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Chapter 2

Coral Reef Fish Diversity of the Northwestern Lagoon of Grande-Terre New Caledonia

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SUMMARY

- A list of fish species was compiled from observations while scuba diving at 57 of the 62 sites assessed in the northwest lagoon (Yandé to Koumac) of New Caledonia. The survey involved approximately 90 hours of scuba dive to a maximum depth of 30m.
- There are currently 1,019 known reef associated reef species. This study observed 526 species in total, representing 52% of the known diversity. Species numbers at the 57 sites for which data was analyzed varied from 46 to 172, with an overall mean value of 117.
- Wrasses (Labridae), Damselfishes (Pomacentridae), and Gobies (Gobiidae) were the dominant groups in the survey area. In these dominant families, 75, 71 and 31 species respectively were observed across the entire survey.
- Outer barrier reef front or outer slope sites had the highest fish diversity with a mean of 141 species per site. Outer barrier reef back sites had a mean of 117 species per site. Outer barrier reef pass sites had a mean of 124 species, intermediate lagoon reefs had a mean of 127 species and inner lagoon reefs had a mean of 81 species recorded. Fish surveys at most sites on inner lagoon and, to a lesser degree, intermediate lagoon reefs were affected by poor visibility.
- Two range extension records for New Caledonia reef fish species were obtained in the survey. These included *Asterropteryx striatus* from the Gobiidae family and *Plectroglyphidodon phoenixensis* from the Pomacentridae family.
- A formula for predicting the total number of reef fish species that could be expected to be found in the survey area was applied to our results, indicating that approximately 773 fish species could be expected to be present. This may be contrasted with the figure of known reef fish species for the entire New Caledonia lagoon and reefs which stands at 1,019.
- Our study indicated relatively high reef fish diversity over an extensive area of the reef sites assessed, supporting the conclusion that the northwest lagoon and reef system is a regionally if not internationally important site in biodiversity terms. The development of a network of marine protected areas to conserve and manage this region is well justified and critical.

INTRODUCTION

This chapter presents the reef fish diversity investigation conducted as part of Conservation International's RAP survey of northwestern lagoon of New Caledonia, December 2007. General information on the survey and survey site descriptions are provided elsewhere in this report.

The objective was to produce a comprehensive list of reef-associated fish species. This was achieved through observations completed by a scuba diver within safe recreational diving depths (to 30m). On a cost and time basis this method is generally perceived to give the best results. Considerable scientific effort has gone into the analysis of the data derived from this

method over many sites by many divers. This provides a basis for comparison between sites and between regions. There are however a number of limitations to this method. For example, the survey method excluded estuarine species, deep water species and open water pelagic species generally such as flying fish, tuna and billfish.

New Caledonia has a significant history of marine survey work. Several institutions based in New Caledonia have also completed significant works that describe reef fish biodiversity and ecology in the New Caledonia lagoon. Leading this work is the Secretariat of the Pacific Community, the Institute of Research for Development (IRD), Government entities of the Northern and Southern Provinces and the University of New Caledonia. Although the majority of reef fish studies in New Caledonia have had a fishing industry focus, they also contain substantial biodiversity information. Kulbicki et al. (2000) carried out an extensive survey of lagoon fish stocks of the northwestern region and Letourneur et al. (2000) completed a study of commercial fish assemblages and the effects of different levels of ground erosion. Both these studies provide important informational background. A survey by Conservation International in 2004 off the northeast coast or Mt Panié region included a study of coral reef fish diversity (Evans 2006).

Current estimates of the total coral reef-associated species vary and will continue to rise as new areas are intensively surveyed and new species continue to be described. For New Caledonia, Allen (2006) lists the figure at 1,019 species. Fishbase currently lists 1,114 reef-associated species. In a recent publication of the IRD 1,694 species are listed as shore species. The IRD shore fish checklist includes fish occurring to 100m depth and estuarine species and is accordingly larger (Fricke and Kulbicki 2006).

New Caledonia occupies an important position on the edge of the Indo tectonic plate. To the north are Indonesia and Papua New Guinea where the highest coral reef fish diversity levels in the world are recorded. The rich diversity sites centered within Indonesia have up to roughly double the overall diversity of New Caledonia. New Caledonia has been historically supplied with species from the Indo region via the warm tropical currents sweeping down. This proximity to the 'coral triangle' of coral reef biodiversity means that New Caledonia's fish fauna is globally significant and ranks very highly when compared with all regions other than the Indo region. New Caledonia has been recognized as part of a significant regional center of endemism (Olsen and Dinersten 2002, Roberts 2002).

Rapid assessment survey methods such as adopted in this study can produce a worthwhile overall picture of the reef fish diversity across broad areas. In most cases new, rare and threatened or indicator species can be observed and compared to other areas. This type of data may also produce information about fishing pressure or the presence of environmental disturbances that impact reef fish community composition or abundances. Fish diversity information at this fundamental level becomes useful and important for forming a baseline of data on community structure and abundance. Further, it can be used in future change over time studies or monitoring designed to test the efficacy of management actions related to fishing or biodiversity protection.

Table 2.1. Rankings by diversity of the top thirteen reef fish families with the number of species observed during survey of the northwest lagoon (Yandé to Koumac) of New Caledonia.

Classement	Famille	Espèces
1	LABRIDAE	75
2	POMACENTRIDAE	71
3	GOBIIDAE	31
4	ACANTHURIDAE	29
5	CHAETODONTIDAE	28
6	SERRANIDAE	25
7	SCARIDAE	20
8	LUTJANIDAE	18
9	APOGONIDAE	19
10	BLENNIIDAE	15
11	CARANGIDAE	17
12	BALISTIDAE	13
13	LETHRINIDAE	14

Survey methods for overall species diversity such as adopted in this study risk under-reporting the actual diversity that occurs in a given locality due to the cryptic nature of some species and the limitations of the diver actually visually making contact with all species present. Gerald Allen (2002a, 2002b, 2005a) has derived a method to estimate total reef fish numbers from the diver survey counts of six predominant fish families. This extrapolation method is based on extensive statistical analysis of known sites and similar survey effort. Used in the context of this study the method allows us to extrapolate our survey numbers to an estimated value for the total number of species we would expect to make up the reef fish diversity of the lagoon area studied. Additionally, this derived total species number allows us to compare estimated total species numbers between different regions and countries that have been surveyed in a similar manner.

METHODS

The fish diversity method employed here closely followed the methods for the Conservation International RAP 42 survey of the northeast lagoon of New Caledonia (Evans 2006). The survey involved approximately 90 hours of scuba diving. The maximum depth surveyed was 30m. A list of all fish species observed was compiled for each site surveyed. The approach involved the diver covering the full

range of depths and habitats during a single dive of 60–110 minutes duration at each site. The name of each observed species was recorded in pencil on a plastic sheet attached to a clipboard. This technique involved descending to the 30m level on the reef or to the reef edge with adjoining soft sediment habitats if this was less than 30m in depth. Where there was a reef edge at depth less than 30m, 5–10 minutes was spent observing species over the adjacent soft sediments then the diver would move on to the reef. The survey effort was divided between the various depth zones of the reef with a larger amount of time devoted to the 1–12m zone where typically the greatest abundance and diversity of reef fish species was located. The diver would move through the habitats in a slow meandering manner looking for the free swimming species as well as spending as much time as possible searching for more cryptic species in amongst the reef substrate. Each dive included a representative sample of all major bottom types and habitat situations present at the site. Examples of the typical habitats encountered are: rocky intertidal, reef flat, steep drop-offs, caves, rubble and sand or sand/mud and soft bottom patches.

Table 2.2. Number of reef fish species observed at each site during the survey of the northwest coast (Yandé to Koumac) of New Caledonia. Underwater visibility and reef site classification with habitat are indicated for each site. For the fish study, the sites were categorized by reef classes with habitats as: (1) outer barrier reefs front denoted as outer barrier, front; (2) outer barrier pass reefs denoted as outer barrier, pass; (3) outer barrier reefs back denoted as outer barrier, back; (4) intermediate lagoon reefs, and (5) inner lagoon reefs.

Rank	Site Rank	Species Site	Visibility	Reef classes with habitat	Rank	Site	Species	Visibility	Habitat
1	**83**	**172**	17	outer barrier, pass	32	**74**	**120**	8	outer barrier, back
2	**63**	**163**	20	outer barrier, back	33	**41**	**116**	5	intermediate lagoon
3	**37**	**157**	20	intermediate lagoon	34	**73**	**114**	10	outer barrier, back
4	**7**	**153**	20	outer barrier, front	35	**33**	**107**	8	intermediate lagoon
5	**2**	**151**	10	intermediate lagoon	36	**62**	**105**	15	outer barrier, back
6	**6**	**148**	20	outer barrier, front	37	**45**	**105**	5	intermediate lagoon
7	**9**	**145**	20	outer barrier, front	38	**32**	**105**	4	inner lagoon
8	**61**	**145**	25	outer barrier, back	39	**10**	**104**	15	outer barrier, pass
9	**87**	**144**	10	intermediate lagoon	40	**12**	**97**	8	outer barrier, back
10	**80**	**143**	20	outer barrier, front	41	**51**	**95**	6	intermediate lagoon
11	**1**	**143**	25	intermediate lagoon	42	**72**	**94**	15	outer barrier, back
12	**42**	**141**	20	intermediate lagoon	43	**13**	**92**	8	outer barrier, back
13	**59**	**139**	20	outer barrier, front	44	**14**	**92**	10	outer barrier, back
14	**69**	**139**	15	outer barrier, back	45	**64**	**85**	4	outer barrier, pass
15	**49**	**139**	10	intermediate lagoon	46	**28**	**85**	20	inner lagoon
16	**3**	**138**	20	intermediate lagoon	47	**65**	**83**	15	outer barrier, back
17	**85**	**138**	10	intermediate lagoon	48	**24**	**83**	4	inner lagoon
18	**58**	**136**	20	outer barrier	49	**22**	**81**	4	inner lagoon
19	**40**	**136**	4	intermediate lagoon	50	**26**	**78**	3	inner lagoon
20	**60**	**135**	15	outer barrier, pass	51	**29**	**78**	3	inner lagoon
21	**84**	**134**	20	outer barrier, back	52	**19**	**76**	6	inner lagoon
22	**38**	**134**	15	intermediate lagoon	53	**20**	**76**	3	inner lagoon
23	**43**	**134**	20	intermediate lagoon	54	**56**	**70**	1.5	inner lagoon
24	**36**	**133**	15	intermediate lagoon	55	**35**	**64**	2.5	inner lagoon
25	**17**	**132**	25	outer barrier, front	56	**18**	**57**	3	inner lagoon
26	**79**	**130**	23	outer barrier, front	57	**4**	**46**	4	intermediate lagoon
27	**16**	**129**	20	outer barrier, back					
28	**52**	**129**	5	intermediate lagoon					
29	**11**	**126**	8	outer barrier, back					
30	**86**	**123**	6	inner lagoon					
31	**48**	**121**	6	intermediate lagoon					

In addition to the species presence records there was also a value for relative abundance recorded for each species observed at each site. If a species was only seen once at a site it was given an abundance score of 1 representing rare. If a range of approximately 2–10 individuals of a species were observed at a site it was given an abundance score of 2 representing occasionally seen. If approximately 11–50 individuals of a species were seen it was given a score of 3 representing common. Where approximately 50 plus individuals were observed at a single site the species was given an abundance score of 4 representing abundant. The abundance scores for all species at all sites were averaged to derive a mean relative abundance score or description for each species ranging across all sites where the species was observed.

Only the names of fishes for which identification was certain were recorded. Where there was any uncertainty in the fish identification an attempt was made to photograph the fish for post-dive analysis. In all cases immediately after the dive the data sheets were checked and all photos taken during the dive were evaluated to finalize the list for the site. During the post-dive checks on occasion the other survey divers contributed observations and photographs of fish that were added to the site list once verified. It is a requirement of this method that the survey diver has considerable experience in reef fish identification due to the limited time available at each site and the complexity of the fish assemblages encountered.

In this survey no invasive methods such as ichthyocide poisoning or capture were utilized. In previous surveys these methods have been used, which results in higher counts for some families most notably the cryptic species of the Gobiidae, Blenniidae and Trypterygiidae families. Capture of fish is an important practice for taxonomic work on new or rare species, but that was not a specific objective of this survey. All photographs from the fish survey were catalogued by site.

Table 2.3. Categories or reef classes with mean number of species observed with range during survey. For the fish study, the sites were categorized by reef classes as: (1) outer barrier reefs front denoted as outer barrier, front; (2) outer barrier pass reefs denoted as outer barrier, pass; (3) outer barrier reefs back denoted as outer barrier, back; (4) intermediate lagoon reefs; and (5) inner lagoon reefs.

Reef classes	Number of sites	Species Mean	Range
outer barrier, front	8	141	130–153
outer barrier, back	14	117	83–163
outer barrier, pass	4	124	85–172
intermediate lagoon reefs	20	127	46–157
inner lagoon reefs	12	81	57–123

RESULTS AND DISCUSSION

General Fish Community Composition

There are currently 1,019 known reef-associated fish species in the New Caledonia lagoon system (Allen 2006). During the course of this survey, fish species were observed and recorded on 57 of the 62 sites visited in the study. Across all sites, 526 species were recorded in the northwest lagoon area. This total represents 52% of the known diversity of reef fish in New Caledonia. The mean abundance values for each species are listed in Appendix 2.

The species numbers across all sites for the thirteen most abundant families are detailed in Table 2.1. The families are ranked in order of diversity from most diverse to least diverse. The top three families in diversity, Labridae (75), Pomacentridae (71), and Gobiidae (31), make up 34% of the total fish species recorded. The top ten (Labridae, Pomacentridae, Gobiidae, Acanthuridae, Chaetodontidae, Serranidae, Scaridae, Lutjanidae, Apogonidae and Blenniidae) families make up 63% of the total fish species recorded.

The pattern of ranking and importance of families recorded in this survey generally follows a similar pattern to results from other studies (Allen 2006) with a few notable exceptions. Generally, the Gobiidae family would be expected to be at or near to the top of the ranking in biodiversity terms. The Blenniidae family similarly would be expected to be in the top six or seventh position, but in our survey Gobiidae and Blenniidae were ranked 3rd and10th respectively. These two families are most likely undersampled in our survey. There are several possible reasons for this. These two families have many species that are small and adopt cryptic lifestyles meaning that they are literally hiding in the coral substrate and very hard to observe. There could be differences between different surveyors in the amount of time devoted to these hard to find species, and in addition experience in identification of these species could make some difference as the level of difficulty and experience required is quite high. Finally, previous surveys that we can compare our data to typically used ichthyocide poisoning or capture techniques to supplement the general swimming visual observation method. In our study we did not use these invasive techniques and this would have made a potentially significant difference in the number of species recorded especially in these two species which are typically cryptic and small in size.

Fish Community Structure

The composition of local reef fish communities in the New Caledonia and more generally in the Indo-Pacific region is dependent on habitat variability. The relatively rich reef fish fauna of the New Caledonia is a result of the very high level of habitat diversity of the northwestern lagoon of New Caledonia. The 62 survey sites visited in this survey were selected to cover nearly every conceivable habitat situation as comprehensively as possible. For the purposes of analysis of the fish diversity data, the sites are categorized by reef

classes with habitats as: (1) outer barrier reefs front or outer slope, (2) outer barrier pass reefs, (3) outer barrier reefs back, (4) intermediate lagoon reefs, and (5) inner lagoon reefs. Amongst the reef site classifications are many variations in the influences of currents, exposure, and sedimentation. All these factors combine to influence the make-up of local reef fish communities. In our study we were only able to analyze our results to the level of the broad habitat classifications just mentioned. As a result of this wide diversity of habitats surveyed the number of species recorded across all sites varies broadly from sites with relatively low species diversity to sites with high diversity. The highest diversity site in

Table 2.4. Coral Fish Diversity Index (CFDI) for restricted localities in the Indo-Pacific region. All data provided by Allen (2002a, 2002b) except for present study (Kerr) and the Mont Panié, New Caledonia that was provided by Evans (2006) (both shown in bold).

Locality	CFDI	No. reef Fishes obs.	Estimate reef fishes
Milne Bay, Papua New Guinea	337	1109	1313
Maumere Bay, Flores, Indonesia	333	1111	1107
Raja Ampat Islands, Indonesia	326	972	1084
Togean and Banggai Islands, Indonesia	308	819	1023
Komodo Islands, Indonesia	280	722	928
Calamianes Islands, Philippines	268	736	888
Madang, Papua New Guinea	257	787	850
Mont Panié, New Caledonia	**255**	**597**	**844**
Kimbe Bay, Papua New Guinea	254	687	840
Manado, Sulawesi, Indonesia	249	624	823
Northwest Lagoon, New Caledonia	**234**	**527**	**773**
Capricorn Group, Great Barrier Reef	232	803	765
Ashmore/Cartier Reefs, Timor Sea	225	669	742
Kashiwa-Jima Island, Japan	224	768	738
Scott/Seringapatam Reefs, West Australia	220	593	725
Samoa Islands, Polynesia	211	852	694
Chesterfield islands, Coral Sea	210	699	691
Sangalakki Islands, Kalimantan, Indonesia	201	461	660
Bodgaya Islands, Sabah, Malaysia	197	516	647
Pulau Weh, Sumatra, Indonesia	196	533	644
Izu Islands, Japan	190	464	623
Christmas Island, Indian Ocean	185	560	606
Sipidan Island, Sabah, Malaysia	184	492	603
Rowley Shoals, West Australia	176	505	576
Northwest Madagascar	176	463	576
Cocos-Keeling Atoll, Indian Ocean	167	528	545
North-West Cape, West Australia	164	527	535
Tunku Abdul Rahman Is., Sabah, Malaysia	139	357	450
Lord Howe island, Australia	139	395	450
Monte Bello Islands, West Australia	119	447	382
Bintan Island, Indonesia	97	304	308
Kimberley Coast, West Australia	89	367	281
Cassini island, West Australia	78	249	243
Johnston island, Central Pacific	78	227	243
Midway Atoll, Pacific, USA	77	250	240
Rapa, Polynesia	77	209	240
Norfolk Island, Australia	72	220	223

this study had a species count of 172, nearly reaching the exceptionally high levels (200 species plus) that are recorded in the high diversity center of the region at sites in Indonesia, Papua New Guinea and the Solomon Islands, often referred to as the 'coral triangle' of coral reef diversity (Allen 2002a, 2002b, 2005a, 2006).

The number of species found at each site is indicated in Table 2.2. Species numbers at the 57 sites for which data was analyzed varied from 46 to 172, with an average value of 117 species per site. Four sites (34, 57, 30 and 31) visited by the survey are not included in this analysis. Site 57 was an intermediate lagoon reef where the visibility was 1 meter. The other three sites were inner lagoon reef sites where the visibility encountered was between 1 and 2m, which is well below the practical limits of the methods used.

Table 2.5. IUCN Red list species of fish observed during this survey. The corresponding IUCN Red list status category is given for each species. Species are arranged by family in alphabetical order.

Species	Category
CARCHARHINIDAE	
Carcharhinus melanopterus (Quoy & Gaimard, 1824)	Near Threatened
*Triaenodon obesus (*Rüppell, 1835)	Near Threatened
DASYATIDAE	
Urogymnus asperrimus (Bloch & Schneider, 1801)	Vulnerable
LABRIDAE	
Cheilinus undulatus (Rüppell, 1835)	Endangered
SCARIDAE	
Bolbometopon muricatum (Valenciennes, 1840)	Vulnerable
SERRANIDAE	
Cromileptes altivelis (Valenciennes, 1828)	Vulnerable
Epinephelus coioides (Hamilton, 1822)	Vulnerable
Epinephelus laceolatus (Bloch, 1790)	Vulnerable
Epinephelus malabaricus (Bloch & Schneider, 1801)	Near Threatened
Epinephelus polyphekadion (Bleeker, 1856)	Near Threatened
Plectropomus laevis (Lacepède, 1802)	Vulnerable
Plectropomus leopardus (Lacepède, 1802)	Near Threatened

Table 2.6. New records for reef fish for New Caledonia. The taxonomic family with species name and sites where observed are given.

Family	Species	Sites
GOBIIDAE	*Asterropteryx striatus*	18, 28, 32, 85, 86, 87, 56, 73, 48, 52
POMACENTRIDAE	*Plectroglyphidodon phoenixensis*	58, 61

Richest Sites for Reef Fishes

The results suggest that reef habitats situated close to major passages can be expected to have high fish diversity (i.e. hotspots). Presumably this is because of the complex habitat structures, the very dynamic and diverse currents which flow by these spots, the effect of fish movements in and out of the lagoon through the passage and the favourable semi-sheltered position that most benefit from.

Four other sites in the top ten diversity sites, sites 7, 6, 9, and 80 were barrier reef front reef sites near passages. This result is to be expected because of the influence of oceanic currents, very clean water, and the high physical complexity of the reefs in these locations. Given the location of the sites it is also possible that their close proximity to the major passages had a positive influence on fish community diversity. It is worth noting that four of the top ten sites for fish diversity were in the proximity of Yandé Island. Yandé Island also had two more sites ranked in the range from 11 to 20 for fish diversity.

An examination of fish species diversity (Table 2.3) by classification of survey sites indicates that the outside or front outer barrier reefs had the highest fish diversity with a mean of 141 species per site. The lowest fish diversity observed was on the inner or inshore lagoon reefs with an average of 81 species.

Fish surveys at most inner reef sites and to a lesser degree at intermediate lagoon sites were affected by poor visibility. The relatively low fish species diversity recorded at the inner reef sites could be due to difficulties in sampling related to low visibility conditions. It is also likely that the long-term effects of high sediment levels in the water column could adversely affect habitat quality and as a result fish diversity. The cause and effect relationship between sediment loads, habitat effects, and fish diversity cannot be determined from the simple method employed for this fish survey.

Coral Fish Diversity Index (CFDI)

A formula for predicting the total number of reef fish species that could be expected to be found in the survey area, based on recorded counts of six dominant reef fish families, has been derived by Gerald Allen (1998). The technique applies a formula based on extensive statistical analysis of actual survey data from a broad range of surveyed sites. A major benefit of this analysis, aside from the ability to predict total fish diversity, is that it enables researchers to more accurately compare fish community diversity and structure across broad geographical areas and to look at changes that occur over time as result of management or environmental developments.

For the analysis of the results of this study we used the formula derived for relatively restricted areas (surrounding seas encompassing less than 2,000km²). The formula applied was:

$$\text{Total expected reef fish species number} = 3.39 \times (\text{CFDI}) - 20.595$$

The CFDI value for this survey was obtained by adding the number of species recorded for the six families: Labridae (75), Pomacentridae (71), Acanthuridae (29), Chaetodontidae (28), Scaridae (20), and Pomacanthidae (11). The resulting CFDI value for this study is 234.

When this formula was applied to our results, it indicated that approximately 773 fish species could be expected to be present in this area. This contrasts with the figure of known reef fish species for New Caledonia which stands at 1,019 and the total number actually recorded in the survey, 526.

Table 2.4 provides the CFDI values, the estimated total reef fish species number predicted by the CFDI formula and the known number of fish species for a range of countries across the Pacific from East to West. The results of this survey are consistent with the broad biogeographical trend that places New Caledonia on the margin of the highest diversity zone of the 'coral reef triangle'. Overall the level of diversity is higher than or comparable to all areas except the Indonesia/Papua New Guinea/Solomon Islands coral reef diversity centre. Results for this survey are also comparable to the fish diversity study conducted during Conservation International survey of the coral reefs off Mont Panié (northeast lagoon) of New Caledonia (Evans 2006).

Threatened Species

Eleven species recorded during the survey appear on the IUCN Red List (Table 2.5). All the species on this list are notable and were present on a number of sites in the survey.

New Fish Records for New Caledonia

Two range extension records for New Caledonia reef fish species (Table 2.6) were obtained in this survey. These records were checked against the list compiled by Fricke and Kulbicki (2006).

One species of the Gobiidae family that is previously unrecorded in the New Caledonia lagoon was observed. Identifications of this species were made with reference to Allen et al (2005b) and Fricke and Kulbicki (2006). This fish was identified as *Asterropteryx striatus*, given the common name of striped goby by Allen. It was found at eleven sites. Three identification photos of moderate to poor quality were taken of *Asterropteryx striatus* and are stored in the survey photo archive. The second new species record for New Caledonia was *Plectroglyphidodon phoenixensis* from the Pomacentridae family. This species was recorded on two sites and a good quality identification photo was obtained and archived. Both new species records for New Caledonia reported here have been previously observed in the Indonesia or Great Barrier Reef regions and therefore could be reasonably expected to be found in New Caledonia.

Another note worthy record from the survey was the sighting of a fish on only one site (49) from the Gobiidae family called *Tomiyamichythys oni*, given the common name of monster shrimp goby by Allen. This species has been reported only once before on a 2006 WWF survey of the northern lagoon of New Caledonia, (G. Allen pers. com.). A good quality identification photo of this fish was collected and is held by the author.

CONSERVATION RECOMMENDATIONS

New Caledonia has significant biogeographical connections with the areas of the 'coral triangle' (Roberts et al. 2002). In the context of threats due to global warming, New Caledonia's position at lower latitude raises important considerations for regional biodiversity security and conservation planning. As the more northern reef systems come under increased pressure from coral bleaching events caused by more frequent 'ocean hotspots' (i.e. elevated seawater temperature), New Caledonia's lagoon system may play a key regional role as a biodiversity refuge for the greater Indo-Pacific Region. This increases the importance of establishing an effective marine protected area (MPA) network in New Caledonia.

The northwestern lagoon of New Caledonia has within it a nearly complete diversity of coral reef habitats. Amongst that diversity are areas that could be described as having little human impact. These areas are becoming a rarity in the Pacific region. Two of these areas that are particularly noteworthy include Yandé Island (together with the Passe de Yandé) and the Passe de Koumac. Therefore these two areas are strongly recommended as high priority for inclusion in the MPA network. Yandé Island with the reef pass has high habitat complexity and an unique set of geological factors, a high island situated close to a major passage in the reef. This in turn creates a very complex array of currents and exposure conditions which translate into maximum potential for fish diversity. In our survey the sites around the Yandé Island and Passe de Yandé occupied the most positions in the top ten sites ranked by fish diversity.

The Passe de Koumac area is similar to the Passe de Yandé in that it is a large pass with strong current flow and the full diversity of reef habitats. During the survey, sites in the Passe de Koumac area were observed to have relatively high fish diversity despite signs that fishing pressure was present and possibly significant. Our results indicate that this area is highly productive and important in terms of reef fish diversity. It is probable that the reefs of this area would show very positive results from high level protection. As a result of the high biodiversity and habitat values in this area and the threat of increasing fishing pressure it is recommended that this area be considered as a priority for inclusion in a MPA network.

The other fundamental recommendation for MPA planning is that every effort made to include representative areas of the fullest possible range of habitats occurring in this region. This strategy will protect the widest possible range of fish diversity while at the same time supporting the full range of ecological functions such as connectivity and life-stage requirements which for some species are quite specific. It should be noted that this approach is also conservative

in the sense that it is the most likely method of protecting species and/or ecological functions that are as not observed or little understood. The list of what we do not know about coral reef ecosystems is still rather long.

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