Reef Fishes of Yap, Federated States of Micronesia

Final Report Prepared by

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Summary

- A list of fishes was compiled for 46 sites including 19 at Yap, 12 at Ngulu, and 15 at Ulithi. The survey involved approximately 60 hours of scuba diving to a maximum depth of 55 m.

- A total of 625 species was recorded including 349 new range records. An additional 91 new records for Yap State, primarily observed by Brian Greene in 2007 are also reported. The total known fish fauna of Yap State now stands at 787 species in 275 genera and 76 families.

- A formula for predicting the total reef fish fauna based on the number of species in six key indicator families indicates that at least 928 species can be expected to occur at Yap and outlying atolls.

- Gobies (Gobiidae), wrasses (Labridae), damselfishes (Pomacentridae), groupers (Serranidae), butterflyfishes (Chaetodontidae), and surgeonfishes (Acanthuridae) are the most speciose families in the Yap region with 103, 92, 68, 47, 34 and 34 species respectively.

- Species numbers at visually sampled sites during the 2007 survey ranged from 35 to 169, with an average of 131.

- Ulithi Atoll had the highest average number of species (143.6) per site, followed by Ngulu Atoll (134.3), and Yap (130.5).

- Outer reefs had the highest fish diversity with an average of 148.6 species per site. Passages were generally less speciose with an average of 135.7 species per site. Lagoon sites and coastal bays at Yap Island were the least diverse habitats with 115.2 and 50.6 species per site respectively. The latter habitat, although poor in number of species, is populated by a unique gobiid community.

- Three new species were collected during the survey including a goby belonging to an apparently undescribed genus, a damselfish in the genus *Pomacentrus*, and a dottyback belonging to *Lubbockichthys*. The goby was common on soft silty bottoms at Yap Island at depths of 10-20 m. The new *Pomacentrus* is apparently widespread in Micronesia and was previously collected at Pohnpei. It was common in a variety of habitats, but was most abundant on the upper edge of outer reef slopes between about 4 and 12 metres. The dottyback was collected on the outer reef at Ulithi in 55 m depth.

- The highly threatened Napoleon Wrasse (*Cheilinus undulatus*) was relatively abundant, being observed at 50 percent of the survey sites. The estimated average total length of observed individuals was 48 cm. Site Y-17 (lagoon hole on east side of Yap) appears to be an important nursery area for both Napoleon Wrasse and Bumphead Parrotfish (*Bolbometopon muricatum*).

- Sharks were seen at 50 percent of the survey sites, but generally in small numbers. They were most abundant at Ulithi Atoll, where 20 or more grey reef sharks (*Carcharhinus amblyrhynchos*) were seen as several sites. Although

environmental conditions appear ideal for reef sharks, relatively few were seen at Ngulu Atoll, which is indicative of foreign shark-fin poaching.

Introduction

The primary goal of the fish survey was to provide a comprehensive inventory of shallow reef fishes inhabiting Yap, Ngulu Atoll, and Ulithi Atoll. Coverage includes fishes living on or near coral reefs down to the limit of safe sport diving or approximately 55 m depth. It therefore excludes most deepwater and offshore pelagic species such as flyingfishes, tunas, and billfishes.

Historical background

No previous comprehensive ichthyological surveys have been conducted for Yap State, although Meyers (1999) recorded 347 species for Yap and Ulithi as part of an extensive appendix list in the third edition of Micronesian Reef Fishes. Check for Yap or Ulithi holdings in USNM website

Methods

The survey involved approximately 60 hours of scuba diving by G. Allen to a maximum depth of 55 m. A comprehensive list of fishes was compiled for 46 sites (Appendix Table 1) between 12-30 July 2007. The basic method consisted of underwater observations made during a single dive at each site with an average duration of about 80 minutes. The name of each observed species was recorded in pencil on waterproof paper attached to a clipboard. The technique usually involved rapid descent to 30-55 m, then a slow, meandering ascent back to the shallows. The majority of time was spent in the 2-15 m depth zone, which consistently harbors the highest number of species. Each dive included all major bottom types and habitat situations in the immediate vicinity.

Brian Greene also recorded rare and unusual species during several survey dives, including one deep dive to about 70 m at site Y-11 utilizing re-breather scuba equipment.

Fishes were photographed underwater while scuba diving with a Nikon SLR camera and 105 mm lens in an aluminum housing. Photographs were obtained of approximately 185 species.

A small collection of mainly cryptic gobies and other secretive fishes was procured with a clove oil-alcohol mixture by squirting this chemical into caves and crevices. Additional specimens of a new *Pomacentrus*, first collected during the 2005 REA at Pohhnpei, were also obtained using a multi-prong spear.

Results

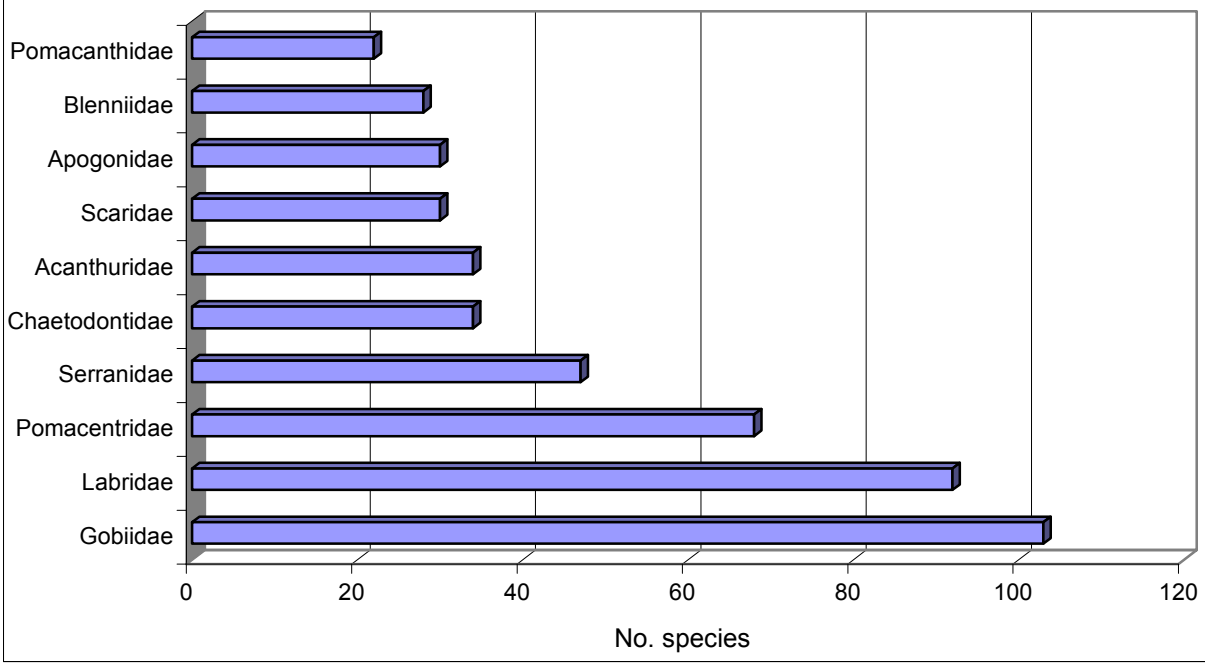
Ichthyological results of the 2007 survey are summarized in Appendix Table 1. A total of 625 species were recorded during the present expedition, including 349 new distribution records. An additional 91 new records, primarily observed by temporary Yap resident and University of Hawaii student Brian Greene in 2007 are also reported. The total known fish fauna of Yap State now stands at 787 species in 275 genera and 76 families. This total includes 347 species that were previously reported

by Meyers (1999). The majority of species included in the present report were illustrated by Allen et al. (2005), Kuiter and Debelius (2006), Myers (1999), and Randall (2005).

General faunal composition

The majority of the fish fauna of theYap region consists of species associated with coral reefs and intermingled habitats including sand, rubble, and seagrass beds. The most abundant families in terms of number of species are gobies (Gobiidae), wrasses (Labridae), damselfishes (Pomacentridae), groupers (Serranidae), butterflyfishes (Chaetodontidae), surgeonfishes (Acanthuridae), parrotfishes (Scaridae), cardinalfishes (Apogonidae), blennies (Blenniidae), and angelfishes (Pomacanthidae). These families collectively account for approximately 62 percent of the total reef fish fauna (Fig. 1).

Figure 1. Ten largest families of Yap fishes.



The relative abundance of Yap fish familles is similar to other reef areas in the Indo-Pacific, although the ranking of individual families tend to vary slightly depending on locality. The top three families, Gobiidae, Labridae, and Pomacentridae, are consistently the same throughout the region. The highly speciose Gobiidae is generally the most abundant family regardless of locality, whereas the Labridae and Pomacentridae variably occupy the number two and three positions. The dominance of these three families reflects their amazing evolutionary diversity that has resulted in a wealth of species adapted to almost every conceivable micro-habitat ranging from mangroves and weed beds to very deep outer reefs.

The composition of local reef fish communities in the Indo-Pacific region is dependent on habitat variability. The rich reef fish fauna of Micronesia directly reflects a relatively high level of habitat diversity, ranging from high islands to atolls,

as well as the proximity of western Micronesia to the species-rich East Indian "Coral Triangle" region. Yap Island in particular presents a microcosm of tropical marine habitats, including silt laden coastal reefs, an extensive sheltered lagoon and associated reefs, and a variety of outer reef conditions.

Similar to other reef areas in the Indo-Pacific, most Yap State fishes are benthic (or at least living near the bottom) diurnal carnivores with approximately 80 percent and 60 percent of species being assigned to these respective categories. Approximately 10 percent of Yap fishes are nocturnal, 4 percent are cryptic crevice dwellers, 4 percent are diurnal mid-water swimmers, and about 3 percent are transient or roving predators. In addition to carnivores, the other major feeding categories include omnivores (16 percent), planktivores (16 percent), and herbivores (8 percent).

Site faunal composition

Yap State supports an excellent range of marine habitats from silty mangrove shores to exceptionally clear waters of isolated, oceanic atolls. However, the fish fauna is relatively limited in comparison to areas farther to the west primarily due to two factors: 1) the distance from the "coral triangle", the region composed mainly of Indonesia, Philippines and Papua New Guinea that is generally acknowledged as the center of Indo-Pacific coral reef fish diversity, and 2) the relatively small physical area occupied by Yap's numerous reefs and islands.

The degree of exposure, depth, and amount of sediment deposition at a given dive location are the major factors that influence the composition or structure of the fish community. Although numerous reef species occur over a wide range of habitat conditions, many others have very specific requirements and show pronounced environmental zonation, being found in primarily outer reef or lagoon environments. The outer reef is generally characterized by relatively clear waters, a shallow surge zone that is exposed to wind and waves, and, a zone of highly variable live coral growth that frequently extends from about 4-30 m. It typically slopes steeply into deep water and there is often an initial bench at about 50 m depth. The lagoon environment, in contrast to the outer reef, provides significant shelter from wind, waves, and oceanic currents. Underwater visibility is highly variable, but generally reduced in comparison to the outer reef. There is also pronounced sedimentation, particularly near the shoreline. Table 1 provides a list of species that are typical indicators of the major habitat types encountered at Yap and surrounding atolls.

Table 1. Typical species associated with major habitat types.

Seaward reefs	**Lagoon reefs**	**Sheltered coasts (Yap only)**
Cephalopholis spiloparea	*Neoniphon argenteus*	*Apogon thermalis*
Pseudanthias spp.	*Pterocaesio trilineata*	*Sphaeramia spp.*
Caranx lugubris	*Pentapodus aureofasciatus*	*Dischistodus spp.*
Caesio teres	*Lethrinus amboinensis*	*Pomacentrus simsiang*
Plectorhinchus albovittata	*Dascyllus auranus*	*Halichoeres chloropterus*
Hemitaurichthys polylepis	*Chromis viridis*	*Halichoeres leucurus*
Apolemichthys trimaculatus	*Pomacentrus bipunctatus*	*Scarus quoyi*
Chromis spp.	*Labrichthys unilineatus*	*Salarias segmentatus*
Pseudodax moluccanus	*Scarus ghobban*	*Amblygobius buanensis*

Halichoeres biocellatus	*Atrosalarias fuscus*	*Cryptocentrus spp.*
Nemateleotris magnifica	*Meiacanthus ditrema*	*Oxyurichthys papuensis*
Naso spp.	*Ctenochaetus binotatus*	*Yongeichthys nebulosus*

There are also suites of species that are closely correlated with various depth regimes. Although most coral reef fishes are encountered at depths between about 3-20 m, certain species are restricted to shallow, wave-swept areas, while others seldom venture above 20 m. Typical members of these categories are listed in Table 2.

Table 2. Typical species that are restricted to shallow and deep habitats.

Shallow, wave-washed reefs	**Deep reefs**
Cirrhitus pinnulatus	*Neoniphon aurolineata*
Chrysiptera brownriggii	*Cepholopholis spiloparaea*
Chrysiptera glauca	*Pseudanthias spp.*
Plectrglyphidodon leucozonus	*Hoplolatilus spp.*
Pomachromis spp.	*Paracaesio spp.*
Thalassoma jansenii	*Chaetodon burgessi*
Thalassoma purpureum	*Genicanthus spp.*
Thalassoma quinquevittatum	*Chrysiptera caeruleolineata*
Blenniella spp.	*Cirrhilabrus earlei*
Istiblennius spp.	*Cirrhilabrus rhomboidalis*
Acanthurus lineatus.	*Nemateleotris decora*
Acanthurus guttatus	*Xanthichthys spp.*

A final category includes species that are closely associated with specific substrate types, the most notable of which are sand or rubble and live coral (Table 3). In addition, another conspicuous group, containing transient predators, is basically pelagic, although they are closely associated with reef environments. Prominent members include certain sharks (Carcharhinidae), manta and devil rays (Mobulidae), half-beaks (Hemiramphidae), needlefishes (Belonidae), trevallies or jacks (Carangidae), tunas and mackerels (Scombridae), and barracuda (Sphyraenidae).

Table 3. Typical species associated with sand/rubble and live coral substrata.

Sand/Rubble species	**Coral species**
Synodus spp.	*Archamia zosterophora*
Malacanthus spp.	*Sphaeramia nematoptera*
Scolopsis affinis	*Chaetodon lunulatus*
Parupeneus pleurostigma	*Chaetodon trifascialis*
Upeneus tragula	*Plectroglyphidodon dickii*
Dischistodus perspicillatus	*Plectroglyphidodon johnstonianus*
Cirrhilabrus spp.	*Labrichthys lineatus*
Coris batuensis	*Scarid spp. (Chlorurus and Scarus)*
Halichoeres hartzfeldi	*Eviota bifasciata*
Parapercis spp.	*Eviota sebreei*
Gobiid spp (*Amblyeleotris,* etc.)	*Gobiodon okinawae*
Bothus mancus	*Oxymonacanthus longirostris*

The number of species recorded at each site is indicated in Table 4. Totals ranged from 76 to 171, with an average of 131 per site**.** Outer reefs and passages were the richest areas for fish diversity with 142.3 species per site compared to 119.3 for lagoon reefs.

Table 4. Number of fish species recorded at each site.

Site	Species	Site	Species	Site	Species	Site	Species
Y-1	149	**Y-13**	161	**N-6**	138	**U-6**	160
Y-2	143	**Y-14**	84	**N-7**	130	**U-7**	164
Y-3	160	**Y-15**	159	**N-8**	122	**U-8**	167
Y-4	132	**Y-16**	162	**N-9**	119	**U-9**	130
Y-5	124	**Y-17**	99	**N-10**	152	**U-10**	154
Y-6	113	**Y-18**	57	**N-11**	123	**U-11**	100
Y-7	114	**Y-19**	61	**N-12**	90	**U-12**	120
Y-8	97	**N-1**	143	**U-1**	117	**U-13**	156
Y-9	35	**N-2**	149	**U-2**	169	**U-14**	166
Y-10	153	**N-3**	139	**U-3**	153	**U-15**	127
Y-11	133	**N-4**	153	**U-4**	138		
Y-12	105	**N-5**	153	**U-5**	133		

The 10 richest sites for fishes are indicated in Table 4. The total species at a particular site is ultimately dependent on the availability of food and shelter and the diversity of substrata. Eight of the 10 richest sites were located on outer reefs that are subjected to periodic strong currents, providing an abundance of planktonic food items, which support numerous plankton-feeding fishes. These sites also included steep to moderate dropoffs, rubble bottoms, relatively good coral cover, and extensive shallow reef crest habitat. Surprisingly the most speciose site was located next to the settlement at Falalop on Ulithi Atoll. Similarly, the third richest site was located next to the village on Mogmog Island, also at Ulithi Atoll. Perhaps fishing pressure targeting large predatory fishes at these locations has allowed a denser than usual population of small reef fishes to flourish.

Table 4. Ten richest fish sites.

Site No.	Location	Total fish spp.
U-2	SW side Falalop, Ulithi Atoll	169
U-8	Inner patch reef, S. Ulithi Atoll	167
U-14	Lagoon reef, Mogmog I., Ulithi	166
U-7	Outer reef, S. tip of Ulithi Atoll	164
Y-16	Outer reef at SW corner Yap	162
Y-13	Outer reef W. side of Yap	161
Y-3	Outer reef off S end of Yap	160
U-6	S. corner Turtle I., Ulithi Atoll	160
Y-15	Outer reef W. side of Yap	159
U-13	Outer reef, NW Ulithi Atoll	156

The major habitats that were surveyed are compared in Table 5. Outer reefs were by far the richest habitat, but passages connecting the outer reef and lagoon were also comparatively diverse. Lagoons were less speciose, although they are inhabited by many species not seen elsewhere. The poorest habitats for fishes were silt-affected coastal reefs and shoreline mangroves that were seen only at Yap Island. Despite their impoverished fish community these sites were highly unique and supported a particularly diverse gobiid fauna including a number of new records for Yap as well as notable range extensions and at least one new species.

Table 5. Comparison of major habitats.

Habitat	No. sites	Avg. spp./site
Outer reef	19	148.6
Passage	7	135.7
Lagoon	17	115.2
Coastal /mangroves	3	50.6

Coral Fish Diversity Index (CFDI)

Allen (1998) devised a convenient method for assessing and comparing overall reef fish diversity. The technique essentially involves an inventory of six key families: Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae. The number of species in these families is totalled to obtain the Coral Fish Diversity Index (CFDI) for a single dive site, relatively restricted geographic areas (eg. Yap State) or countries and large regions (eg. western Pacific Ocean).

CFDI values can be used to make a reasonably accurate estimate of the total coral reef fish fauna of a particular locality by means of regression formulas. The latter were obtained after analysis of 35 Indo-Pacific locations for which reliable, comprehensive species lists exist. The data were first divided into two groups: those from relatively restricted localities (surrounding seas encompassing less than 2,000 km^2) and those from much larger areas (surrounding seas encompassing more than 50,000 km^2). Simple regression analysis revealed a highly significant difference ($P = 0.0001$) between these two groups. Therefore, the data were separated and subjected to additional analysis. The Macintosh program Statview was used to perform simple linear regression analyses on each data set in order to determine a predictor formula, using CFDI as the predictor variable (x) for estimating the independent variable (y) or total coral reef fish fauna. The resultant formulae were obtained: 1. total fauna of areas with surrounding seas encompassing more than 50,000 km^2 = 4.234(CFDI) - 114.446 (d.f = 15; $R^2 = 0.964$; $P = 0.0001$); 2. total fauna of areas with surrounding seas encompassing less than 2,000 km^2 = 3.39 (CFDI) - 20.595 (d.f = 18; $R^2 = 0.96$; $P = 0.0001$).

CFDI is useful for short term surveys such as the present one because it is capable of accurately predicting the overall faunal total. The main premise of the CFDI method is that short term surveys of only 3-4 weeks duration are sufficient to record most members of the six indicator families due to their conspicuous nature. The CFDI for Yap State is 280, composed of the following elements: Chaetodontidae (34), Pomacanthidae (22), Pomacentridae (68), Labridae (92), Scaridae (30), and Acanthuridae (34). The resultant predicted faunal total is 928 species. Comparison of

this total with the actual number of species (787) currently recorded from the area indicates that at least 141 additional species of shallow reef fishes can be expected from the area.

The CFDI method is especially useful when time is limited and there is heavy reliance on visual observations, as was the case for the present survey. The CFDI total for Yap and the outlying atolls of Ngulu and Ulithi indicates that about 85 percent of the fauna was actually observed during the present survey in combination with Brian Greene's observations/collections at Yap.

Table 6 presents a comparison of Yap State with various Indo-west and central Pacific locations that were surveyed by the author or various colleagues.

Table 6. Coral fish diversity index (CFDI) values for restricted localities, number of coral reef fish species as determined by surveys to date, and estimated numbers using the CFDI regression formula (refer to text for details).

Locality	CFDI	No. reef fishes	Estim. reef fishes
Raja Ampat Islands, Indonesia	351	1124	1372
Milne Bay, Papua New Guinea	337	1109	1313
Maumere Bay, Flores, Indonesia	333	1111	1107
Fak Fak Peninsula/Kaimana region, W. New Guinea	315	940	1220
Togean and Banggai Islands, Indonesia	308	819	1023
Southwestern Halmahera, Indonesia	305	803	1177
Cenderawasih Bay, W. New Guinea (Indonesia)	295	716	1156
Komodo Islands, Indonesia	280	722	928
Yap State, FSM	**280**	**787**	**928**
Madang, Papua New Guinea	257	787	850
Kimbe Bay, Papua New Guinea	254	687	840
Manado, Sulawesi, Indonesia	249	624	823
El Nido-Bacuit Bay, Philippines	243	694	803
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, Western. Australia	220	593	725
Samoa Islands	211	852	694
Chesterfield Islands, Coral Sea	210	699	691
Pohnpei and nearby atolls, FSM	202	470	664
Layang Layang Atoll, Malaysia	202	458	664
Sangalakki Island, Kalimantan,	201	461	660
Bodgaya Islands, Sabah, Malaysia	197	516	647
Pulau Weh, Sumatra, Indonesia	196	533	644
Izu Islands	190	464	623
Christmas Island, Indian Ocean	185	560	606
Sipadan Island, Sabah, Malaysia	184	492	603
Rowley Shoals, Western Australia	176	505	576
Cocos-Keeling Atoll, Indian Ocean	167	528	545
North-West Cape, Western Australia	164	527	535
Tunku Abdul Rahman Is., Sabah	139	357	450
Lord Howe Island, Australia	139	395	450
Monte Bello Islands, W. Australia	119	447	382

Bintan Island, Indonesia	97	304	308
Kimberley Coast, Western Australia	89	367	281
Cassini Island, Western Australia	78	249	243
Johnston Island, Central Pacific	78	227	243
Midway Atoll	77	250	240
Rapa	77	209	240
Norfolk Island	72	220	223

Zoogeographic affinities

Yap State and Micronesia in general belongs to the overall Indo-west Pacific faunal community. Its reef fishes are very similar to those inhabiting other areas within this vast region, stretching eastward from East Africa and the Red Sea to the islands of Micronesia and Polynesia. Although most families, and many genera and species are consistently present across the region, the species composition varies greatly according to locality.

Considering its oceanic position, Yap State has one of the richest reef fish faunas of any similar-sized area in Oceania. It is strategically located on the edge of the "Andesite Line" and forms an integral part of the Carolines "conduit", a series of island "stepping stones" which according to Springer (1982) form an important dispersal pathway between the East Indies and Pacific Plate. Consequently, the Yap fish community contains an interesting blend of elements from these two major faunal provinces.

Yap represents the easternmost portion of the range for many Coral Triangle species. Most of these are primarily restricted to sheltered coastal reefs, often with relatively high levels of siltation and freshwater discharge. For example, the pomacentrids *Amblyglyphidodon batunai*, *Hemiglyphidodon plagiometapon, Dischistodus chrysopoecilus, D. perspicillatus, and Chrysiptera cyanea* reach the easternmost point of their distribution at Yap. In addition, Yap represents the eastern limit for several other East Indian pomacentrids including *Dischistodus melanotus, Chromis delta, C. lineata, C. retrofasciata, C. xanthochira, Neoglyphidodon melas, N. nigroris,* and *Pomacentrus bankanensis*. Several gobiid species that have an affinity for soft silt bottoms of sheltered coasts offer an additional example of this distribution pattern. The latter group includes species such as *Acentrogobius caninus, Amblygobius buanensis, Arcygobius baliurus, Cryptocentrus leptocephalus,* and *Exyrias puntang*. Apparently, the relatively short distance from Palau to Yap Island (about 381 km) lies within the range of larval dispersal capability of these species, but the distance from Yap to the next suitable habitat (high islands with extensive sheltered lagoons) at Chuuk (1500 km away) or Pohnpei (2250 km) exceeds the dispersal threshold.

There is a general attenuation of species richness in the Indo-Pacific region with increased distance from the Coral Triangle. Yap is therefore intermediate between the biodiversity "bullseye" situated in eastern Indonesia and the relatively impoverished fauna of eastern Polynesia (Table 7).

Table 7. Comparison of total number of reef fishes for various locations in the western and central Pacific Ocean (adapted from Allen, 2007)

Location	Total species
Indonesia	2122
Papua New Guinea	1635
Vanuatu	1105
Yap (including Ngulu and Ulithi atolls)	787
Pohnpei	642
Society Islands	560
Tuamotu Islands	389
Marquesas Islands	331

The largest segment of the fauna or approximately 88 percent consists of species that are broadly distributed in the Indo-west and central Pacific region. This is not surprising as nearly all coral reef fishes have a pelagic larval stage of variable duration, depending on the species. Dispersal capabilities and length of larval life of a given species are usually reflected in its geographic distribution. At least 60 percent of the species range widely across this region from East Africa to the islands of Oceania and approximately 20 percent are restricted to the western and central Pacific region. The balance of the fauna consists of 36 species that are primarily restricted to Oceania (Table 8), about 50 species that are largely confined to the Coral Triangle and immediately adjacent areas, and seven circumtropical species.

Table 8. Species occurring at Yap and outlying atolls that are mainly confined to Oceania.

Congridae
Gorgasia galzini
Holocentridae
Myripristis amaena
Syngnathidae
Corythoichthys nigripectus
Pseudochromidae
Lubbockichthys sp.
Apogonidae
Apogon luteus
Mullidae
Parupeneus insularis
Chaetodontidae
Chaetodon quadrimaculatus
Pomacanthidae
Centropyge loricula
Centropyge multicolor
Genicanthus watanabei
Pomacentridae
Chrysiptera trayceyi
Pomacentrus bipunctatus
Pomacentrus sp.
Pomachromis exilis
Pomachromis guamensis
Labridae
Cirrhilabrus balteatus
Cirrhilabrus earlei
Cirrhilabrus johnsoni
Cirrhilabrus katherinae
Cirrhilabrus rhomboidalis
Labropsis micronesica
Paracheilinus bellae
Pseudocheilinus ocellatus
Scaridae
Scarus altipinnis
Blenniidae
Cirripectes fuscoguttatus
Cirrpectes variolosus
Ecsenius opsifrontalis
Gobiidae
Eviota cometae
Pleurosicya carolinensis
Ptereleotridae
Nemateleotris helfrichi
Acanthuridae
Naso casius
Zebrasoma flavescens
Sphyraenidae
Sphyraena helleri

Notable elements of the Yap reef fish fauna

Endemism
Considering the broad dispersal capabilities via the pelagic larval stage of most reef fishes it is unlikely that any species are endemic to the area. An undescribed species belonging to the pseudochromid genus *Lubbockichthys* and new gobiid belonging to a possibly undescribed genus are currently known only from Yap, but future collecting or observations will probably expand the known range to other parts of Micronesia.

1. *Lubbockichthys* sp. (Pseudochromidae) – a single specimen, approximately 60 mm total length, was collected in 55 m depth at site U-7. Coloration is generally brown, intensely dark over much of the posterior half of the body, grading to pinkish orange on the head.

Fig. 2. Lubbockichthys sp., approximately 60 mm SL, Ulithi Atoll.

2. Gobiid sp. (Gobiidae) – This undescribed species apparently also represents an undescribed genus. It appears to be different from another new species belonging to this same genus that was illustrated from the Ryukyu Islands of Japan by Senou et al. (2004). Numerous individuals were observed on silty bottoms at depths between about 10-20 m at sites Y-9 and Y-19, both sheltered coastal areas on Yap Island. The fish is approximately 35-40 mm total length, overall light tan in colour with several brown blotches along the middle of the side, and a long mast-like first dorsal fin that extends beyond the tail base. There is a small black spot on the last few dorsal spines at the base of the dorsal “mast”.

Fig. 3. Undescribed genus and species of goby, approximately35 mm TL, Yap.

New distribution records
A total of 440 species observed during the current survey represent new distribution records for Yap State. The species without an asterisk in Appendix Table 1 represent new distribution records.

Inter-island comparisons
The current survey offered an excellent opportunity to compare and contrast oceanic atoll environments (Ngulu and Ulithi) with the more complex system on Yap Island, characterized by a relatively large, high land mass and associated freshwater runoff, mangrove shoreline, extensive lagoon, and surrounding barrier reef. Predictably, Yap had a more diverse fish fauna than the atoll locations (Table 9).

Table 9. Comparison of number of species recorded during 2007 survey.

Location	**No. species**
Yap	479
Ulithi Atoll	410
Ngulu Atoll	379

Although the three locations generally had similar fish faunas, the main difference was the unique presence at Yap of a suite of species that are closely associated with well sheltered coastal reefs and mangrove shorelines subjected to silt-laden freshwater runoff. Species in this category include various cardinafishes (*Apogon ceramensis, A. leptacanthus, A. quadrifasciata, Archamia zosterophora, Sphaeramia* spp.), the grunter *Terapon jarbua*, archerfish (*Toxotes jaculatrix*), the *gerreiid Gerres filamentosus*, several damselfishes (*Dischistodus* spp., *Hemiglyphidodon plagiometopon, Pomacentrus simsiang*), at least three wrasses (*Halichoeres*

chloropterus, H. leucurus, and *Oxycheilinus celebicus*), the parrotfish *Scarus quoyi*, two blennies (*Meiacanthus ditrema* and *M. grammistes*), and a host of gobies in the genera *Acentrogobius, Cryptocentrus, Arcygobius, Exyrias, Mahidolia, Oplopomus, Oxyurichthys*, and *Yongeichthys*.

Discussion and Conservation recommendations

Allen (2007) provided an in-depth analysis of coral reef fish diversity in the Indo-Pacific with emphasis on the identification of conservation "hotspots" of both diversity and endemism. One result of this study was the recognition of 13 megadiversity centers, the exclusive "1000-club" or countries that have more than 1000 reef-associated fishes (Table 10). The Federated States of Micronesia is ranked number 13 on this list, highlighting its exceptional wealth of coral reef fishes. It is the only country on the list that lies more than 1000 km away from the Coral Triangle centre of diversity. The next most remote location is Japan, whose Yaeyama Islands are situated 670 km from the Philippines. The FSM's position in this elite group of countries is largely due to the contribution of Yap State, which lies closer to the "Triangle" and shares more of its faunal elements than Chuuk, Pohnpe, or Kosrae. Therefore, the special faunal elements of Yap State need to be carefully managed and conserved to insure the continuation of the FSM's strong global position. The best way to achieve this is to set aside representative habitats as Marine Protected areas (MPAs). Yap State could very well play a crucial role in a broad-based conservation program for the western Pacific. Due to the vagaries of marine dispersal it is vital for all countries throughout the Indo-Pacific region to work together towards the common goal of conserving biodiversity. Unlike terrestrial systems where restricted-range species are an important component of local diversity, marine systems are characterized by prodigious numbers of wide-ranging species. Allen's (2007) analysis revealed an average range of 9,357,070 km^2 for Indo-central Pacific reef fishes or roughly the size of China. Approximately 40 percent of species have geographic ranges spanning more than 10,000,000 km^2. Even so called limited-range endemics have distributions that frequently cross political boundaries, requiring multi-national conservation initiatives. For example Yap State forms a vital portion of the distribution of five Micronesian endemic species of damselfishes (*Chrysiptera traycei, Pomachromis exilis, P. guamensis, Pomacentrus bipunctatus*, and *Pomacentrus* n. sp) as well as six wrasses (*Cirrhilabrus balteatus, C. earlei, C. johnsoni, C. rhomboidalis, Labropsis micronesica,* and *Paracheilinus bellae*). Effective conservation of these Micronesian specialties can only be achieved through coordinated management plans that involve all Micronesian partners including the FSM, Palau, Guam, Saipan, and the Marshall Islands.

Table 10. Countries with more than 1000 coral reef fishes including percentage of the total reef fish fauna of the Indo-west and central Pacific region (IWCP), estimated coral reef area, density based on the number of species per km^2, and number of endemics.

Country	Species	Percent IWCP spp.	Reef Area (km^2)	Spp. / km^2	endemics
Indonesia	2,122	54.4	51,020	0.042	78
Australia	1,827	46.8	48,960	0.037	93
Philippines	1,790	45.9	25,060	0.071	29
Papua New Guinea	1,635	41.9	13,840	0.118	22
Malaysia	1,549	39.7	3,600	0.430	1
Japan	1,462	37.5	2,900	0.504	26
Taiwan	1,374	35.2	940	1.462	7
Solomon Islands	1,371	35.2	5,750	0.238	3
Republic of Palau	1,254	32.2	1,661	0.755	3
Vanuatu	1,105	28.3	4,110	0.269	2
Fiji	1068	27.4	10,020	0.107	15
New Caledonia	1060	27.2	5,980	0.177	7
Fed. States of Micronesia	**1,031**	**26.4**	**4,340**	**0.238**	**7**

Although it now appears there are few if any endemic fishes inhabiting Yap State, genetic studies of reef fishes currently in progress by the author and collaborators from Boston University indicate that island endemism may be considerably more prevalent than formerly believed. For example, recent DNA analysis reveals that six populations from Fiji previously considered as geographic colour variants of wide ranging species are genetically distinct lineages. Therefore in-depth genetic studies that involve comparisons of Yap species with their counterparts from surrounding areas need to be undertaken and should form an integral part of conservation action plans.

The insatiable oriental market for shark fins and live reef fishes has seriously depleted stocks of groupers (Serrandiae) and other large fishes throughout the Coral Triangle and the devastation continues over an increasingly growing area involving many countries in the western Pacific. One of the prime targets of the Asian-based live restaurant fish trade is the Napoleon Wrasse (*Cheilinus undulatus*), one of the largest species of reef fish, growing to well in excess of 100 cm. Young fish (under about 50 cm) are generally targeted because they are easier to ship and market. The author has noticed an appreciable decline in this species, particularly in the Coral Triangle region over the past three decades. Indeed, data gathered on recent biological surveys indicate that it is rare or absent at many locations (Table 11). This species is now listed in Appendix II of CITES, but illegal trade will no doubt continue as long as the huge demand remains on the Asian market. Judging from observations during the current survey Yap and the outlying atolls appear to be intermediate to the Coral Triangle region and more remote areas of Oceania farther to the east with regards to the abundance of this species.

There appears to be an ever-expanding circle of exploitation of this threatened species, as well as large groupers and sharks. As stocks disappear from the Coral Triangle region, dealers from China, Taiwan, and South Korea, constantly seek new fishing areas and endeavour to make deals with local fishermen and/or politicians. The result is always the same –valuable marine resources are fished to dangerously low levels or entirely eliminated, a few local people make a moderate profit at the expense of the entire community, and Asian entrepreneurs reap huge dividends.

Table 11. Frequency of Napoleon Wrasse (*Cheilinus undulatus*) for various locations in the Indo-Pacific previously surveyed by G. Allen.

Location	**No. sites where seen**	**% of total sites**	**Approx. no. seen**
Phoenix Islands 2002	47	83.92	412
Milne Bay, PNG – 2000	28	49.12	90
Milne Bay, PNG – 1997	28	52.83	85
Pohnpei - 2005	28	68.29	63
Yap - 2007	**23**	**50.00**	**47**
Raja Ampat Islands – 2001	7	15.55	7
Togean/Banggai Islands – 1998	6	12.76	8
Weh Island, Sumatra – 1999	0	0.00	0
Calamianes Is., Philippines – 1998	3	7.89	5

Although there is only one case involving the recent extinction of a reef fish (Ferreira *et al*., 2005), coral reefs are increasingly at risk. Coral bleaching, elevated sea temperatures, destructive fishing practices, and sedimentation due to careless logging or agricultural practices are among the most obvious threats. There is an urgent need to establish a network of MPAs throughout the Indo-Pacific and other tropical seas. There is still much to learn about life history cycles of reef fishes and especially "source-sink" relationships of marine larvae, but if we wait for researchers to provide this information it may already be too late for many species. It would be far better to implement a network of MPAs as soon as possible.

A logical strategy would be to establish an MPA network throughout the FSM and neighboring countries/territories of Micronesia. This plan, if carefully designed, would form a critical refuge for 36 Micronesian endemics, as well as providing a measure of protection for approximately 1000 species or roughly 25 percent of the total reef fish species in the Indo-west and central Pacific region. Admittedly, this plan may sound over-simplified, especially in light of the argument that most existing MPAs are too small and too far apart to effectively maintain genetic connectivity (Rodrigues and Gaston, 2001). However, such a network would provide a strategic foundation for future MPA expansion that will be necessary once critical information on genetic connectivity is revealed. Moreover, there is increasing evidence (Jones *et al*., 2005) for highly localized self-sustaining recruitment in reef fish populations. For example, Jones *et al*. (1999) estimated that 15-60 percent of juvenile damselfish (*Pomacentrus amboinensis*) self-recruited back to their natal population at Lizard Island on the Great Barrier Reef. Accordingly, Leis (2002) suggested the geographic

size of management-conservation units is probably much smaller than previously thought, perhaps on the scale of 10s of km^2.

The Bird's Head region (far western New Guinea) of Indonesia provides an excellent working example of how grass roots conservation is being implemented in a vital area of the Coral Triangle. Major biological assessment surveys conducted by Conservation International (McKenna *et al*., 2002) and The Nature Conservancy (Donnelly *et al*., 2003) confirmed this region as an exceptionally rich corridor for both diversity and endemism. The urgent establishment of an MPA network was recommended to appropriate local and national agencies on the basis of the rapid assessment findings. Over the following four-year period government officials, in consultation with local and international NGOs, formulated a strategic network of seven MPAs, occupying a total surface area of approximately 6,540 km^2, scheduled for implementation in mid-2007. The combination of the seven new MPAs and an existing national park will proved a refuge for 1264 species of reef fishes, including at least 20 suspected endemics. The Bird's Head conservation initiative represents an important addition to an Indo-Pacific network that currently includes major MPA networks on Australia's Great Barrier Reef (347,800 km^2) and the northwestern Hawaiian Islands (362,580 km^2). Hopefully, additional regions such as Micronesia will initiate similar action.

Specific recommendations

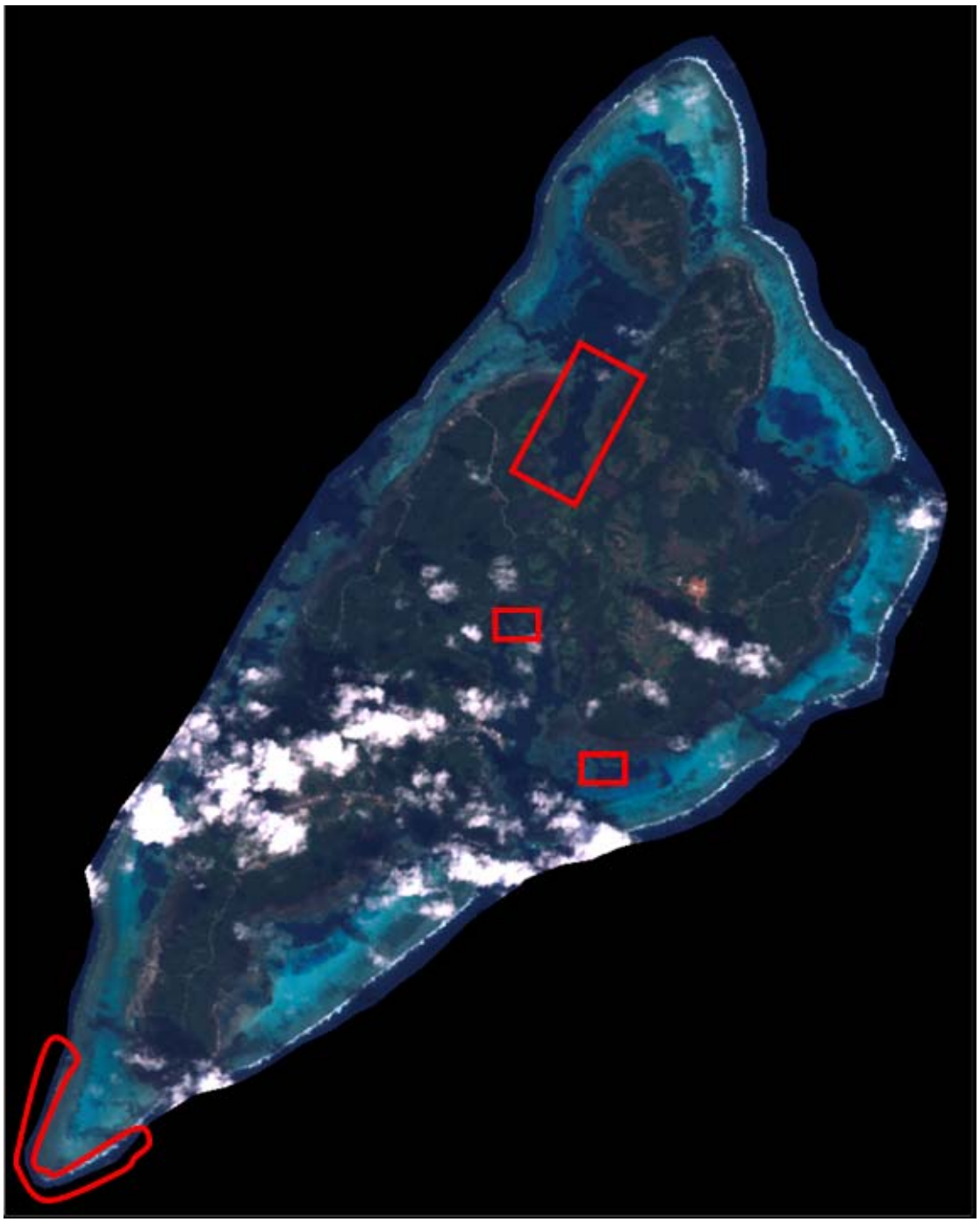
Ngulu Atoll –I recorded fewer species at Ngulu than at Yap and Ulithi, although this was probably at least partly attributable to the fact that fewer sites were visited than at the other locations. Ngulu provides a classic example of an oceanic atoll ecosystem. I was particularly impressed with the general abundance of fishes and especially the underwater visibility, probably the best I have seen in the entire Indo-Pacific region. Several species including Galzin's Garden Eel (*Gorgasia galzini*), Dark-tailed Parrotfish (*Scarus fuscocaudatus*), sand-divers (*Trichonotus* spp.), and Jeweled Blenny (*Salarias fasciatus*) were only seen at Ngulu. In addition, the Festive Parrotfish (*Scarus festivus*), which was rare or absent at Yap and Ulithi, was common on outer reefs at Ngulu.

Given its remote location, sparse human population (and consequent extremely low fishing pressure), and excellent reef condition the atoll would make an excellent MPA site. The atoll also appears to have escaped recent coral-bleaching episodes that have destroyed living corals in numerous areas of the Indo-Pacific region. I would recommend the declaration of the entire atoll as an MPA. Perhaps donor money from an NGO could be sought to fund a modest field station that could serve as the MPA headquarters and local people could be paid to provide ranger services that would include monitoring of key faunal elements (sharks, turtles, Napoleon wrasses, large groupers, etc.). It would also be essential to provide a radio link to FSM law enforcement agencies in order to provide assistance in apprehending illegal fishers, particularly foreign boats targeting sharks, large fishes, and turtles.

Yap – Yap Island offers a wider range of habitat diversity compared to Ngulu and Ulithi. While harbouring a variety of fishes that are typical of outer reefs, channels, and lagoons, its fauna is further enriched by a unique fish community that is strictly associated with well sheltered coastal reefs and mangrove shorelines subjected to silt-laden freshwater runoff. This coastal habitat is largely ignored by divers because of its

lack of aesthetic appeal, poor underwater visibility, and an impoverished fauna compared to other major habitats. However, it is deserving of protection and needs to be represented in any MPA network that is established around the island. One particular area that is a prime location for possible MPA status is the mangrove coast and bays on the west coast adjacent to the northern entrance to the German Channel (Fig. 4). This area abounds in unusual gobies and other silt-bottom specialists. Another excellent area is situated in the vicinity of sites Y-18 and Y-19 (Fig. 4).

Fig. 4. Recommended sites for MPA consideration on Yap.



An additional prime candidate for MPA consideration is the reef on the east coast which we surveyed as site Y-17 (Fig. 4). Numerous small (3-20 cm total length)

individuals of both the Napoleon wrasse (*Cheilinus undulatus*) and Bumphead parrotfish (*Bolbometopon muricatum*) were encountered, indicative that it is an important nursery area for these threatened/endangered species.

Virtually all major passes or channels and immediately adjacent outer reefs are also candidates for MPA consideration. Passages frequently harbour rich and interesting fish assemblages due to the "loading" factor that results from the transitional nature of this habitat. Over just a few hundred metres distance there is a dramatic gradation between outer reef and lagoon faunas. Lastly, I was very impressed with the MPA potential of site Y-16, near the southernmost tip of Yap. Its relatively remote location and open sea exposure conveys a certain degree of natural protection that helps to promote a relatively "pristine" reef condition. Accordingly, the entire southern tip region (Fig. 4) is an obvious candidate for MPA inclusion.

Ulithi Atoll – Ulithi offers an excellent example of an oceanic atoll and representative habitats should be considered for any MPA plan that is initiated. I would recommend expansion of the Turtle Islands protected area to include the adjacent reef complex that surrounds and connects the two islands. The outer reef is particularly rich for small reef fishes and harbours a healthy shark population. I was also impressed with the pristine condition, aesthetic appeal (spectacular canyons and steep dropoff), and abundant fish life at the southernmost portion of the main atoll (site U-7). This was the only site of the entire survey where the relatively rare Red Parrotfish (*Scarus xanthopleura*) was seen. It also harboured exceptionally large numbers of Flame angelfish (*Centropyge loricula*) and Double-lined mackerel (*Grammatorcynus bilineatus*), species that were either rare or generally seen in small numbers elsewhere during the survey. The lagoon reef adjacent to Mogmog is another area worthy of MPA consideration. It was the third richest site for fishes of the entire survey and also appears to be an important nursery area for snappers (*Lutjanus* spp.) and emperors (*Lethrinus amboinensis* and *L. obsoletus*).

Two important sites were situated at Falalop Island. Site U-2, situated on the southwestern side of the island, was the richest site for fishes for the entire survey with 169 species recorded. Although basically an outer reef it offers a good mixture of habitat which includes reef flat, surge channels with a transition to deep canyons, extensive sand and rubble bottom, walls, and variable steep slopes. The highly exposed outer reef site at the northwestern corner of the island (site U-1), although lacking in overall diversity, was one of the most interesting sites for fishes due to the super-abundance of many species that were either absent or seen in relatively small numbers elsewhere including Silverstreak anthias (*Pseudanthias cooperi*), Pixie hawkfish (*Cirrhitichthys oxycephalus*), Herald's angelfish (*Centropyge heraldi*), Slender Damselfish (*Pomachromis exilis*), Bicolor Blenny (*Ecsenius bicolor*), and Bluespine unicornfish (*Naso unicornis*). It was also the only site where the relatively rare Spotted soapfish (*Pogonoperca punctata*) was observed.

Sharks, especially Grey reef sharks (*Carcharhinus amblyrhynchos*), were more abundant at Ulithi than at Ngulu or Yap. I would recommend that future surveys target the identification of important nursery areas for sharks as a priority activity and at least a portion of these be incorporated into the local MPA network. One potential site was the lagoon patch reef at site U-15, where large numbers of small (approximately 100 cm total length) grey reef sharks were encountered.

Sharks - Reef sharks are becoming increasingly threatened throughout the tropical Pacific due to the merciless assault of the South-east Asian-based shark fin fishery. Certainly consideration should be given to protecting local reef shark populations (including Black-tip, White-tip, Grey Reef, and Silvertip sharks) The huge amount of damage to global shark stocks by foreign fishing vessels underlines their fragility. Intense fishing over a relatively short period can severely reduce local shark populations due to their territoriality, slow growth rate, and low fecundity. For these reasons I would recommend a total ban on shark-fishing throughout Yap State. Sharks are often caught on hooks when fishing for other species. They can easily be released after capture and are able to survive rough handling and several minutes out of water. An education program would be required to inform the community of the global plight of sharks and their importance in the reef food chain.

Napoleon Wrasse and Bumphead Parrotfish - I would also recommend blanket protection of these two species that are increasingly threatened throughout the Asia-Pacific region. At the very least, the harvest of these species needs to be carefully managed to prevent their over-utilization. Further survey work at Yap and the outlying atolls should focus on the recognition and conservation of key nursery areas for both species.

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References

Allen, G.R. 2007. Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. *Aquatic Conservation: Marine and Freshwater Ecosystems* **17**: 1-16.

Allen, G., Steene, R., Humann, P., and Deloach, N. 2007. Reef Fish Identification: Tropical Pacific. 457 pp.

Donnelly R., Neville D., and Mous, P.J. (eds). 2003. *Report on a rapid ecological assessment of the Raja Ampat Islands, Papua, eastern Indonesia held October 30-November 22, 2002*. The Nature Conservancy-Southeast Asia Center for Marine Protected Areas, Sanur, Bali, Indonesia.

Ferreira, C.E.L., Gasparini, J.L., Carvalho-Filho, A. and Floeter, S.R. 2005. A recently extinct parrotfish species from Brazil. *Coral Reefs* **24**: 128-131.

Jones, G.P., Millcich, M.J., Emslle, M.J. and Lunow, C. 1999. Self-recruitment in a coral reef fish population. *Nature* **402**: 802-804.

Jones, G.P., Planes, S. and Thorrold, S. 2005. Coral reef fish larvae settle close to home. *Current Biology* **15**: 1314-1318.

Kuiter, R.H. and Debelius, H. World atlas of marine fishes. Ikan, Frankfurt. 357 pp.

Leis, J.M. 2002. Pacific coral-reef fishes: the implications of behaviour and ecology of larvae for biodiversity and conservation, and a reassessment of the open population paradigm. *Environmental Biology of Fishes* **65**: 199-208.

McKenna, S.A., Allen, G.R. and Suryadi, S. (eds). 2002. A marine rapid assessment of the Raja Ampat Islands, Papua Province, Indonesia. *RAP Bulletin of Biological Assessment* **22**. Conservation International, Washington, DC: 1-193.

Meyers, R.F. 1999. Micronesian Reef Fishes. Third revised and expanded edition. Coral Graphics, Guam. 330 pp.

Randall, J. E. 2005. Reef and shore fishes of the South Pacific: New Caledonia to Tahiti and the Pitcairn Islands. University of Hawaii Press, Honolulu. 707 pp.

Rodrigues, A.S.L. and Gaston, K.J. 2001. How large do reserve networks need to be? *Ecology Letters* **4**: 602-609.

Senou, H, Suzuki, T., Shibukawa, K. and Yano, K. 2004. A photographic guide to the gobiioid fishes of Japan. Heibonsha, Tokyo. 534 pp.

Springer, V. G. 1982. Pacific plate biogeography with special reference to shorefishes. Smithsonian Contributions to Zoology **367**: 1-182.