUSEUM

Kermadec Biodiscovery Expedition 2011

Edited by
Thomas Trnski and Heidi Ann Schlumpf

www.aucklandmuseum.com

New records, checklist and biogeography of Kermadec Islands' coastal fishes

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Abstract

The Kermadec Islands coastal fish fauna is still incompletely known, and recent expeditions there have added new fish records, and improved our understanding of its diversity and composition. This study documents 18 new fish records, presents an updated checklist of coastal fishes, and analyses the species biodiversity and biogeography. The coastal fish fauna now consists of 175 species and is dominated by tropical (45%) and subtropical (43%) species having Indo-Pacific or south-west Pacific distributions. Eight coastal species (4.6%) are endemic, but some of these, viz. *Girella fimbriata*, *Parma kermadecensis* and *Chrysiptera rapanui*, stray to north-eastern New Zealand. The coastal fish fauna of the Kermadec Islands is not particularly diverse but the mix of fish species present, the abundance of subtropical species, the presence of endemic species, and the abundance of top predators, produce a unique and interesting fauna.

Keywords

Distribution; endemism; fish fauna; Lord Howe Island; Norfolk Island; tropical; subtropical

INTRODUCTION

Situated in the subtropical belt of the south-west Pacific Ocean and spanning about 250 km and 2.2 degrees of latitude, the Kermadec Islands harbour an interesting mix of tropical, subtropical and temperate fishes (Francis 1993). The Islands are small specks of land in a large ocean, with the nearest significant landmass (New Zealand) being about 730 km away. Norfolk Island and Lord Howe Island lie upstream to the west in similar latitudes in the north Tasman Sea. The Kermadec fish fauna is strongly influenced by the remoteness of the Islands and their location in a subtropical mixing zone, and the low frequency of recruitment of fish larvae from upstream sources (Francis 1993).

The Kermadec Islands have attracted considerable ichthyological attention despite being difficult to access. The first checklist of fishes was published over 100 years ago by Waite (1910) and updated two years later (Waite 1912). Waite's checklist contained 32 species of coastal fishes, many of which were collected by the naturalist W.R.B. Oliver who spent nine months at the Islands. After a gap of 73 years, the known fauna more than doubled to 72 species when Paulin & Stewart (1985) listed the Kermadec Islands teleost fishes held in the Museum of New Zealand Te Papa Tongarewa. During the mid 1980s and early 1990s, the advent of scuba diving as a marine research tool led to several scientific expeditions (Schiel *et al.* 1986; Francis *et al.* 1987;

Francis 1991) that observed, photographed and collected many new fishes, resulting in another doubling of the fauna to 145 species (Francis 1993).

Although the Kermadec Islands fish fauna has many similarities with those of Norfolk and Lord Howe Islands, it also differs substantially in its richness and composition. The Kermadec Islands fauna is depauperate compared with Norfolk and Lord Howe Islands, and has a smaller proportion of tropical species and larger proportions of subtropical and temperate species than its western neighbours (Francis 1993). The Kermadec Islands also have a small number of endemic species, some of which, along with other subtropical fishes, are abundant. This creates a unique coastal fish fauna.

The Kermadec fish fauna is still incompletely known, and expeditions since 1993 have added further new records (Trnski *et al.* 2015), and an improved understanding of the diversity and composition of the coastal fishes. In this paper, we document new Kermadec coastal fishes based on visual records, present an updated checklist of coastal fishes, and analyse the species biodiversity and biogeography.

METHODS

We define coastal fishes as those species that occur within 50 m of the surface and 1 km of the shore, excluding oceanic pelagic species. Most species covered by this study are reef fishes, but species living on or in sand, and in open water near the coast, are also included.

Using the last checklist of Kermadec Islands coastal fishes (Francis 1993) as a starting point, we compiled new fish records from the literature, unpublished documents, museum specimens, and observations made during two major scientific expeditions to the Kermadec Islands on 4–11 November 2004 (Duffy 2005) and 12–26 May 2011 (Trnski & de Lange 2015), and other shorter scientific visits. Those expeditions employed extensive scuba diving, underwater photography and specimen collecting using a range of techniques including the ichthyocide rotenone, hand-spear, lines and set nets. Here we report records of new coastal fishes that were observed and photographed during both expeditions; new records represented by specimens deposited in museum collections are reported elsewhere (Trnski *et al.* 2015) but are included in the present checklist.

Images were sent to fish specialists for confirmation of species identifications: G. R. Allen (Western Australian Museum, Perth, Western Australia), J. H. Choat (James Cook University, Townsville, Australia), R. H. Kuiter (Aquatic Photographics, Seaford, Victoria, Australia), H. Motomura (Kagoshima University, Japan), J. E. Randall (Bishop Museum, Hawaii, USA), B. C. Russell (Museum & Art Gallery of the Northern Territory, Darwin, Australia), and W. F. Smith-Vaniz (University of Florida, Florida Museum of Natural History, USA). A few species included in the previous checklist were omitted because (a) they were considered unlikely to occur shallower than 50 m around the Islands, (b) the only known records were from the Kermadec Ridge some distance from the Islands themselves, or (c) there were doubts about their identification.

The affinities of checklist fishes with major water masses (tropical, subtropical and temperate), and their geographical distributions, were determined from published and unpublished sources and personal communications with specialists. The distribution of each species was classified into one of nine categories:

- Endemic – found only at the Kermadec Islands, apart from a few strays recorded elsewhere
- Kermadec to New Zealand – present at the Kermadec Islands and elsewhere in New Zealand
- Lord Howe to Kermadec – present at the Kermadec Islands and one or both of Norfolk and Lord Howe Islands
- Lord Howe to New Zealand – present at the Kermadec Islands, New Zealand and one or both of Norfolk and Lord Howe Islands
- South-west Pacific – species that range to Australia and/or tropical islands of the south-west Pacific (e.g. New Caledonia, Fiji, Tonga)
- South Pacific – species that range from Australia or Lord Howe Island to the central or eastern Pacific, usually in subtropical waters
- Pacific – species present in the western and central (and sometimes eastern) North and South Pacific; includes species found along the eastern margin of the Indian Ocean off Indonesia and Western Australia
- Indo-Pacific – widespread in the Indian and Pacific Oceans
- Worldwide – widespread in the Atlantic, Indian and Pacific Oceans

RESULTS

New Kermadec Islands fish records

Eighteen coastal fish species from 12 families are newly reported here from the Kermadec Islands (Table 1, Figures 1–15). Fourteen are also new records for the New Zealand region. Sixteen of the new records are supported by underwater photographs and identifications were based on those. Two species, *Parupeneus pleurostigma* and *Ecsenius bicolor* were observed but not photographed; the former was readily identified by its distinctive colour pattern, and the latter was distinguished from the similarly coloured *Pictichromis coralensis* by colour pattern, steeply-sloping head, benthic habitat, and ‘hopping’ movement (Randall 2005). Photographs or specimens are required to confirm these two identifications.

Most of the new records were of large individuals, indicating that they had settled some months or years earlier. All but one species were very rare, being represented by sightings of fewer than five individuals despite many hours of underwater observation. The exception was a species of *Decapterus* (family Carangidae) which formed small schools, often in association with Galapagos sharks (*Carcharhinus galapagensis*). Francis (1993) previously reported an unknown species of *Decapterus* from the Kermadec Islands, and indicated that it may have been *D. muroadsi*. The Kermadec *Decapterus* has a broad gold stripe along the upper body (Figure 3), and it was tentatively confirmed from our images by W. F. Smith-Vaniz as *D. ?muroadsi*. This identification is consistent with the subtropical–temperate distribution of this species in the south-west Pacific, which includes eastern Australia, northern New Zealand, Lord Howe Island and possibly Norfolk Island (Francis 1993; Kuiter 2000; Hoese & Gates 2006). Collection of specimens is required to confirm this identification.

Diversity and biogeography

A checklist of Kermadec Islands coastal fishes is given in Appendix 1. Deletions and additions to the previous checklist (Francis 1993) have resulted in a current total of 175 known coastal fishes. The Kermadec Islands have a depauperate fish fauna compared with those of Lord Howe and Norfolk Islands (with 518 and 270 species respectively) (Francis 1993; M. Francis unpubl. data). The Kermadec fish fauna is composed mainly of tropical (45%) and subtropical (43%) species, with a small proportion (10%) of temperate species (Table 2). Lord Howe and Norfolk Islands have higher proportions of tropical fishes (72% and 61% respectively) and lower proportions of subtropical (24% and 33% respectively) and temperate (4% and 6% respectively) species. There is a clear decline in the proportion of tropical species, and an increase in the proportions of subtropical and

Table 1. New coastal fish records from the Kermadec Islands. KI = Kermadec Islands, NZ = New Zealand

Family	Species	Location, date and source of record	New record
Synodontidae	<i>Synodus dermatogenys</i> Fowler 1912	Meyer Is., 23 Jan 2015, R. Robinson photo	KI & NZ
Scorpaenidae	<i>Dendrochirus brachypterus</i> (Cuvier 1829)	Denham Bay, Raoul Is., 10 Nov 2004, MPF photo (2 seen)	KI & NZ
Carangidae	<i>Decapterus ?muroadsi</i> (Temminck & Schlegel 1844)	Denham Bay, Raoul Is., 10 Nov 2004, MPF & CD (photos)	KI
	<i>Seriola dumerili</i> (Risso 1810)	Napier Is., Nov 2004, M. Page & F. Smith photo Milne Rocks, Raoul Is., 15 May 2011, MPF photo	KI & NZ
Mullidae	<i>Parupeneus pleurostigma</i> (Bennett 1831)	Meyer Is., 12 May 2011, CD obs	KI & NZ
		Chanter Is., 16 May 2011, CD obs	
Chaetodontidae	<i>Chaetodon lunula</i> (Lacepède 1802)	Meyer Is., Nov 2008, T. Hitchon photo	KI & NZ
		Meyer Is., 12 May 2011, CD obs	
		Fishing Rock, Raoul Is., 17 May 2011, MPF obs	
Pomacentridae	<i>Stegastes gascoynei</i> (Whitley 1964)	Meyer Is., 7 Nov 2004, CD photo Chanter Is., 16 May 2011, MPF photo;	KI
Labridae	<i>Coris aygula</i> Lacepède 1801	Meyer Is., Nov 2008, T. Hitchon photo	KI & NZ
	<i>Coris dorsomacula</i> Fowler 1908	Meyer Is., 8 Nov 2004, MPF photo (2 seen) Denham Bay, Raoul Is., 10 Nov 2004, CD obs (2 seen)	KI
	<i>Coris gaimard</i> (Quoy & Gaimard 1824)	Meyer Is., 23 Jan 2015, R. Robinson photo	KI & NZ
	<i>Iniistius pavo</i> (Valenciennes 1840)	Meyer Is., 23 Jan 2015, R. Robinson photo	KI & NZ
	<i>Macropharyngodon meleagris</i> (Valenciennes 1839)	Meyer Is., 23 Jan 2015, R. Robinson photo	KI & NZ
	<i>Scarus ghobban</i> Forsskål 1775	Meyer Is., 7 Nov 2004, MPF photo	KI & NZ
Blenniidae	<i>Ecsenius bicolor</i> (Day 1888)	Denham Bay, Raoul Is., 10 Nov 2004, CD obs	KI & NZ
Acanthuridae	<i>Acanthurus dussumieri</i> Valenciennes 1835	Meyer Is., 19 May 2011, R. Robinson photo, MPF obs	KI
		Cheeseman Is., 23 May 2011, CD & MPF obs	
		Curtis Is., 25 May 2011, MPF obs	
Bothidae	<i>Bothus mancus</i> (Broussonet 1782)	Meyer Is., 23 Jan 2015, R. Robinson photo	KI & NZ
Monacanthidae	<i>Cantherhines dumerilii</i> (Hollard 1854)	Meyer Is., 20 May 2011, R. Robinson photo	KI & NZ
Diodontidae	<i>Diodon holocanthus</i> Linnaeus 1758	Milne Rocks, Raoul Is., 2 Jan 2012, G. Edgar photo Meyer Is., 23 Jan 2015, R. Robinson photo	KI & NZ

temperate species, from west (Lord Howe Island) to east (Kermadec Islands).

Kermadec Islands coastal fishes have distributions ranging from very broad (worldwide) to very narrow (endemic to the Kermadec Islands). Species with Indo-Pacific Ocean (39%) or south-west Pacific Ocean (22%) distributions dominate the fauna (Table 3). Widespread species, with Pacific Ocean distributions or wider, account for 57% of the fauna. Species with distributions limited to the Kermadec Islands and one or more of Lord Howe Island, Norfolk Island and New Zealand are relatively uncommon (9%).

Eight coastal fish species (4.6% of the fauna) are endemic to the Kermadec Islands (Table 4). Several of them have also been recorded as strays around north-eastern New Zealand. *Girella fimbriata* (Figure 16) has been observed occasionally at a number of sites

between 1969 and 2011 (Table 5). *Parma kermadecensis* (Figure 17) has been reported from the Poor Knights Islands and the Hen and Chicken Islands (Table 6). All but two of the Poor Knights records were of one or a pair of fish seen in a small part of Bartle's Bay, and almost certainly represent the same two individuals observed repeatedly between April 1997 and September 2007 (Francis *et al.* 1999; unpubl. obs. compiled by MPF). *Chrysiptera rapanui* was described from Easter Island in the eastern Pacific, but specimens from there lack the yellow coloration found in Kermadec Islands fishes (Allen 1991; Francis 2012). The Kermadec colour form (Figure 18) is probably genetically isolated from Easter Island fish and may be a distinct species, and so is regarded here as endemic. However two yellow morphs have been photographed at the Poor Knights Islands in north-eastern New Zealand (Francis *et al.* 1999; Table 7).



Figure 1. *Synodus dermatogenys*, Meyer Is. Photo R. Robinson.



Figure 2. *Dendrochirus brachypterus*, Denham Bay, Raoul Is. Photo MPF.



Figure 3. *Decapterus* ?*muroadsi*, Denham Bay, Raoul Is. Photo MPF.



Figure 4. *Seriola dumerili*, Milne Rocks, Raoul Is. Photo MPF.



Figure 5. *Chaetodon lunula*, Meyer Is. Photo T. Hitchon.



Figure 6. *Stegastes gascoynei*, Chanter Is. Photo MPF.



Figure 7. *Coris aygula*, Meyer Is. Photo T. Hitchon.



Figure 8. *Coris dorsomacula*, Meyer Is. Photo MPF.



Figure 9. *Coris gaimard*, Meyer Is. Photo R. Robinson.



Figure 10. *Macropharyngodon meleagris*, Meyer Is. Photo R. Robinson.

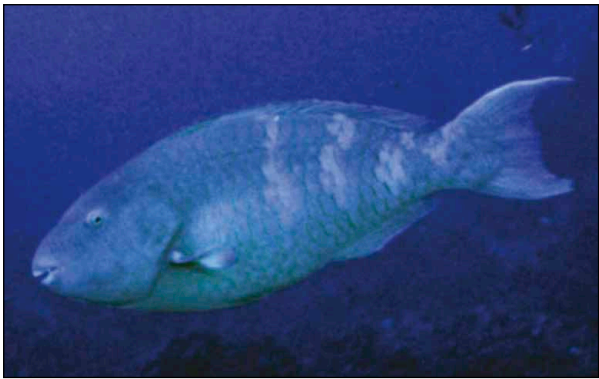


Figure 11. *Scarus ghobban*, Meyer Is. Photo MPF.



Figure 12. *Acanthurus dussumieri*, Meyer Is. Photo R. Robinson.

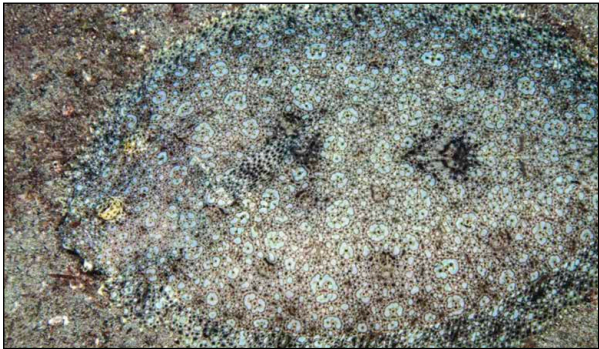


Figure 13. *Bothus mancus*, Meyer Is. Photo R. Robinson.



Figure 14. *Cantherhines dumerilii*, Milne Rocks, Raoul Is. Photo G. Edgar.



Figure 15. *Diodon holocanthus*, Meyer Is. Photo R. Robinson.

Table 2. Classification of Lord Howe, Norfolk and Kermadec islands coastal fish faunas by water temperature zone (percentage of fauna).

Temp zone	Lord Howe	Norfolk	Kermadec
Tropical	71.8	60.9	45.1
Subtropical	24.3	32.5	42.9
Temperate	3.7	5.9	10.3
Unknown	0.2	0.7	1.7
Total	100.0	100.0	100.0

The remaining five endemic fishes, including three undescribed species, have not been recorded outside the Kermadec Islands. The undescribed gobioid clingfish (Fig. 19) is probably referable to *Aspasmogaster* (Kevin Conway, pers. comm.). Seven of the endemics have reproductive modes that result in limited dispersal potential (Table 4). Two species produce live young without a larval phase, and five species lay benthic eggs from which well-developed larvae hatch; the planktonic larval durations of these species are probably very short. Only *Girella fimbriata* produces pelagic eggs that are amenable to widespread dispersal, though the larval duration of this species is unknown.

Two species are restricted to the Kermadec Islands and New Zealand (and are therefore New Zealand endemics). *Chromis dispila* is an abundant damselfish at the Kermadec Islands and in north-eastern New Zealand (Francis *et al.* 1987; Francis 2012). *Optivus elongatus* is patchily distributed at the Kermadec Islands, being common only at Curtis and Cheeseman Islands (Francis *et al.* 1987), and is common around north-eastern New Zealand. The stargazer *Kathetostoma binigrasella* comes close to being a New Zealand endemic, but there is one record from outside the New Zealand EEZ on the Norfolk Ridge (Gomon & Roberts 2011), and the species may prove to be more widespread along the Ridge. Three species (*Chironemus microlepis*, *Genicanthus*

semicinctus and *Engyprosopon raoulensis*) are restricted to the Kermadec Islands and either or both of Lord Howe and Norfolk Islands. However *Genicanthus semicinctus* should probably be regarded as a Lord Howe endemic as it is otherwise known from a single Kermadec Island individual (Francis *et al.* 1987).

Table 3. Biogeographic distribution of Kermadec Islands coastal fishes.

Region	Number	Percent
Worldwide	19	10.9
Indo-Pacific	68	38.9
Pacific	12	6.9
South Pacific	10	5.7
South-west Pacific	39	22.3
Lord Howe – NZ	11	6.3
Lord Howe – Kermadec	3	1.7
Kermadec – NZ	2	1.1
Endemic	8	4.6
Unknown	3	1.7
Total	175	100.0



Figure 16. *Girella fimbriata*, Nugent Is., Raoul Is. Photo MPF.

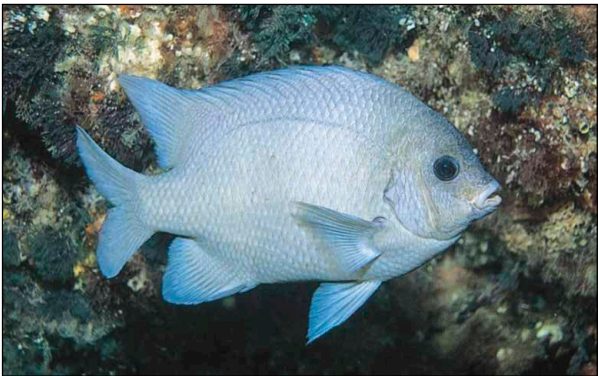


Figure 17. *Parma kermadecensis*, Bartle's Bay, Poor Knights Is. Photo MPF.



Figure 18. *Chrysiptera rapanui*, Raoul Is. Photo R. Robinson.



Figure 19. *Aspasmogaster* sp., Raoul Is. Photo R. Robinson.

Table 4. Kermadec Islands endemic coastal fishes. L = live bearer, B = benthic eggs, P = pelagic eggs

Family	Species	Common name	Reproductive mode
Triakidae	<i>Mustelus</i> sp.	Kermadec rig	L
Bythitidae	<i>Microbrotula punicea</i> Anderson 2007	Orange brotula	L
Gobiesocidae	<i>Aspasmogaster</i> sp.	Urchin clingfish	B
Girellidae	<i>Girella fimbriata</i> (McCulloch 1920)	Caramel drummer	P
Pomacentridae	<i>Parma kermadecensis</i> Allen 1987	Kermadec scalyfin	B
Pomacentridae	<i>Chrysiptera rapanui</i> (Greenfield & Hensley 1970)	Kermadec demoiselle	B
Tripterygiidae	<i>Enneapterygius kermadecensis</i> Fricke 1994	Kermadec triplefin	B
Gobiidae	<i>Eviota kermadecensis</i> Hoese & Stewart 2012	Kermadec goby	B

Table 5. Records of *Girella fimbriata* from sites in north-eastern New Zealand. * Identification confirmed from specimen or photo by K. Clements, University of Auckland.

Date	Place	Source	Evidence
21 Jun 1969	The Pinnacles, Poor Knights Islands, 3 m depth	B. Russell	Specimen speared, photo in Doak (1969)
21 Jul 2002	Rakitu (Arid) Island, Great Barrier Island, 8–10 m depth	P. Swanson, E. Arron	Observation, ca. 30–35 cm total length
26 May 2007	The Needles, Great Barrier Island, 7 m depth	D. Shields	Photos*
23 Jan 2008	Motiti Island, Bay of Plenty, 3–4 m depth	J. Anderson	Photos and video*
? Jan 2010	Lady Alice Island, Hen and Chicken Islands	J. Anderson	Speared; necropsied by K. Clements*
Jun 2011	Northern Aorangi Is, Poor Knights Is	S. Baker	Group of 4–8 seen periodically over previous few years in same location

Table 6. Records of *Parma kermadecensis* from sites in north-eastern New Zealand.

Date	Place	Source	Evidence
25 Apr 1997	Bartle's Bay, Poor Knights Islands	K. Clements	Photo, one fish
24 Mar 1998	Bartle's Bay, Poor Knights Islands	M. Francis	Photo, one fish
ca. 2000	Bartle's Bay, Poor Knights Islands	W. Doak	http://www.youtube.com/watch?v=4YQSIPcNqSY (4:06–4:47 mins), one fish
Aug 2002	Bartle's Bay, Poor Knights Islands	D. Abbott	Two seen
12 Sep 2002	Bartle's Bay, Poor Knights Islands	L. Howe	Photo; two fish
Jan 2004	Bartle's Bay, Poor Knights Islands	D. Abbott	Two seen
1 Sep 2007	Bartle's Bay, Poor Knights Islands	S. Franicevic	Photo; two fish
Sep 2010	Coppermine Island pinnacles, Hen and Chicken Islands, 10–12 m depth	N. Stretton	Whitish body with slightly darker forehead
3 Sep 2011	Barren Arch, Poor Knights Islands, 14–30 m	K. White	One fish

Table 7. Records of *Chrysiptera rapanui* from sites in north-eastern New Zealand.

Date	Place	Source	Evidence
1984–1986	Cave Bay, Poor Knights Islands	Q. Bennett	Photo in Francis <i>et al.</i> (1999)
Jan 2012	Brady's Corner, Poor Knights Islands	S. Baker	Photos

DISCUSSION

The known Kermadec Islands coastal fish fauna comprises 175 species, an increase of 30 species over the previous total (Francis 1993). Many of the additions are tropical reef fishes that were recorded in very low numbers, fulfilling the prediction of Francis (1993) that larval dispersal from upstream sources such as Norfolk and Lord Howe Islands will continue to introduce rare tropical 'strays'. Although only a subset of tropical species have larval durations and thermal tolerances that enable them to recruit to remote subtropical locations, the available pool of species is very large, so new tropical strays should continue to arrive at the Kermadec Islands. We endorse the earlier conclusion that "because of the haphazard nature of larval dispersal and recruitment, it is unlikely that a complete checklist will ever be possible" (Francis 1993).

Eight endemic Kermadec Islands fish species are reported here (see Table 4). However, two species still await specific identification and description and one (*Chrysiptera rapanui*) awaits genetic and morphological comparison of the Kermadec and Easter Islands populations to determine its taxonomic status. Three of the endemic species have been recorded as strays around north-eastern North Island, New Zealand (Tables 5–7). Application of a stricter definition of endemism that excludes undescribed species and species recorded from elsewhere as strays (e.g. Kulbicki 2007) would reduce the Kermadec Islands list of endemics to just three species – *Microbrotula punicea*, *Enneapterygius kermadecensis* and *Eviota kermadecensis*. We have adopted the broader definition of endemism here in order to highlight the presence at the Kermadec Islands of a small group of species whose highly restricted geographic distributions make them an important and potentially vulnerable component of the fauna. The Kermadec Islands endemism rate (4.6%) is greater than those of Grand Terre in New Caledonia (3.3%) and Rapa Island in the subtropical eastern South Pacific (2.2%), albeit based on a more restrictive definition of endemism (Kulbicki 2007), but much lower than the extremely isolated Hawaiian Islands (25%) and Easter Island (22%) (Randall *et al.* 2005; Randall 2007).

Most of the Kermadec endemics have reproductive strategies involving no, or short, larval stages. This may be an important adaptation for species endemic to small, remote islands as it increases the probability of self-recruitment by reducing the chance that eggs and larvae will be carried far away from their source. Self-recruitment may also be facilitated by eddies that form downstream of islands, and the ability of fish larvae to swim strongly towards land, especially during later larval life (Fisher 2005).

Population sizes of *Girella fimbriata*, *Parma kermadecensis* and *Chrysiptera rapanui* around north-eastern New Zealand are apparently extremely small, and it is unlikely that those species breed successfully there. The individuals seen in New Zealand almost certainly recruited as larvae from spawning

populations at the Kermadec Islands. Although transport of fish larvae from Norfolk Island to New Zealand via the East Australian Current and East Auckland Current appears to be routine (Francis & Evans 1993; Francis *et al.* 1999), currents flowing from the Kermadec Islands to New Zealand have not been reported. The main oceanic flows north of New Zealand are eastward, with some north-eastwards flow to and past the Kermadec Islands (Ridgway & Heath 1975; Roemmich & Cornuelle 1990; Hamilton 1996; Whitworth *et al.* 1999; Ridgway & Dunn 2003), resulting in the transport of flotsam from New Zealand to the Kermadec Islands (Oliver 1910; Sykes & Godley 1968; Nelson & Adams 1984). The occurrence of Kermadec endemics in New Zealand indicates that there must periodically be either a reversal of these prevailing flows, or that the large anticyclonic eddies present in the region (Roemmich & Sutton 1998; Ridgway & Dunn 2003) can transport larvae in an overall south-westerly direction.

The relationships among the coastal fish faunas of Kermadec, Norfolk and Lord Howe Islands are essentially unchanged from those described by Francis (1993). Updated checklists of the faunas of Lord Howe and Norfolk contain 518 and 270 coastal fishes respectively (M. Francis, unpubl. data) compared with 175 at the Kermadec Islands, confirming the strong west-to-east cline in species richness across the subtropical south-west Pacific. All three islands are on the fringes of the tropical Pacific, which itself has strong west-to-east and latitudinal clines in reef fish diversity (Bellwood & Hughes 2001). In a predictive model fitted to reef fish taxonomic composition for 63 fish faunas throughout the Indo-Pacific Ocean (including the 1993 checklists for Lord Howe, Norfolk and Kermadec Islands), Bellwood & Hughes (2001) found that habitat area, longitude and latitude explained more than 74% of the variance (see Kulbicki 2007 for a similar alternative analysis). The low species richness at the Kermadec Islands fits the model well, as these islands have a small reef area (they are the emergent tops of steep-sided volcanoes), are a considerable distance east of the Indo-Malay Archipelago centre of diversity, and are in a relatively high latitude.

The percentages of tropical fishes in the Lord Howe, Norfolk and Kermadec Islands faunas have all increased by 4–5% from those reported in an earlier analysis (Francis 1993), whereas the percentages of subtropical species have declined slightly (see Table 2). The proportion of temperate species has declined at the Kermadec Islands but not at the other islands. These changes reflect the fact that new records at all three island groups are increasingly of tropical species recruiting from upstream sources, notably Australia's Great Barrier Reef and each successive island in the subtropical chain. Species with temperate and subtropical affinities are now well known at the three island groups, and are not expected to increase substantially in future. However, tropical species are likely to continue to increase.

Despite the large contribution of tropical fishes to the species richness of the Kermadec Islands, they are

typically not very abundant there. Many are known only from a few strays, and most are uncommon. Instead, subtropical species are most abundant (Francis *et al.* 1987; Cole *et al.* 1992; Eddy 2011; Trnski *et al.* 2015). These include the planktivorous *Bathystethus cultratus*, *Labracoglossa nitida*, *Chromis dispila*, *Chrysiptera rapanui* and *Scorpius violacea*; the herbivorous *Stegastes fasciolatus*, *Aplodactylus etheridgii*, *Kyphosus sectatrix* and *Parma kermadecensis*; and the carnivorous *Pseudolabrus luculentus* (Cole *et al.* 1992). The wide latitudinal spread of the Kermadec Islands is reflected in latitudinal trends in abundance for 35% of coastal fishes. Francis *et al.* (1987) found that out of 77 fish species, five species decreased in abundance northwards, 18 species increased in abundance northwards, four species peaked in abundance in the central Kermadec Islands, and 50 species showed no latitudinal trend. Cole *et al.* (1992) found strong depth gradients for many schooling and demersal fishes that result in distinct depth-stratified fish communities.

Top predators are common at the Kermadec Islands, notably Galapagos sharks and spotted black grouper (*Epinephelus daemeli*) (Francis *et al.* 2015). Both these species are mainly restricted to depths shallower than 50 m and consequently have a small habitat area at the Kermadec Islands. Both species are also long-lived, slow-growing, and have low reproductive rates. These habitat and biological characteristics combine to make them highly vulnerable to fishing. Marine reserve status at the Kermadec Islands has protected these species and maintained them at apparently natural levels of abundance; elsewhere, they have been severely depleted by fishing (Francis *et al.* 2015).

The coastal fish fauna of the Kermadec Islands is not particularly diverse but the mix of fish species present, the abundance of subtropical species, the presence of endemic species, and the abundance of top predators, produce a unique and interesting fauna.

ACKNOWLEDGMENTS

We thank our numerous colleagues and the crews of the 2004 and 2011 Kermadec Islands research expeditions for their invaluable observations, support and good company. We especially appreciate the efforts of Tom Trnski in organising the latter trip and making it a success. Richie Robinson was responsible for six of the new Kermadec fish records reported here. We thank the following for help identifying fishes and clarifying nomenclature: G. Allen, J. Choat, K. Clements, W. Eschmeyer, S. Knudsen, R. Kuitert, J. Leis, J. McCosker, H. Motomura, J. Randall, B. Russell, D. Smith, W. Smith-Vaniz and A. Stewart. Records and images of Kermadec Islands fish species in New Zealand waters were provided by the many people named in Tables 5–7, and their contributions are greatly appreciated. We also thank R. Robinson, G. Edgar, T. Hitchon, M. Page and F. Smith for providing us with their underwater images of Kermadec Islands fishes, and allowing us to reproduce some of them here.

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Article submitted 20 April 2012; revised and accepted: 16 September 2015.

APPENDIX 1: Checklist of Kermadec Islands coastal fishes, with biogeographical distribution categories as in Table 3. The sources of name changes from those reported in the previous checklist by Francis (1993), and of new records, are also provided. LH=Lord Howe Island, Kerm=Kermadec Islands, NZ=New Zealand.

Family	Species	Distribution	Sources
Odontaspidae	<i>Odontaspis ferox</i> (Risso 1810)	Worldwide	
Lamnidae	<i>Carcharodon carcharias</i> (Linnaeus 1758)	Worldwide	New record (Duffy <i>et al.</i> 2012)
Triakidae	<i>Mustelus</i> sp.	Endemic	Reported as <i>M. lenticulatus</i> (C. Duffy & M. Francis unpubl. data)
Carcharhinidae	<i>Carcharhinus galapagensis</i> (Snodgrass & Heller 1905)	Worldwide	
Carcharhinidae	<i>Galeocerdo cuvier</i> (Peron & LeSueur 1822)	Worldwide	
Sphyrnidae	<i>Sphyrna zygaena</i> (Linnaeus 1758)	Worldwide	
Dasyatidae	<i>Dasyatis brevicaudata</i> (Hutton 1875)	Indo-Pacific	
Myliobatidae	<i>Myliobatis tenuicaudatus</i> Hector 1877	LH-NZ	
Muraenidae	<i>Anarchias seychellensis</i> Smith 1962	Indo-Pacific	New record (McCosker & Stewart 2006)
Muraenidae	<i>Enchelycore ramosa</i> (Griffin 1926)	S Pacific	
Muraenidae	<i>Gymnothorax eurostus</i> (Abbott 1860)	Indo-Pacific	
Muraenidae	<i>Gymnothorax nubilus</i> (Richardson 1848)	LH-NZ	
Muraenidae	<i>Gymnothorax pictus</i> (Ahl 1789)	Indo-Pacific	
Muraenidae	<i>Gymnothorax porphyreus</i> (Guichenot 1848)	S Pacific	Reported as <i>G. griffini</i> (Bohlke & McCosker 2001, McCosker & Stewart 2006)
Muraenidae	<i>Gymnothorax thyrsoideus</i> (Richardson 1845)	Indo-Pacific	New record (Trnski <i>et al.</i> 2015)
Ophichthidae	<i>Apterichthys australis</i> McCosker & Randall 2005	S Pacific	New record (McCosker & Randall 2005)
Ophichthidae	<i>Leiuranus semicinctus</i> (Lay & Bennett 1839)	Indo-Pacific	New record (Trnski <i>et al.</i> 2015)
Ophichthidae	<i>Myrichthys maculosus</i> (Cuvier 1816)	Indo-Pacific	
Ophichthidae	<i>Scolecenchelys australis</i> (Macleay 1881)	SW Pacific	
Congridae	<i>Ariosoma howensis</i> (McCulloch & Waite 1916)	SW Pacific	Reported as <i>Poecilconger</i> sp. (D. Smith, Smithsonian, pers. comm.)
Congridae	<i>Conger cinereus</i> Rüppell 1830	Indo-Pacific	
Congridae	<i>Conger wilsoni</i> (Bloch & Schneider 1801)	Indo-Pacific	
Congridae	<i>Gnathophis umbrellabius</i> (Whitley 1948)	SW Pacific	

Family	Species	Distribution	Sources
Engraulidae	<i>Engraulis australis</i> (White 1790)	SW Pacific	
Gonorynchidae	<i>Gonorynchus greyi</i> (Richardson 1845)	S Pacific	
Synodontidae	<i>Synodus dermatogenys</i> Fowler 1912	Indo-Pacific	New record (present study)
Synodontidae	<i>Synodus doaki</i> Russell & Cressey 1979	Indo-Pacific	
Synodontidae	<i>Synodus similis</i> McCulloch 1921	SW Pacific	New record (Trnski <i>et al.</i> 2015)
Synodontidae	<i>Synodus variegatus</i> (Lacepède 1803)	Indo-Pacific	
Synodontidae	<i>Trachinocephalus myops</i> (Forster 1801)	Worldwide	
Moridae	<i>Lotella phycis</i> (Temminck & Schlegel 1846)	Pacific	
Moridae	<i>Lotella rhacina</i> (Forster 1801)	SW Pacific	
Carapidae	<i>Omuxodon fowleri</i> (Smith 1955)	Indo-Pacific	
Bythitidae	<i>Microbrotula punicea</i> Anderson 2007	Endemic	New record (Anderson 2007)
Gobiesocidae	<i>Aspasmogaster</i> sp.	Endemic	Reported as ‘Undescribed genus and species’
Hemiramphidae	<i>Euleptorhamphus viridis</i> (van Hasselt 1823)	Indo-Pacific	
Belonidae	<i>Ablennes hians</i> (Valenciennes 1846)	Worldwide	
Belonidae	<i>Platybelone platyura</i> (Bennett 1832)	Indo-Pacific	Reported as <i>P. argalus</i> (Eschmeyer & Fricke 2012)
Isonidae	<i>Iso rhotophilus</i> (Ogilby 1895)	Indo-Pacific	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)
Monocentridae	<i>Monocentris japonica</i> (Houttuyn 1782)	Indo-Pacific	
Exocoetidae	<i>Hirundichthys rufipinnis</i> (Valenciennes 1847)	Worldwide	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)
Trachichthyidae	<i>Optivus elongatus</i> (Günther 1859)	Kerm-NZ	
Berycidae	<i>Centroberyx affinis</i> (Günther 1859)	SW Pacific	
Holocentridae	<i>Myripristis berndti</i> Jordan & Evermann 1903	Indo-Pacific	
Holocentridae	<i>Pristilepis oligolepis</i> (Whitley 1941)	Indo-Pacific	
Aulostomidae	<i>Aulostomus chinensis</i> (Linnaeus 1766)	Indo-Pacific	
Fistulariidae	<i>Fistularia commersonii</i> Rüppell 1838	Worldwide	
Syngnathidae	<i>Cosmocampus howensis</i> (Whitley 1948)	S Pacific	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)
Scorpaenidae	<i>Dendrochirus brachypterus</i> (Cuvier 1829)	Indo-Pacific	New record (present study)
Scorpaenidae	<i>Dendrochirus zebra</i> (Cuvier 1829)	Indo-Pacific	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)
Scorpaenidae	<i>Pterois antennata</i> (Bloch 1787)	Indo-Pacific	
Scorpaenidae	<i>Pterois volitans</i> (Linnaeus 1758)	Pacific	
Scorpaenidae	<i>Scorpaena cardinalis</i> Solander & Richardson 1842	SW Pacific	Reported as <i>S. cookii</i> (Motomura <i>et al.</i> 2011)
Scorpaenidae	<i>Scorpaenodes evides</i> (Jordan & Thompson 1914)	Indo-Pacific	Reported as <i>S. scaber</i> (Motomura <i>et al.</i> 2010, H. Motomura pers. comm.)
Neosebastidae	<i>Maxillicosta raoulensis</i> Eschmeyer & Poss 1976	LH-NZ	
Serranidae	<i>Acanthistius cinctus</i> (Günther 1859)	SW Pacific	
Serranidae	<i>Aulacocephalus temminckii</i> Bleeker 1855	Indo-Pacific	
Serranidae	<i>Caprodon longimanus</i> (Günther 1859)	Pacific	
Serranidae	<i>Epinephelus daemeli</i> (Günther 1876)	SW Pacific	
Serranidae	<i>Grammistes sexlineatus</i> (Thunberg 1792)	Indo-Pacific	
Serranidae	<i>Hypoplectrodes</i> sp.	LH-NZ	
Serranidae	<i>Trachypoma macracanthus</i> Günther 1859	S Pacific	
Kuhliidae	<i>Kuhlia mugil</i> (Forster 1801)	Indo-Pacific	
Priacanthidae	<i>Priacanthus macracanthus</i> Cuvier 1829	Indo-Pacific	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)

Family	Species	Distribution	Sources
Apogonidae	<i>Ostorhinchus fukuui</i> (Hayashi 1990)	Indo-Pacific	Reported as <i>A. doederleini</i> (Trnski <i>et al.</i> 2015)
Apogonidae	<i>Pristiapogon kallopterus</i> (Bleeker 1856)	Indo-Pacific	
Echeneididae	<i>Echeneis naucrates</i> Linnaeus 1758	Worldwide	
Echeneididae	<i>Remora remora</i> (Linnaeus 1758)	Worldwide	
Carangidae	<i>Decapterus ?muroadsi</i> (Temminck & Schlegel 1844)	Worldwide	Identity previously uncertain, now thought likely to be this species (present study)
Carangidae	<i>Pseudocaranx georgianus</i> (Cuvier 1833)	SW Pacific	Reported as <i>P. dentex</i>
Carangidae	<i>Seriola dumerili</i> (Risso 1810)	Worldwide	New record (present study)
Carangidae	<i>Seriola lalandi</i> Valenciennes 1833	Worldwide	
Carangidae	<i>Seriola rivoliana</i> Valenciennes 1833	Worldwide	
Carangidae	<i>Trachurus declivis</i> (Jenyns 1841)	SW Pacific	
Arripidae	<i>Arripis trutta</i> (Forster 1801)	SW Pacific	
Arripidae	<i>Arripis xylabion</i> Paulin 1993	LH-NZ	Reported as <i>Arripis</i> sp. (Paulin 1993)
Lutjanidae	<i>Lutjanus kasmira</i> (Forsskål 1775)	Indo-Pacific	
Lutjanidae	<i>Paracaesio xanthura</i> (Bleeker 1869)	Indo-Pacific	
Mullidae	<i>Mulloidichthys vanicolensis</i> (Valenciennes 1831)	Indo-Pacific	
Mullidae	<i>Parupeneus pleurostigma</i> (Bennett 1831)	Indo-Pacific	New record (present study)
Mullidae	<i>Parupeneus spilurus</i> (Bleeker 1854)	Pacific	
Mullidae	<i>Upeneichthys porosus</i> (Cuvier 1829)	LH-NZ	Reported as <i>U. lineatus</i> (Kim 2002)
Mullidae	<i>Upeneus francisi</i> Randall & Guézé 1992	LH-NZ	
Pempheridae	<i>Pempheris analis</i> Waite 1910	SW Pacific	
Girellidae	<i>Girella cyanea</i> Macleay 1881	SW Pacific	
Girellidae	<i>Girella fimbriata</i> (McCulloch 1920)	Endemic	
Kyphosidae	<i>Kyphosus bigibbus</i> Lacepède 1801	Worldwide	
Kyphosidae	<i>Kyphosus sectatrix</i> (Linnaeus 1758)	Worldwide	New record (Knudsen & Clements 2013)
Microcanthidae	<i>Atypichthys latus</i> McCulloch & Waite 1916	LH-NZ	
Scorpididae	<i>Bathystethus cultratus</i> (Bloch & Schneider 1801)	SW Pacific	
Scorpididae	<i>Labracoglossa nitida</i> McCulloch & Waite 1916	SW Pacific	
Scorpididae	<i>Scorpis violacea</i> (Hutton 1873)	SW Pacific	
Chaetodontidae	<i>Amphichaetodon howensis</i> (Waite 1903)	SW Pacific	
Chaetodontidae	<i>Chaetodon auriga</i> Forsskål 1775	Indo-Pacific	
Chaetodontidae	<i>Chaetodon lunula</i> (Lacepède 1802)	Indo-Pacific	New record (present study)
Chaetodontidae	<i>Forcipiger flavissimus</i> Jordan & McGregor 1898	Indo-Pacific	
Chaetodontidae	<i>Heniochus diphreutes</i> Jordan 1903	Indo-Pacific	
Pomacanthidae	<i>Genicanthus semicinctus</i> (Waite 1900)	LH-Kerm	
Pentacerotidae	<i>Evistias acutirostris</i> (Temminck & Schlegel 1844)	Pacific	
Pomacentridae	<i>Abudefduf sordidus</i> (Forsskål 1775)	Indo-Pacific	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)
Pomacentridae	<i>Chromis dispila</i> Griffin 1923	Kerm-NZ	
Pomacentridae	<i>Chromis vanderbilti</i> (Fowler 1941)	Pacific	
Pomacentridae	<i>Chrysiptera rapanui</i> (Greenfield & Hensley 1970)	Endemic	
Pomacentridae	<i>Parma alboscaphularis</i> Allen & Hoesé 1975	LH-NZ	
Pomacentridae	<i>Parma kermadecensis</i> Allen 1987	Endemic	
Pomacentridae	<i>Stegastes fasciolatus</i> (Ogilby 1889)	Indo-Pacific	
Pomacentridae	<i>Stegastes gascoynei</i> (Whitley 1964)	SW Pacific	New record (present study)
Cirrhitidae	<i>Cirrhitus pinnulatus</i> (Forster 1801)	Indo-Pacific	

Family	Species	Distribution	Sources
Cirrhitidae	<i>Notocirrhitis splendens</i> (Ogilby 1889)	SW Pacific	
Chironemidae	<i>Chironemus microlepis</i> Waite 1916	LH-Kerm	
Aplodactylidae	<i>Aplodactylus etheridgii</i> (Ogilby 1889)	LH-NZ	
Latridae	<i>Chirodactylus ephippium</i> (McCulloch & Waite 1916)	SW Pacific	
Latridae	<i>Goniistius francisi</i> (Burrige 2004)	SW Pacific	Reported as <i>Cheilodactylus vittatus</i> (Burrige 2004)
Latridae	<i>Latridopsis ciliaris</i> (Forster 1801)	SW Pacific	
Latridae	<i>Nemadactylus douglasii</i> (Hector 1875)	SW Pacific	
Mugilidae	<i>Chelon melinoptera</i> (Valenciennes 1836)	Indo-Pacific	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)
Sphyaenidae	<i>Sphyaena</i> sp.	Unknown	Reported as <i>S. acutipinnis</i>
Labridae	<i>Anampses caeruleopunctatus</i> Rüppell 1829	Indo-Pacific	
Labridae	<i>Anampses elegans</i> Ogilby 1889	SW Pacific	
Labridae	<i>Bodianus unimaculatus</i> (Günther 1862)	S Pacific	
Labridae	<i>Coris aygula</i> Lacepède 1801	Indo-Pacific	New record (present study)
Labridae	<i>Coris dorsomacula</i> Fowler 1908	Indo-Pacific	New record (present study)
Labridae	<i>Coris gaimard</i> (Quoy & Gaimard 1824)	Pacific	New record (present study)
Labridae	<i>Coris picta</i> (Bloch & Schneider 1801)	SW Pacific	
Labridae	<i>Coris sandeyeri</i> (Hector 1884)	SW Pacific	Reported as <i>C. sandageri</i> (Russell 2011)
Labridae	<i>Halichoeres margaritaceus</i> (Valenciennes 1839)	Indo-Pacific	
Labridae	<i>Iniistius pavo</i> (Valenciennes 1840)	Indo-Pacific	New record (present study)
Labridae	<i>Macropharyngodon meleagris</i> (Valenciennes 1839)	Pacific	New record (present study)
Labridae	<i>Notolabrus inscriptus</i> (Richardson 1848)	SW Pacific	
Labridae	<i>Pseudocoris yamashiroi</i> (Schmidt 1931)	Indo-Pacific	
Labridae	<i>Pseudojuloides elongatus</i> Ayling & Russell 1977	Pacific	New record (Trnski <i>et al.</i> 2015)
Labridae	<i>Pseudolabrus luculentus</i> (Richardson 1848)	SW Pacific	
Labridae	<i>Scarus ghobban</i> Forsskål 1775	Indo-Pacific	New record (present study)
Labridae	<i>Scarus</i> sp.	Unknown	
Labridae	<i>Stethojulis bandanensis</i> (Bleeker 1851)	Pacific	
Labridae	<i>Suezichthys arquatus</i> Russell 1985	SW Pacific	
Labridae	<i>Suezichthys aylingi</i> Russell 1985	SW Pacific	
Labridae	<i>Thalassoma amblycephalum</i> (Bleeker 1856)	Indo-Pacific	
Labridae	<i>Thalassoma lunare</i> (Linnaeus 1758)	Indo-Pacific	
Labridae	<i>Thalassoma lutescens</i> (Lay & Bennett 1839)	Indo-Pacific	
Labridae	<i>Thalassoma nigrofasciatum</i> Randall 2003	SW Pacific	Reported as <i>T. janseni</i> (Randall 2003)
Labridae	<i>Thalassoma purpureum</i> (Forsskål 1775)	Indo-Pacific	
Labridae	<i>Thalassoma trilobatum</i> (Lacepède 1801)	Indo-Pacific	
Uranoscopidae	<i>Kathetostoma binigrasella</i> Gomon & Roberts 2011	LH-NZ	Reported as <i>Kathetostoma</i> sp.
Creediidae	<i>Limnichthys fasciatus</i> Waite 1904	Pacific	
Tripterygiidae	<i>Enneapterygius kermadecensis</i> Fricke 1994	Endemic	Reported as <i>E. rufopilea</i> (Fricke 1994)
Blenniidae	<i>Cirripectes alboapicalis</i> (Ogilby 1899)	S Pacific	
Blenniidae	<i>Cirripectes castaneus</i> (Valenciennes 1836)	Indo-Pacific	
Blenniidae	<i>Ecsenius bicolor</i> (Day 1888)	Indo-Pacific	New record (present study)
Blenniidae	<i>Entomacrodus caudofasciatus</i> (Regan 1909)	Indo-Pacific	
Blenniidae	<i>Entomacrodus cymatobiotus</i> Schultz & Chapman 1960	Pacific	
Blenniidae	<i>Entomacrodus niuafoouensis</i> (Fowler 1932)	Indo-Pacific	

Family	Species	Distribution	Sources
Blenniidae	<i>Parablennius laticlavius</i> (Griffin 1926)	SW Pacific	
Blenniidae	<i>Plagiotremus tapeinosoma</i> (Bleeker 1857)	Indo-Pacific	
Gobiidae	<i>Eviota kermadecensis</i> Hoese & Stewart 2012	Endemic	Reported as <i>Eviota</i> sp.
Gobiidae	<i>Priolepis psygmophilia</i> Winterbottom & Burridge 1993	S Pacific	Reported as <i>Priolepis</i> sp. (Winterbottom & Burridge 1993)
Acanthuridae	<i>Acanthurus dussumieri</i> Valenciennes 1835	Indo-Pacific	New record (present study)
Acanthuridae	<i>Acanthurus nigrofusus</i> (Forsskål 1775)	Indo-Pacific	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)
Acanthuridae	<i>Acanthurus triostegus</i> (Linnaeus 1758)	Indo-Pacific	
Acanthuridae	<i>Prionurus maculatus</i> Ogilby 1887	SW Pacific	
Zanclidae	<i>Zanclus cornutus</i> (Linnaeus 1758)	Indo-Pacific	
Bothidae	<i>Asterorhombus</i> sp.	Unknown	New record (Trnski <i>et al.</i> 2015, Roberts <i>et al.</i> 2015)
Bothidae	<i>Bothus mancus</i> (Broussonet 1782)	Indo-Pacific	New record (present study)
Bothidae	<i>Engyprosopon raoulensis</i> Amaoka & Mihara 1995	LH-Kerm	Reported as <i>Engyprosopon</i> sp. (Amaoka & Mihara 1995)
Soleidae	<i>Aseraggodes bahamondei</i> Randall & Meléndez 1987	S Pacific	
Balistidae	<i>Rhinecanthus rectangulus</i> (Bloch & Schneider 1801)	Indo-Pacific	
Monacanthidae	<i>Cantherhines dumerilii</i> (Hollard 1854)	Indo-Pacific	New record (present study)
Monacanthidae	<i>Meuschenia scaber</i> (Forster 1801)	SW Pacific	
Monacanthidae	<i>Thamnaconus analis</i> (Waite 1904)	SW Pacific	
Ostraciidae	<i>Lactoria diaphana</i> (Bloch & Schneider 1801)	Indo-Pacific	
Ostraciidae	<i>Ostracion cubicus</i> Linnaeus 1758	Indo-Pacific	
Tetraodontidae	<i>Canthigaster callisterna</i> (Ogilby 1889)	SW Pacific	
Tetraodontidae	<i>Torquigener altipinnis</i> (Ogilby 1891)	SW Pacific	
Diodontidae	<i>Diodon holocanthus</i> Linnaeus 1758	Worldwide	New record (present study)
Diodontidae	<i>Diodon hystrix</i> Linnaeus 1758	Worldwide	

