

## **Coral Reef Fishes of the Bird's Head Peninsula, Indonesia**

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### **Summary**

- A list of fishes was compiled for Cenderawasih Bay (32 sites and 71 hours of scuba diving) and the Fak Fak-Kaimana Coast (34 sites and 73 hours of diving) to a maximum depth of 60 m.
- A total of 975 species were recorded for the combined 2006 Cenderawasih Bay and Fak Fak-Kaimana surveys.
- A formula for predicting the total reef fish fauna based on the number of species in six key indicator families (Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae) indicates that at least 1118 and 1236 species can be expected to occur at Cenderawasih Bay and the Fak Fak-Kaimana Coast respectively.
- Gobies (Gobiidae), wrasses (Labridae), damselfishes (Pomacentridae), cardinalfishes (Apogonidae), and groupers (Serranidae) are the dominant groups in the region in both number of species and number of individuals, comprising about 46 percent of the total observed fauna (excluding cryptic species).
- Species numbers at visually sampled sites during the two surveys ranged from 79 to 257, with an average of 173.8 for Cenderawasih Bay and between 87-335, with an average of 215.8 for the Fak Fak-Kaimana area.
- 200 or more species per site is considered the benchmark for an excellent fish count. This total was achieved at 38 percent of Cenderawasih sites and 62 percent of Fak Fak-Kaimana sites.
- A record breaking total of 335 species was observed at Site 26 (Papasol Rock) about 95 km southwest of Kaimana. The previous record high for a single scuba dive was 303 species recorded by the author at Ioa Island, southwest Halmahera.
- The results of the 2006 Cenderawasih Bay and Fak Fak-Kaimana surveys combined with post-survey visits in 2007-2008 and previous collections/observations at the Raja Ampat Islands includes a total recorded fish fauna of 1,323 species with an estimated overall fauna of 1,473 species. These are among the highest totals for any similar-sized area and indicative of the global importance of the Bird's Head Seascape.
- Triton Bay and the adjoining Triton Lakes region is recommended for a wildlife reserve based on the rich fish fauna and outstanding terrestrial scenery.

- Post-survey visits during January/February 2007, April/May 2007, August 2007, October 2007, November 2007, and January 2008 yielded 81 additional new records for the Raja Ampat Islands and 97 new records for the Fak Fak-Kaimana region, including a new species of pseudochromid from the latter area.
- The 2006 surveys and 2007-2008 post-survey visits resulted in 105 new records for the Bird's Head Seascape.

## Introduction

The primary goal of the fish survey was to provide a comprehensive inventory of reef species inhabiting the Bird's Head Peninsula. This segment of the fauna includes fishes living on or near coral reefs down to the limit of safe sport diving or approximately 60 m depth. It therefore excludes deepwater fishes, offshore pelagic species such as flyingfishes, tunas, and billfishes, and most estuarine forms. Survey results facilitate comparison of key locations within the Bird's Head Seascape (Cenderawasih Bay, Fak Fak-Kaimana Coast, and Raja Ampat Islands) as well as inter-regional and global comparisons.

## Historical background

The Bird's Head region has attracted the attention of naturalists and scientists ever since it was first visited by European explorers. The Raja Ampat Group and Waigeo Island, in particular, was the focus of early French visits by several vessels including L'Uranie (1818-1819), La Coquille (1823), and L'Astrolabe (1826). Consequently, approximately 70 fish species were recorded from the region primarily by Quoy and Gaimard (1824 and 1834), Lesson (1828-1830), and Cuvier and Valenciennes (1828-1849). Waigeo is an important type locality for a variety of widespread species including the Black-tipped Shark (*Carcharhinus melanopterus*), Bluefin Trevally (*Caranx melampygus*), Bigeye Trevally (*Caranx sexfasciatus*), Semicircular Angelfish (*Pomacanthus semicirculatus*), and Sergeant Major (*Abudefduf vaigiensis*).

Following the early French explorations, most ichthyological activity was provided by Dutch researchers. The famous surgeon-naturalist Pieter Bleeker periodically received specimens from government agents and in 1868 published on a collection of Waigeo fishes that included 88 species. He added a further 12 species in subsequent papers. Albert Günther, the Curator of Fishes at the British Museum, recorded 28 species from the island of Misool, during the cruise of the "Curacao" in 1865 (Günther, 1873). The Dutch ichthyologists Weber and de Beaufort were keenly interested in New Guinean freshwater and marine fishes and contributed to our knowledge of Raja Ampat fishes during the first half of the past century. The work of de Beaufort (1913), in particular, was the most extensive effort on Raja Ampat fishes until recent times, and includes accounts of 117 species based on 748 specimens. These were obtained by de Beaufort during a visit to the East Indies in 1909-1910, and were mainly collected at Waigeo in the vicinity of Saonek Island and Mayalibit Bay. Weber and De Beaufort and various co-

authors including Koumans, Chapman, and Briggs reported an additional 67 records from Waigeo and Misool in the Fishes of the Indo-Australian Archipelago (E.J. Brill, Leiden; 11 volumes published between 1921-1962). The Denison-Crockett South Pacific Expedition made small collections at Batanta and Salawati consisting of 29 species that were reported by Fowler (1939). The only other fish collection of note was that by Collette (1977) who recorded 37 species from mangrove habitats on Misool and Batanta. The author made the first comprehensive underwater observations of Raja Ampat fishes during two brief visits in 1998-1999. Although freshwater fish research was the main focus, approximately 20 hours of scuba and snorkel diving yielded observations of more than 500 coral reef fishes. The first major survey of the islands was conducted in 2001. The author participated in a marine rapid assessment survey (RAP) organized by Conservation International. A total of 45 sites were assessed during a 15-day period (Allen, 2002). An additional 50 sites were visited in 2002 during a rapid ecological assessment (REA) conducted by The Nature Conservancy. The author's combined CI-TNC effort raised the number of the known reef fishes of the Raja Ampats from about 236 to 1,102 (Allen, 2003).

Compared to the Raja Ampat Islands, the remainder of the Bird's Head Seascape has been largely ignored by previous researchers. Therefore, the results of the 2006 surveys of Cenderawasih Bay and the Fak Fak-Kaimana Coast are particularly critical for filling a gap in our knowledge of this important region.

## **Methods**

The fish portion of the Cenderawasih and Fak Fak-Kaimana surveys involved 144 hours of scuba diving by G. Allen to a maximum depth of 52 m. A list of fishes was compiled for 66 sites. The basic method consisted of underwater observations made during one or two 60-90 minute dives at each site. The name of each observed species was recorded in pencil on a plastic sheet attached to a clipboard. The technique usually involved rapid descent to 20-50 m, then a slow, meandering ascent back to the shallows. The majority of time was spent in the 2-12 m depth zone, which consistently harbors the largest number of species. Each dive included a representative sample of all major bottom types and habitat situations, for example rocky intertidal, reef flat, steep drop-offs, caves (utilizing a flashlight if necessary), rubble and sand patches.

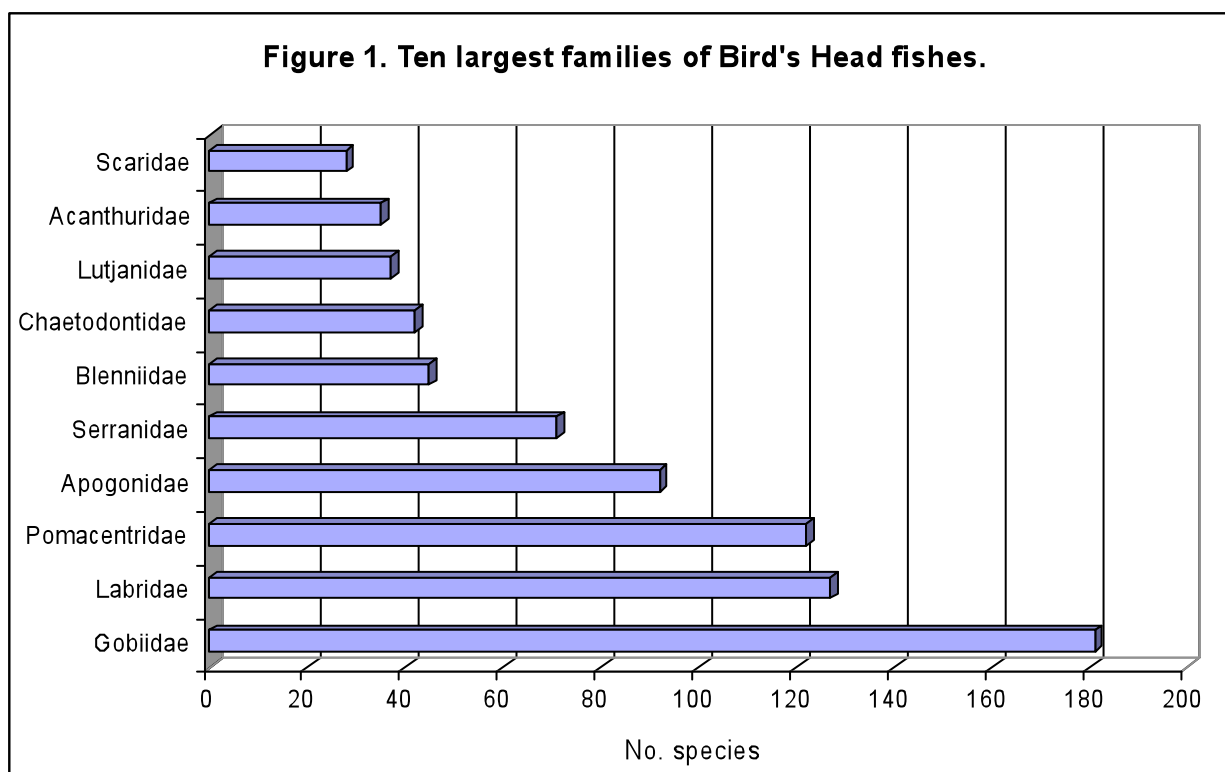
Only the names of fishes for which identification was absolutely certain were recorded. However, very few, less than one percent of those observed, could not be identified to species. This high level of recognition is based on more than 35 years of diving experience in the Indo-Pacific and an intimate knowledge of the reef fishes of this vast region as a result of extensive laboratory and field studies. The visual survey was supplemented with occasional small collections procured with rotenone, quinaldine sulphate, clove oil, and a rubber-propelled spear.

## Results

The total reef fish fauna of the Bird's Head Peninsula region reported herein consists of 1,323 species belonging to 102 families (Appendix 1). This figure is based on three main geographic areas: Raja Ampat Islands – 1,185 species, Cenderawasih Bay – 718 species (Appendix Table II), and the Fak Fak-Kaimana Coast – 959 species (Appendix Table I). A total of 975 species was actually recorded during the present survey of Cenderawasih Bay and the Fak Fak-Kaimana region, including 101 new records for the Bird's Head Seascape. An additional 250 species were recorded by the author at the Raja Ampat Islands during five previous visits between 1998-2002 (Allen, 2002 and 2003). The final tally also includes six post-survey visits to the Bird's Head region by the author and/or Mark Erdmann between January 2007 and February 2008, which involved approximately 200 additional hours of diving. The latter efforts yielded 81 additional new records for the Raja Ampat Islands and 97 new records for the Fak Fak-Kaimana region.

### General faunal composition

The fish fauna of the Bird's Head region consists mainly of species associated with coral reefs. The most abundant families in terms of number of species are gobies (Gobiidae), wrasses (Labridae), damselfishes (Pomacentridae), cardinalfishes (Apogonidae), groupers (Serranidae), blennies (Blenniidae), butterflyfishes (Chaetodontidae), snappers (Lutjanidae), surgeonfishes (Acanthuridae), and parrotfishes (Scaridae). These 10 families collectively account for 60 percent of the total reef fauna (Fig. 1).



The relative abundance of Bird's Head fish families is similar to other reef areas in the Indo-Pacific, although the ranking of individual families is variable. Even though the Gobiidae was the leading family, it was not adequately collected due to the small size and cryptic habits of many species. Similarly, the moray eel family Muraenidae is consistently among the most speciose groups at other localities, and is no doubt abundant in the Bird's Head region. However, they are best sampled with rotenone due to their cryptic habits.

The composition of local reef fish communities in the Indo-Pacific region is dependent on habitat variability. The incredibly rich reef fish fauna of Indonesia directly reflects a high level of habitat diversity. Nearly every conceivable habitat situation is present from highly sheltered embayments with a large influx of freshwater to oceanic atolls and outer barrier reefs. Indeed, the Raja Ampat Islands presents a cross-section of this impressive array of marine environments. However, due to prevailing weather conditions and the protective influence of various large islands, much of the surrounding seas are inordinately calm for most of the year. Therefore, fishes usually associated with sheltered reefs are especially well represented.

Similar to other reef areas in the Indo-Pacific, most Bird's Head 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 Raja Ampat 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

The fishes at a particular site are generally composed of faunal elements that include both generalist species occurring over a broad range of habitats as well as a suite of specialist species that are adapted to various levels of exposure to general sea conditions. For example, certain species are exclusively encountered on outer or seaward reefs that provide maximum exposure, whereas others are restricted to sheltered silty bays. Between these two extremes there is a vaguely defined situation with variable degrees of moderate exposure, which is also characterized by certain species, although this habitat generally contains a variable mixture of outer and inner reef specialists depending on the level of exposure. Table 1 provides a list of species that are typical indicators of the major habitat types.

**Table 1.** Typical species associated with major habitat types.

Seaward reefs	Moderate exposure	Sheltered reefs
<i>Cephalopholis spiloparea</i>	<i>Lutjanus biguttatus</i>	<i>Myripristis hexagona</i>
<i>Caranx sexfasciatus</i>	<i>Lutjanus button</i>	<i>Pterois n. sp.</i>

<i>Lutjanus monostigma</i>	<i>Pentapodus aureofasciatus</i>	<i>Cephalopholis microprion</i>
<i>Caesio teres</i>	<i>Coradion spp.</i>	<i>Plectropomus maculatus</i>
<i>Hemitaurichthys polylepis</i>	<i>Chaetodontoplus mesoleucus</i>	<i>Chaetodon octofasciatus</i>
<i>Apolemichthys trimaculatus</i>	<i>Choerodon anchorago</i>	<i>Chrysiptera pricei</i>
<i>Pomacentrus vaiuli</i>	<i>Neoglyphidodon nigroris</i>	<i>Pomacentrus burroughi</i>
<i>Bodianus anthioides</i>	<i>Pomacentrus nigromanus</i>	<i>Pomacentrus albimaculus</i>
<i>Halichoeres biocellatus</i>	<i>Diproctacanthus xanthurus</i>	<i>Halichoeres chloroperus</i>
<i>Nemateleotris magnifica</i>	<i>Halichoeres leucurus</i>	<i>Ecsenius stigmatura</i>
<i>Naso hexacanthus</i>	<i>Scarus quoyi</i>	<i>Amblygobius nocurna</i>
<i>Balistoides conspicillum</i>	<i>Acanthurus fowleri</i>	<i>Signigobius biocellatus</i>

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
<i>Cirrhitus pinnulatus</i>	<i>Myripristis vittata</i>
<i>Chrysiptera brownriggii</i>	<i>Cephalopholis polleni</i>
<i>Plectroglyphidodon leucozonus</i>	<i>Pseudanthias flavoguttatus</i>
<i>Stegastes albimarginatus</i>	<i>Pseudanthias luzonensis</i>
<i>Thalassoma janseni</i>	<i>Pseudanthias pleurotaenia</i>
<i>Thalassoma purpureum</i>	<i>Pseudanthias randalli</i>
<i>Blenniella spp.</i>	<i>Oxycirrhites typus</i>
<i>Entomacrodus spp.</i>	<i>Hoplolatilus spp.</i>
<i>Istiblennius spp.</i>	<i>Paracaesio sordidus</i>
<i>Bathygobius spp.</i>	<i>Chaetodon burgessi</i>
<i>Acanthurus lineatus</i>	<i>Genicanthus spp.</i>
<i>Acanthurus guttatus</i>	<i>Xanthichthys spp.</i>

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
<i>Synodus spp.</i>	<i>Archamia zosterophora</i>
<i>Hoplolatilus spp.</i>	<i>Sphaeramia nematoptera</i>

<i>Scolopsis affinis</i>	<i>Chaetodon baronessa</i>
<i>Upeneus tragula</i>	<i>Chaetodon trifascialis</i>
<i>Parachaetodon ocellatus</i>	<i>Cheiloprion labiatus</i>
<i>Dischistodus perspicillatus</i>	<i>Plectroglyphidodon dickii</i>
<i>Cirrhilabrus spp.</i>	<i>Pomcentrus moluccensis</i>
<i>Paracheilinus spp.</i>	<i>Labrichthys lineatus</i>
<i>Coris batuensis</i>	<i>Scarid spp. (Chlorurus and Scarus)</i>
<i>Parapercis spp.</i>	<i>Eviota bifasciata</i>
<i>Gobiid spp (Amblyeleotris, etc.)</i>	<i>Eviota sebreei</i>
<i>Soleiid, bothid spp.</i>	<i>Oxymonacanthus longirostris</i>

### 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 totaled to obtain the Coral Fish Diversity Index (CFDI) for a single dive site, relatively restricted geographic areas (e.g. Raja Ampat Islands) or countries and large regions (eg. Indonesia).

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<sup>2</sup>) and those from much larger areas (surrounding seas encompassing more than 50,000 km<sup>2</sup>). 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<sup>2</sup> = 4.234(CFDI) - 114.446 (d.f = 15; R<sup>2</sup> = 0.964; P = 0.0001); 2. total fauna of areas with surrounding seas encompassing less than 2,000 km<sup>2</sup> = 3.39 (CFDI) - 20.595 (d.f = 18; R<sup>2</sup> = 0.96; P = 0.0001).

The CFDI predictor value is especially useful to gauge the thoroughness of a particular short-term survey that is either currently in progress or already completed. For example, the CFDI for all Bird's Head surveys (including Raja Ampat Islands) is 367 and the appropriate regression formula (4.234 x 368 - 114.446) predicts an approximate total of 1,444 species, indicating that at least 166 more species can be expected.

On a much large scale the CFDI can be used to estimate the reef fish fauna of the entire Indo-west Pacific region, a frequent subject of conjecture. Using this method Allen and Adrim (2003) estimated a faunal total of 3,764 species, a figure that is remarkably close to the 3,890 total obtained by the author as a result of a comprehensive species mapping

project for this region. It also compares favorably with the approximately 3,950 total proposed by Springer (1982). Moreover, Springer's figure covers shore fishes rather than reef fishes and therefore includes species not always associated with reefs (e.g. estuarine fishes).

The total CFDI for the Bird's Head region has the following components: Labridae (127), Pomacentridae (122), Chaetodontidae (42), Acanthuridae (35), Scaridae (28), and Pomacanthidae (21). Table 4 presents a ranking of Indo-Pacific areas that have been surveyed to date based on CFDI values. It also includes the number of reef fishes thus far recorded for each area, as well as the total fauna predicted by the CFDI regression formula.

The Bird's Head is the highest ranked region that the author has sampled to date. Its diversity of fishes surpasses that of Milne Bay, Papua New Guinea and Maumere Bay, on the Indonesian island of Flores, areas that have been studied far more intensively. Conservational International conducted two RAP surveys at Milne Bay (1997 and 2000) with a total of 110 sites. Moreover, additional records were obtained that covered a 20-year period. Similarly, Maumere Bay was the focus of numerous field trips by G. Allen and R. Kuitert in the 1980s and extensive rotenone collections were obtained during a government-sponsored workshop in 1992.

**Table 4.** Coral fish diversity index (CFDI) values for selected localities in the Indo-west Pacific region. The total number of fishes thus far recorded from each region and estimated total based on the CFDI regression formula (see text for details) are also indicated.

Locality	CFDI	No. reef fishes	Estim. Reef fishes
<b>Bird's Head Peninsula, Indonesia</b>	<b>375</b>	<b>1323</b>	<b>1473</b>
Milne Bay, Papua New Guinea	337	1109	1313
Great Barrier Reef, Australia	343	1325	1338
Maumere Bay, Flores, Indonesia	333	1111	1107
Taiwan	319	1172	1237
New Caledonia	300	1097	1156
North West Shelf, Australia	273	932	1042
Marshall Islands, Micronesia	221	795	822
Maldiv Islands	219	894	813
Society Islands, French Polynesia	160	560	563
Hawaiian Islands	<b>121</b>	435	398

## 2006 Survey Sites

### Cenderawasih Bay

The number of species found at each site is indicated in Table 5. Totals ranged from 79 to 257, with an average of 174.8 per site.



**Table 5.** Number of fish species observed at each site during 2006 survey of Cenderawasih Bay.

Site	Species	Site	Species	Site	Species	Site	Species
1	219	9	225	17	144	25	216
2	207	10	79	18	160	26	206
3	219	11	136	19	88	27	96
4	187	12	157	20	116	28	167
5	248	13	171	21	222	29	139
6	125	14	129	22	257	30	193
7	145	15	210	23	174	31	194
8	231	16	119	24	226	32	190

The highest and lowest diversity were encountered on outer reef slopes and relatively turbid, sheltered reefs respectively (Table 6). Moderately exposed fringing reefs and offshore patch reefs were intermediate for overall fish species, although the latter habitat was relatively impoverished with about 148 species per site.

**Table 6.** Average number of fish species per site recorded for major habitat situations of Cenderawasih Bay.

General habitat	No. Sites	Site nos.	Avg. species/site
Outer reef slopes	10	1-5, 8-9, 13, 21-22	218.6
Semi-sheltered fringing reefs	10	7, 14-16, 24-26, 30-32	182.8
Offshore patch reefs	4	12, 17-18, 23	147.8
Sheltered bays and fringing reefs	8	6, 10-11, 19-20, 28-30	118.3

### **Fak Fak-Kaimana Coast**

The number of species found at each site is indicated in Table 7. Totals ranged from 92 to 335, with an average of 215.8 per site.

**Table 7.** Number of fish species observed at each site during 2006 survey of Fak Fak-Kaimana Coast (note: no fish dive at site 25).

Site	Species	Site	Species	Site	Species	Site	Species
1	139	10	242	19	205	29	171
2	257	11	223	20	242	30	162
3	202	12	176	21	315	31	284
4	152	13	213	22	291	32	246
5	177	14	253	23	181	33	163
6	220	15	279	25	264	34	239
7	182	16	92	26	335	35	228
8	197	17	214	27	257		
9	172	18	186	28	270		

Table 8 presents a comparison of overall fish diversity between major geographic areas including the Fak Fak Coast (Tanjung Fatagar to Tanjung Papisoi), Kaimana Coast (Tanjung Papisoi to Kayu Merah Bay) and the Pisang Islands. The average species site for all major areas was outstanding compared to nearly all previous areas surveyed by the author. The only exception is southwestern Halmahera where the similar figure of 225 species per site was obtained by the author in September 2005.

**Table 8.** Average number of fish species per site recorded for major geographic areas.

General area	No. Sites	Site nos.	Avg. species/site
Kaimana Coast	22	4-26	215.2
Fak Fak Coast	10	1-3, 27-33	214.2
Pisang Islands	2	34-35	230.0

Generally about 30 more species per site were found on seaward reefs and passages compared to more sheltered areas (Table 9). An unusually high number of species was recorded at sheltered sites compared to most previously surveyed locations. Surprisingly, the highest number of species was found at a predominately sheltered site (26)

**Table 9.** Average number of fish species per site recorded for major habitat situations at Fak Fak-Kaimana Coast.

General habitat	No. sites	Site nos.	Avg. species/site
Bays and sheltered reefs	13	1-2, 5, 7, 12-13, 16, 23, 26, 28-30, 32	197.5
Seaward reefs and passes	21	3-4, 6, 8-11, 14-15, 17-22, 24-25, 27, 31, 33-35	227.0

## Combined results

A total of 975 species were recorded during the 2006 surveys of Cenderawasih Bay and the Fak Fak-Kaimana Coast. Combined with previous work by the author in the Raja Ampat Islands and post-survey observations/collections in 2007-2008 the overall total for the Bird's Head region now stands at 1323 species (Table 10).

**Table 10.** Summary of results for all fish surveys in the Bird's Head region.

Location	Year(s)	Total spp.	CFDI	Est. Spp.
Raja Ampat Islands	1998-2008	1185	356	1393
Cenderawasih Bay	2006	718	291	1118
Fak Fak-Kaimana Coast	2006-2008	959	319	1236
Combined Bird's Head	1998-2008	1323	375	1473

The most speciose sites for fishes during the 2006 surveys of Cenderawasih Bay and the Fak Fak-Kaimana Coast are summarized in Table 11.

**Table 11.** Richest fish sites during 2006 surveys.

Site no.	General locations	No. spp.
25	Papisoi Rocki, Fak Fak Coast	335
21	Pulau Baronusu, Kaimana Coast	315
22	Pulau Lauzaro, Kaimana Coast	291
31	Pulau Urat, Fak Fak Coast	284
15	Selat Iris, Kaimana	279
28	Tuburuasa, Fak Fak Coast	270
25	Tumbu Tumbu, Kaimana Coast	264
22	Tridacna Atoll, Cenderawasih Bay	257
27	Nasaulong, Kaimana Coast	257
2	Teluk Sanggala, Fak Fak Coast	257

Table 12 presents the average number of species per site, number of sites where more than 200 species were observed, and the greatest number seen at a single site for recent marine surveys by the author in the Coral Triangle region of South East Asia. Despite a deliberate attempt to sample all habitats, including a relatively high proportion of sheltered environments where fish numbers are often poor, the three areas of the Bird's Head exhibited extraordinary faunal richness. A total of 200 or more species is generally considered as the benchmark for an excellent fish count for a single site. This figure was obtained at 52 percent of Raja Ampat sites, exceeded in the author's experience only by southwestern Halmahera and the Solomon Islands.

**Table 12.** Comparison of site data for marine surveys in the coral triangle 1997-2002.

Location	No. sites	Average spp./site	No. 200+ sites	Most spp. one site
Combined Bird's Head surveys (1998-2006)	161	189	83 (52%)	335
Fak Fak-Kaimana Coast (CI 2006)	34	216	21 (62%)	335
Cenderawasih Bay (2006)	32	175	12 (38%)	257
Raja Ampat Islands (CI 2001 and TNC 2002)	95	184	49 (52%)	284
Halmahera (New England Aquarium 2005)	27	229	24(86%)	304
Solomon Islands (TNC 2004)	65	184.7	37 (57%)	279
NE Kalimantan (TNC 2003)	42	187	18 (43%)	273
Milne Bay, PNG (CI 1997 and 2000)	110	192	46 (42%)	270
Togean/Banggai Is., Sulawesi (CI 1998)	47	173	9 (19%)	266
Calamianes Is., Philippines (CI 1998)	21	158	4 (10.5%)	208

### Inter-regional comparisons

A comparison of the faunal composition of the three surveyed areas of the Bird's Head Peninsula reveals that the Raja Ampat Islands harbors the richest fish diversity. However, many of the species that were found there, but not seen at Cenderawasih Bay or on the Fak Fak-Kaimana Coast are a reflection of the survey methodology. Numerous cryptic species were recorded on the basis of collections involving the use of rotenone and quinaldine, which is effective for flushing out small fishes from reef crevices. Moreover, considerably more survey time, totalling about 10 weeks, was expended at the Raja Ampats. Despite these qualifications, this island group obviously possesses the richest fauna of the Bird's Head region.

Analysis of survey results indicates that the core fauna of the Bird's Head Seascape consist of 593 species or 46 percent of the overall total that are shared with all three major areas. A further 242, 93, and 25 species are presently known only from the Raja Ampat Islands, Fak Fak-Kaimana Coast and Cenderawasih Bay respectively. Species that are common to two of the three areas are summarized in Table 13.

**Table 13.** Summary of species shared by two of the three major areas of Cenderawasih Bay.

	Cenderawasih Bay	Fak Fak-Kaimana
Raja Ampat Islands	679	848
Cenderawasih Bay	-----	606

Many of the species that were found at only one of the three major areas were rare, often reported on the basis of just 1-3 individuals. Judging from the relatively wide distributions of most of these species, it is reasonable to assume that they are likely to occur anywhere in the Bird's Head region, assuming that suitable habitat exists. However, there does appear to be at least 66 species that are common at some areas and genuinely absent or rare at others. These are summarized in Appendix Table IV.

## Discussion

The Indonesian Archipelago is the world's premier area for marine biodiversity, mainly due to the extraordinary wealth of coral reef organisms. Allen and Adrim (2003) recorded 2,056 species from Indonesia, confirming its position as the richest country in the world for coral reef fishes. Combined with the adjoining countries of the Philippines, Malaysia, Papua New Guinea, and Solomon Islands, the region is universally acknowledged as the global center of marine diversity and is often referred to as the "Coral Triangle". However, there is considerable conjecture regarding the precise location of the absolute center or prime hotspot within this large ecologically variable region.

Carpenter and Springer (2004) provided evidence that the Verde Passage in the central Philippines is the world's richest site for fish diversity. However, their data were based mainly on commercial or edible food fishes, rather than reef species. My own data, based on more 30 years of field work on coral reefs throughout the region and a current GIS project involving the preparation of distribution maps for every reef species in the Indo-west and central Pacific, confirms that the central Philippines is indeed one of the richest areas. However, the GIS data yields different results dependent on the scale of comparisons. If, for example, rectangular areas of 500,000 km<sup>2</sup> are considered, the richest area lies between the western tip of New Guinea and the North Sulawesi Peninsula. In contrast, analysis of 100,000 km<sup>2</sup> grids reveals that the richest area is situated in the central Philippines. Most importantly the GIS-species distribution data reveals that the "heart" of the Coral Triangle extends from eastern Indonesia to the north-central Philippines. This corresponds with the 1500 species contour and within this area species numbers fluctuate narrowly over a range of about 100 species.

Although 1500 species appears to be the hallmark of a localized (less than 100,000 km<sup>2</sup>) area within the heart of the Coral Triangle, this figure has never been documented in the field. It is based on expected range distributions which in turn are based on numerous collection and observation records over the past few decades. The highest actual totals for the region based on localized field surveys by the author between 1985 and the

present time were obtained at the Raja Ampat Islands (1,185 species), Maumere Bay, Flores (1,111 species), and Milne Bay, Papua New Guinea (1,109 species). Therefore, the combined Bird's Head total of 1,323 species confirms that it is indeed one of the richest areas of its size for reef fish diversity and an integral part of the inner Coral Triangle.

### **Bird's Head endemism**

The presence of endemic species is a considerable asset in promoting and justifying conservation action for a particular area. Considering the broad dispersal capabilities via the pelagic larval stage of most reef fishes it is surprising that at least 22 species are apparently confined to the Bird' Head Seascape. However, this status is provisional, pending further collecting in adjacent areas, particularly Halmahera. Each species is briefly discussed in the following paragraphs.

*Hemiscyllium freycineti* (Quoy and Gaimard, 1824) (Hemiscyllidae) - known on the basis of five specimens deposited at the Muséum National d'Histoire Naturelle, Paris and an additional specimen at the Western Australian Museum. French naturalists collected the original specimens between 1817 and 1825 in the vicinity of Waigeo Island. The species is relatively common on shallow reefs, and is mainly seen at night.

*Hemiscyllium galei* Allen and Erdmann, 2008 (Hemiscyllidae) – observed and photographed at Rumberpon in Cenderawasih Bay. The species is similar to and was initially mistaken for *H. freycineti*, but has fewer and larger spots on the body and prominent white spots on the back. No specimens were obtained during the survey, but M. Erdmann obtained two male specimens in February 2007.

*Hemiscyllium henryi* Allen and Erdmann, 2008 (Hemiscyllidae) – a single specimen was obtained at Triton Bay during the 2006 survey and two additional samples were collected by M. Erdmann in January 2007. It is similar to *H. ocellatum* from northern Australia, but differs slightly in coloration. In addition, recent genetic testing revealed significant differences between the two.

*Diancistrus niger* Schwarzhans, Moller, and Nielsen, 2005 (Bythitidae) – known on the basis of eight specimens collected by the author at Mansuar and Batanta islands in the Raja Ampat Group. It is a secretive crevice-dwelling species that was collected with rotenone at depths between about 0-4 m.

*Manonichthys jamali* Allen and Erdmann, 2007. (Pseudochromidae) – occasionally observed at Tumbu Tumbu (site 25) and sites along the Fak Fak coast. In addition, one specimen was collected at southeastern Misool in 2008. The habitat consists of dense thickets of staghorn *Acropora*, encrusting layers of *Galaxea* corals, or rocky debris at depths between about 9-16 m. Fish are encountered solitarily or in loose groups of 2-4 individuals. They appear to range over an area of about 1.5-2 m. The coloration is overall yellow tan with a prominent black bar across the anterior tail base and adjacent basal

portions of the dorsal and anal fins. The colour pattern and behaviour indicates it is a mimic of the more common damselfish *Chromis retrofasciatus*, with which it co-occurs.

*Pseudochromis* sp. (Pseudochromidae) – commonly sighted in the Raja Ampat Islands on rubble bottoms at the base of steep slopes in about 18 to 20 m depth. It was generally seen solitarily or in pairs. It is apparently new and closely related to *P. colei* from the Philippines.

*Pseudochromis jace* Allen, Gill, and Erdmann, 2008 (Pseudochromidae) – three specimens collected and several others observed at depths below about 45 m in the vicinity of Triton Bay during post-survey visit in January 2007. It has also been collected by M. Erdmann at the Raja Ampat Islands. The species is most similar to *P. pictus* from the Indonesian island of Alor, which lies about 1130 km southwest of Triton Bay. The two species are easily separated on the basis of colour pattern. In addition, *P. pictus* has fewer lateral scales (33-35 versus 37-39), more circumpeduncular scales (20 versus 18-19), and more circumorbital pores (27-30 versus 20-23).

*Pictichromis caitlinae* Allen, Gill, and Erdmann, 2008 (Pseudochromidae) - this bright magenta fish with a yellow snout and forehead was abundant in the inner portion of Cenderawasih Bay around rocky outcrops on relatively silty, turbid reefs at depths between about 10-55 m. The species has been confused by previous authors (including Gill, 2004) with the similar *P. auriformis* (Lubbock, 1980), which was described on the basis of a single specimen from near Port Moresby, Papua New Guinea.

*Opistognathus rufilineatus* Smith-Vaniz and Allen, 2007 (Opistognathidae) – two specimens of this jawfish were collected with clove oil by Mark Erdmann at site 16 (north Triton Bay). It is a relatively drab brown fish with a few dark spots on the head.

*Apogon leptofasciatus* Allen, 2001a (Apogonidae) – described on the basis of three specimens collected by the author at Batanta Island in 2001. Less than 15 individuals have been observed.

*Apogon oxygrammus* Allen, 2001a - another cardinalfish that is apparently rare. Three specimens were collected by the author in 45-50 m depth at Pef Island, off the western tip of Gam Island in the Raja Ampat Group. An additional pair was sighted at Teluk Papuma, southern Yapen. The habitat consists of rocky outcrops on silt/mud or *Halimeda*-covered rubble bottom.

*Apogon* sp. – observed and collected at two sites on the Fak Fak-Triton coast at depths between 30-42 m. It occurs in aggregations around dead coral outcrops. The overall color is semi-translucent white with a pair of thin brown stripes on the upper half of the body and prominent black spot on the tail base. It is similar to *A. franssedai*, which occurs from Flores to Sumatra, but differs in having a longer upper stripe, dark anterior margin on the first dorsal fin, and dark stripe basally on the second dorsal fin.

*Siphamia* sp. (Apogonidae) – About 30 specimens were collected at Selat Iris (site 13) near Triton Bay. This aggregation were living in association with a crinoid on a small rock outcrop situated in a silty bay at a depth of 11.5 m. The species differs from all known members of the genus on the basis of color pattern, which consists of a semi-translucent body with a single narrow stripe mid-laterally on the body.

*Hoplolatilus erdmanni* Allen, 2007. (Malacanthidae) – a recently described species that was first observed by M. Erdmann on two occasions (sites 15 and 20) along the Kaimana Coast. It occurs in relatively deep water (50-60 m) on sand/rubble bottoms where it constructs huge mounds from dead coral rubble. The species is undescribed, but closely allied to *H. fronticinctus*, from which it is easily distinguished on the basis of color pattern. Unlike the mainly plain blue *H. fronticinctus*, the new species is characterized by about 15 yellow bars on the side and a dark-edged white tip on the upper caudal lobe.

*Pterocaesio monikae* Allen and Erdmann, 2008 (Caesionidae) - commonly encountered in the inner part of Cenderawasih Bay, occurring in large schools, containing up to several hundred individuals. It was frequently in mixed schools with *Pterocasesio pisang* and *Gymnocaesio gymnopterus*. The usual habitat consists of the upper edge of seaward reef slopes, commonly at depths ranging from the surface to about 15 m, but we also sighted schools as deep as 55 m. It is most similar to *P. lativittata*, an uncommon species thus far known only from Chagos Archipelago, Cocos-Keeling Islands, Papua New Guinea (Hermit Islands), and the Phoenix Islands. These two species share an unusually slender body shape and colour pattern consisting of a single, relatively broad yellow stripe on the upper side. However, the center line of the stripe on *P. lativittata* is positioned below the lateral line, whereas in the Cenderawasih fish it is above the lateral line.

*Pentapodus* sp. (Nemipteridae) – one specimen collected off Batanta Island in the Raja Ampats by M. Erdmann in 2007, but also photographed by the author at Triton Bay. Confirmed as a new species by nemipterid expert Barry Russell of the Northern Territory Museum, Darwin. The colour is overall bluish grey with reddish fins. Males can “switch” on pale yellowish midlateral stripe.

*Chrysiptera pricei* Allen & Adrim, 1992 (Pomacentridae) – originally described from Yapen Island and common in sheltered, relatively silty habitats throughout the inner portion of Cenderawasih Bay.

*Pomacentrus* sp. (Pomacentridae) – A plain, dark brown to blackish species that has 14 dorsal spines. Known only from silty fringing reefs in shallow (3-8 m) water. It has been collected at Karawatu Island, east of Kaimana and at the Kokas Islands on the northern Fakfak Peninsula.

*Cirrhilabrus cenderawasih* Allen and Erdmann 2006 (Labridae) - common on sheltered seaward reefs of Cenderawasih Bay, primarily on the inner and eastern portions of the bay at depths between about 22-60 m, although it is more abundant below about 35 m. Groups of about 10-20 individuals, including 1-5 males, were



typically encountered on rubble slopes or on rubble substrates at the base of slopes. The species apparently feeds on zooplankton a short distance above the bottom, which is typical for the genus. The new species is closely related to *C. walindi* Allen and Randall (1996) from northern and eastern Papua New Guinea and the Solomon Islands. Both species share similar meristic features and morphometric proportions, which is not an unusual trait among the various members of the genus, which are best separated on the basis of colour pattern differences. The two species also share similar colour patterns with the notable exception of the black blotches on the body and adjacent dorsal fin. *Cirrhilabrus walindi* invariably possesses two horizontally elongate blotches that are typically on the basal part of the dorsal fin, extending only slightly on to the back. In contrast, the Cenderawasih species has 4-5, irregularly rounded blotches that extend much farther onto the body.

*Paracheilinus walton* Allen and Erdmann, 2007 (Labridae) - regularly encountered in the inner portion of Cenderawasih Bay on rubble bottoms at depths to at least 35 m. The species is related to the sympatric *P. cyaneus*, but differs significantly with regards to the male courtship (“flasher”) pattern. The pattern *P. cyaneus* consists of either a brilliant turquoise blue) or whitish dorsal fin and upper back with red to pinkish elongate dorsal rays. In contrast, the Cenderawasih fish has a white to slightly yellowish dorsal fin that strongly contrasts with the intense red colour (black when viewed under ambient light) of the adjacent back. Moreover, there is a pronounced difference in the shape and orientation of the elongate filaments. In Cenderawasih fish these are relatively broad and uniform in width throughout their length terminating in rounded, club-shaped tips. When fully erect, the distal third of the protruding rays are curved posteriorly. In contrast, the slender, tapered rays of *P. cyaneus* are essentially straight.

*Paracheilinus nursalim* Allen and Erdmann, 2008— common on rubble bottoms along the Fak Fak-Kaimana coast at depths between about 4-40 m. Unlike other members of the genus, which have intense dark marking along the back of males during courtship (“flasher”) display, this species has a distinct rectangular blackish marking on the ventral half of the caudal peduncle in combination with a similar marking on the anterior part of the back. The male display is further enhanced by the fully erect, white filamentous dorsal rays and golden yellow colour of the body.

*Eviota raja* Allen, 2001b (Gobiidae) – This tiny, mid-water hovering goby is common in the Raja Ampat Islands. The habitat consists of sheltered water with rich coral growth. It is very similar *E. bifasciata*, a sympatric species that is distributed across the Indo-Australian Archipelago. The two species differ in colour pattern, most notably the mid-lateral stripe (white in *E. bifasciata*, yellow in the new species) and the dark markings at the upper and lower caudal-fin base (horizontal streaks in *E. bifasciata*, vertically elongate spots in the new species). They also differ in counts for segmented rays in the second dorsal fin and lateral scale rows (usually 9 and 22 respectively for *E. bifasciata* and 10 and 25 in the new species).

## Faunal highlights of the 2006 surveys

### Extraordinary fish diversity of Triton Bay

The sites at Baronusu and Lauzaro, two small islands situated at the southern entrance to Triton Bay were exceptionally rich for fish diversity. The second highest global count for a single reef site, 315 species was obtained at the former location (site 21) and 274 species were recorded at the latter (site 22). Although the nearby site (14) at Sarue Nus did not have the highest total species, it was notable for its sheer abundance of numbers and incredible overall biomass. The site is situated in a narrow, rocky passage (42 m depth) between two islands and is exposed to strong currents. The bottom was covered with an impressive array of colorful sessile invertebrates including *Tubastrea* coral, gorgonian fans, black coral, soft corals, sponges, and tunicates. The impression conveyed by the abundance of sessile invertebrates was reminiscent of the renowned southern Komodo islands. The abundance of fishes at Sarue Nus was also impressive. Particularly notable were schools of barracuda (*Sphraena jello*), surgeonfishes (*Acanthurus mata* and *A. xanthopterus*), large trevallies (*Caranx ignobilis*, *C. melampygus*, and *Gnathanodon speciosus*), groupers (*Cromileptes altivelis*, *Epinephelus lanceolatus*, *E. fuscoguttatus*, and *E. malabaricus*), sweetlips (*Plectorhinchus chrysotaenia* and *P. polytaenia*) and snappers (*Lutjanus argentimaculatus*). In addition to these large species there was an amazing abundance of fairy basslets (*Pseudanthias huchtii*), and damselfishes (*Chromis scotochilopterus* and *Neopomacentrus cyanomos*).

### World record fish count at Papisol Bay

The author has been involved in rapid assessment surveys throughout the Indo-Pacific region during the past three decades. One of the interesting sidelights of this work is the ranking of individual sites based on the number of species recorded during 1-2 scuba dives per site (Table 14). The most species previously recorded for a single site was at Kayoa Island, southwest Halmahera, during September 2005. However, this total was exceeded on two occasions during the Fak Fak-Kaimana survey. Totals of 335 and 315 were recorded at Papisoi Rock (site 26) and Pulau Baronusu (site 21) respectively.

The site at Papisol Bay was characterised by the unusual combination of extremely clear water and significant sedimentation. Other prominent features included a well developed reef edge at depths between about 3-15 m, sloping to a sand/rubble slope with numerous garden eels and gobioid fishes, a secondary reef edge closer to shore at depths between 3-7 m, and extensive mud bottom habitat at depths between about 16-18 m.

**Table 11.** G. Allen's 10 all-time best dive sites for fish diversity.

Rank	Location	No. spp.
1	Papisol Bay	335
2	Pulau Baronusu, Triton Bay	315
3	Kayoa Island, southeast Halmahera	304
4	Wambong Bay, Kofiau, Raja Ampat Is.	284
5	Kri Island, Raja Ampat Is.	283

6	SE of Miosba I., Fam Is., Raja Ampat Is.	281
7	Urat, Fak Fak Coast	279
8	Widi Islands, southern Halmahera	278
8	Cape Tawali, Kasiruta Island, Halmahera	278
8	Watjoke Island, off SE Misool, Raja Ampat Is.	275
10	Pulau Lauzaro, Triton Bay	274

### **Faunal peculiarities of Cenderawasih Bay**

The survey of Cenderawasih Bay revealed a rich fish community with several unique peculiarities indicative of isolation from neighbouring areas in the geological past. The most obvious of these include several new/recently described species that appear to be endemic to the bay, additional species that occur widely in neighbouring regions, but exhibit unusual colour variation in the bay, and several deep reef species that occur in unusually shallow water within the bay. We hypothesize that the bay was essentially isolated for a substantial period over the past five million years and present day geographic/oceanographic conditions continue to provide a degree of isolation.

The majority of present day reef species appear to have evolved over the past five million years (Briggs, 2006). This same geological period must have therefore provided opportunities for isolation and consequent speciation within Cenderawasih Bay. In fact, a number of significant events that shaped the present landscape of northern New Guinea did occur, foremost of which was the collision of the Australian and Pacific plates and resultant westerly drift of the latter, along with large island fragments, including the South Caroline Arc, that eventually accreted along the northern margin of New Guinea. Although details are sketchy at best, it appears that the Tosem Block of the South Caroline Arc slid across the entrance of Cenderawasih Bay between about 3-5 million years ago before finally docking along the northern edge of the Bird's Head Peninsula (Hill and Hall, 2004). Certainly this formidable barrier could have provided an isolating mechanism to account for the apparent endemism and other faunal peculiarities. The case for isolation is further strengthened by the concurrent discovery of at least 18 new coral species, which judging from collections in surrounding regions are most likely endemic to the bay (Devantier and Turak, personal communication).

Present day ocean current patterns (see Carpenter and Springer, 2004 for overview) and the presence of large islands or island groups in the outer half of the bay including Biak, Paidado Islands, Yapen, Mios Num, and Numfoor continue to form at least partial barriers to marine larval dispersal or may deflect current flow from the surrounding Pacific. Similarly the configuration of the Bird's Head Peninsula may also play a deflection role, essentially shielding the bay from eastward flowing currents that predominate during part of the year.

Three species were collected for the first time during the expedition and are unknown from other locations: *Pterocaesio monikae*. (Caesionidae), *Paracheilinus walton*. (Labridae), and *Cirrhilabrus cenderawasih*. (Labridae). Although subsequent collecting efforts at adjacent regions may eventually prove that some of these are wider ranging,

they are presently considered as Cenderawasih Bay endemics. Moreover, extensive observations at northern Papua New Guinea and the Raja Ampat Islands, lying to the respective east and west, indicate these species are not found there. In addition, the pomacentrid *Chrysiptera pricei*, previously described by Allen from Yapen Island is common in sheltered, silty habitats and apparently restricted to Cenderawasih Bay. An additional species of pseudochromid (*Pictichromis caitlinae*) that was previously confused with *Pictichromis aurifrons*, also appears to be endemic.

At least seven species exhibit unusual color pattern variations that are possibly unique to Cenderawasih Bay. Subsequent genetic research may provide evidence of separate species status for the Cenderawasih population.

*Amblyglyphidon aureus* (Pomacentridae) – Depending on geographic location this fish is either entirely yellow or yellow with a strong bluish hue. Cenderawasih Bay individuals are similar to the latter variant, but have a dusky brown appearance.

*Chrysiptera oxycephalus* (Pomacentridae) – This fish is generally pale yellowish with numerous small blue dots on the scales and a bluish wash on the forehead. Individuals from sheltered coastal inlets of the inner bay were bright golden yellow with a grayish wash on the forehead.

*Neoglyphidodon nigroris* (Pomacentridae) – Cenderawasih adults are entirely brown, including the median fins in contrast to fish from adjacent regions of Papua New Guinea and the Raja Ampat Islands, which have a bright yellow caudal fin. The drab variety of this fish also occurs in western Indonesia and off the coast of northwestern Australia.

*Pomacentrus albimaculus* (Pomacentridae) – Previously known from northern Papua New Guinea and the Solomon Islands, where the fish is overall grey brown with a white saddle on the upper caudal peduncle. Cenderawasih adults are mainly white with the gray brown coloration restricted to the upper back.

*Forcipiger longirostris* (Chaetodontidae) – At most areas the body of this fish is bright yellow, but Cenderawasih Bay individuals have a dusky brownish hue of variable intensity. This species sometimes exhibits a melanistic phase, particularly around high volcanic islands, but from my experience it is relatively rare (about 1 of 10-20 individuals) at most areas. Only one melanistic phase individual was seen during the expedition, but virtually every fish seen had some degree of brownish hue and the species was very common. Another Cenderawasih anomaly involves the abundance of this species relative to its closely-related sister species, *F. flavissimus*. At most areas, especially in the Coral Triangle, the latter fish is generally much more abundant, but at Cenderawasih Bay it was uncommon, and *F. longirostris* was the dominant species.

*Halichoeres rubricephalus* (Labridae) – This rare species was previously known on the basis of a few specimens collected at Maumere Bay, Flores, Indonesia. Male individuals from the type locality are entirely dark green with blue margins on the fins and a striking bright red head. Males from Cenderawasih Bay are similar, but instead of bright red the head is brownish orange with some faint irregular stripes.

*Meiacanthus grammistes* (Blenniidae) – This species is widely distributed in the western Pacific and generally uniformly coloured without geographic variation. The Cenderawasih Bay population differs markedly in lacking extensive yellow colour on the head and back, relatively diffuse brown, instead of vivid black stripes on the body, and only 1-2 spots versus numerous spots on the caudal peduncle.

The Cenderawasih Bay fish community is further characterized by the unusually shallow occurrence of several species that at most locations in the Indo-Pacific are confined to depths below about 20-30 m. Species in this category, with the minimum depth indicated in parentheses include the following: *Cephalopholis spiloparea* – Serranidae (7 m), *Genicanthus bellus* - Pomacanthidae (20 m), *Paracentropyge multifasciatus* – Pomacanthidae (8 m), *Chromis alpha* - Pomacentridae (4 m), *Pomacentrus nigromarginatus* – Pomacentridae (6 m), *Halichoeres melasmapomus* – Labridae (8 m), *Acanthurus nubilus* – Acanthuridae (5 m), and *Xanthichthys auromarginatus* - Balistidae (6 m). The occurrence of *Genicanthus bellus* is particularly notable. This species is known from only a few scattered locations between the Cocos-Keeling Islands in the eastern Indian Ocean to the Society Islands in southeastern Oceania and invariably occurs at depths below about 45-50 m. This species was exceedingly common at several sites (especially site 23) between depths of 20-55 m.

Further evidence for the isolation of Cenderawasih Bay from adjoining regions is provided by the presence or absence of certain species. Appendix Table IV indicates that 13 species were common in the bay, but either rare or absent from the Raja Ampat Islands and the Fak Fak-Kaimana Coast. Conversely, 53 species were common at either one or both of the previously mentioned locations, but absent in the bay.

### **Fishing pressure**

Although illegal fishing with explosives and cyanide occurs at scattered locations there appears to be less impact from these activities compared to other parts of Indonesia. The majority of sites visited were in good condition with an abundance of fishes and relatively little damage to reef habitats due to explosives was noted. One exception was on the northern side of Pulau Adi (site 5 of Fak Fak-Kaimana survey) where five fish bombs were detonated (estimated within 3 km radius) during our dive. In addition, extensive damage from crown-of-thorns starfish was noted at several sites, particularly along the Kaimana Coast.

Villagers informed us that cyanide is sometimes used to catch groupers and Napoleon wrasse for the live fish trade. Limited underwater observations of the latter species, a conspicuous indicator of fishing pressure, show that it is indeed heavily exploited in some parts of the Bird's Head, a typical situation in Indonesia. Judging from underwater observations, Napoleon wrasse appear to be most heavily exploited in the Raja Ampat Islands compared to Cenderawasih Bay and the Fak Fak-Kaimana Coast. However, it is far more common at areas of low population or where illegal fishing methods are seldom used such as the Phoenix Islands in the central Pacific or Milne Bay Province, Papua New Guinea (Table 15).

Most of the Napoleon wrasse observed during previous surveys at the Raja Ampat Islands were juveniles under 30-40 cm in length. In contrast, those seen at Cenderawasih Bay and along the Fak Fak-Kaimana Coast were primarily large adults or subadults. The estimated average length of 56 individuals was 82 cm. The situation was particularly

encouraging at Cenderawasih Bay where large Napoleons were sighted on a regular basis and 11 individuals were seen at Tanjung Mangguar (site 21).

**Table 15.** Frequency of Napoleon Wrasse (*Cheilinus undulatus*) for various locations in the Indo-Pacific (G. Allen data).

Location	No. sites where seen	% of total sites	No. seen
Phoenix Islands 2002	47	83.92	412
Milne Bay, PNG – 1997	28	52.83	85
Milne Bay, PNG – 2000	28	49.12	90
Solomon Islands - 2004	31	47.69	56
Cenderawasih Bay - 2006	12	37.5	33
Fak Fak-Kaimana Coast	11	32.35	23
Raja Ampat Islands – 2002	9	18.0	14
Raja Ampat Islands – 2001	7	15.55	7
Togean/Banggai Islands – 1998	6	12.76	8
Calamianes Is., Philippines – 1998	3	7.89	5
Weh Island, Sumatra – 1999	0	0.00	0

Carcharhinid sharks were also more common in Cenderawasih Bay, although seen on relatively few occasions. Grey whalers (*Carcharhinus amblyrhynchos*), white-tips (*Triaenodon obesus*), black-tips (*Carcharhinus melanopterus*), and silver-tips (*C. albimarginatus*) were observed at five, five, four, and two sites respectively. Sharks were seldom seen at the Raja Ampat Islands and the Fak Fak-Kaimana Coast, with the exception of bamboo sharks (Hemiscyllidae) and tasselled wobbegongs (*Eucrossorhinus dasypogon*). The paucity of reef sharks is at least partly explained by the shark-fin trade, which has operated steadily throughout Indonesia for at least the past 3-4 decades.

### Recommended areas for conservation

Allen (2002 and 2003) presented compelling reasons why the Raja Ampat Islands have more potential for marine conservation than any other location in the Indonesian Archipelago. These same criteria certainly apply to Cenderawasih Bay and the Fak Fak-Kaimana Coast. These include extraordinary levels of biodiversity and habitat variability, superb above-water and underwater scenery, a sparse human population, highly compatible reef conservation values of the indigenous population, and adjacent forests with a highly unique flora and fauna that provides rare terrestrial/marine conservation opportunities.

Allen (2002 and 2003) listed several high priority conservation areas in the Raja Ampat Islands including the southeastern Misool Archipelago, West Misool Islands, Kofiau, and the Wayag Islands. Although some of these areas lie within gazetted wildlife reserves, there is a critical need to implement on-the-ground/water conservation action.

Fortunately, a diversity of representative marine habitats with excellent conservation potential lie within the existing boundaries of Teluk Cenderawasih National Park. Therefore, a good foundation already exists for implementing marine conservation, although enforcement capacity appears to be lacking. Additionally, further biological surveys, both terrestrial and marine, are required to comprehensively document the park's flora and fauna, which appears to contain numerous unique elements.

In the Fak Fak-Kaimana region, the area with perhaps the most conservation potential is Triton Bay. The area has both exceptional above-water scenery and some of the richest sites for fishes in the entire Indonesian Archipelago. A combined terrestrial-marine park should include the three Triton Lakes as well as the entire bay, including the outer island of Lauzaro and adjacent rock outcrops. It would also be advisable to include the northern portion of Aiduma Island and the adjacent Selat Iris for additional habitat variability. This would capture the world-class dive site at Saruenus (site 14) near the northern entrance of Selat Iris.

The author (Allen 1996) has also surveyed the Triton Lakes, a spectacularly wild landscape with high conservation value. The lakes are set among karst topography without any above ground outlets or connections between one another. The freshwater fish fauna, containing only about 10 species is entirely endemic, including three colorful rainbowfishes in the family Melanotaeniidae.

## References

- Allen, G.R. 1996. Kamaka - Aiwaso - Lakamora. *Aqua Geo-graphia*, 13: 64-74.
- Allen, G. R. 2001a. Two new species of cardinalfishes (Apogonidae) from the Raja Ampat Islands, Indonesia. *Aqua, J. Ichthy. Aquat. Biol.* 4 (4): 143-149.
- Allen, G. R. 2001b. Description of two new gobies (*Eviota*, Gobiidae) from Indonesian seas. *Aqua, J. Ichthy. Aquat. Biol.* 4 (4): 125-130.
- Allen, G. R. 2002. Chapter 3. Reef of the Raja Ampat Islands, Papua Province, Indonesia. *In: McKenna, S.A., G.R.Allen, and Suryadi, S. (eds.). A Marine Rapid Assessment of the Raja Ampat Islands, Papua Province, Indonesia. RAP Bulletin of Biological Assessment 22, Conservation International, Washington, DC.*
- Allen, G.R. 2003. Coral reef fishes of the Raja Ampat Islands. *In: Donnelly, R., D. Neville, and P.J. Mous (eds.) Report on a rapid ecological assessment of the Raja Ampat Islands, Papua, Eastern Indonesia held October 30-November 22, 2003. The Nature Conservancy-Southeast Asia Center for Marine Protected Areas, Sanur, Bali, Indonesia.*

- Allen, G.R. & M. Adrim. 1992. A new species of damselfish (*Chrysiptera*: Pomacentridae) from Irian Jaya, Indonesia. *Rec. West. Aust. Mus.*, 16 (1): 103-108.
- Allen, G. R. and M. Adrim. 2003. Coral reef fishes of Indonesia. *Zool. Stud.* 42(1): 1-72.
- Bleeker, P. 1868. Notice sur la faune ichthyologique de l'île de Waigiou. *Versl. Akad. Amsterdam* (2) II: 295-301.
- Briggs, J.C. Proximate sources of marine biodiversity. *J. Biogeog.* 33: 1-10.
- Carpenter, K.E. and Springer, V.G. 2005. The center of the center of marine shore fish biodiversity: the Philippine Islands. *Evol. Biol. Fishes* 72: 467-480.
- Collette, B. B. 1977. Mangrove fishes of New Guinea. *In*: Teas, H. J. (ed.) *Tasks for vegetation science*. W. Junk Publishers, The Hague: 91-102.
- Cuvier, G. and A. Valenciennes. 1828-1849. *Histoire naturelle des poissons*. 22 volumes. Paris.
- de Beaufort, L. F. 1913. Fishes of the eastern part of the Indo-Australian Archipelago with remarks on its zoogeography. *Bijdr. Neder. Dierk.*, Amsterdam 19: 95-163.
- Fowler, H. W. 1939. Zoological results of the Denison-Crockett South Pacific Expedition for the Academy of Natural Sciences of Philadelphia, 1937-1938. Part III. – Fishes. *Proc. Acad. Nat. Sci. Philadelphia* 91: 77-96.
- Gill, A.C. 2004. Revision of the Indo-Pacific dotted-back fish subfamily Pseudochrominae (Perciformes: Pseudochromidae). *Smithiana. Monograph* 1: 1-213.
- Günther, A. 1873. Reptiles and fishes of the South Sea islands. *In*: Brenchley, J. L. *Jottings during the cruise of H. M. S. Curaçao among the South Sea Islands in 1865*. *Cruise Curaçao*: 1-487, Pls. 1-59.
- Lesson, R. P. 1828. Description du nouveau genre *Ichthyophis* et de plusieurs espèces inédites ou peu connues de poissons, recueillis dans le voyage autour du monde de la Corvette “La Coquille”. *Mem. Soc. Nat. Hist. Paris* v. 4: 397-412.
- Lesson, R. P. 1830-31. Poissons. *In*: Duperrey, L. (ed.) *Voyage autour du monde, ..., sur la corvette de La Majesté La Coquille, pendant les années 1822, 1823, 1824 et 1825...*, Zoologie. *Zool.* v. 2 (part 1): 66-238.
- Quoy, J. R. C. and J. P. Gaimard. 1824. *Voyage autour du monde, Entrepris par ordre du Roi exécuté sur les corvettes de S. M. “L’Uranie” et “La Physicienne” pendant*



- les années 1817, 1818, 1819, et 1820, par M. Louis de Freycinet. Zool. Poissons: 183-401.
- Quoy, J. R. C. and J. P. Gaimard. 1834. Voyage de découvertes de "L'Astrolabe" exécuté par ordre du Roi, pendant les années 1826-1829, sous le commandement de M. J. Dumont d'Urville. Poissons III: 647-720.
- Schwarzhan, W., P.R. Moller, and J.G. Nielsen. 2005. Review of the Dinemichthyini (Teleostei: Bythitidae) of the Indo-west Pacific. Part I. *Diancistrus* and two new genera with 26 new species. Beagle, Recs. Mus. Art Gallery No. Territory 21: 73-163
- Weber, M. 1908. Süßwasserfische von Neu-Guinea ein Beitrag zur Frage nach dem früheren Zusammenhang von Neu-Guinea und Australien. In: Nova Guinea. Résultats de l'expédition scientifique Néerlandaise à la Nouvelle-Guinée. Süßwasserfische Neu-Guinea v. 5 (Zool.) pt 2: 201-267, Pls. 11-13.