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The Freshwater Ichthyofauna of Bougainville Island, Papua New Guinea[1]

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ABSTRACT: Tailings disposal from the Bougainville Copper Limited open-cut porphyry copper mine on Bougainville Island, Papua New Guinea (1972–1989) impacted the ichthyofauna of the Jaba River, one of the largest rivers on the island. To assess the extent of this impact, comparative freshwater ichthyological surveys were conducted in five rivers on the island during the period 1975–1988. Fifty-eight fish species were recorded, including one introduction, *Oreochromis mossambicus*. The icthyofauna is dominated by euryhaline marine species consistent with that of the Australian region, but more depauperate. There are more than 100 species present on mainland New Guinea that are absent from Bougainville streams. *Oreochromis mossambicus* was the most abundant species in the sampled streams, accounting for 45% of the catch. The most abundant native fishes were the mainly small Gobiidae and Eleotridae. There were few native fish of potential value as food and these were restricted to an eleotrid gudgeon (*Ophieleotris aporos*), tarpon (*Megalops cyprinoides*), eel (*Anguilla marmorata*), and snappers (*Lutjanus argentimaculatus* and *Lutjanus fuscescens*). Fish production in the rivers is limited by the morphology of the streams and the depauperate ichthyofauna. Fish yield from the Jaba River in its premining state is estimated to have ranged from 7 to 12 t/yr. The population living in the Jaba catchment in 1988 (approximately 4,600 persons) shared this resource, resulting in an extremely low per-capita fish consumption rate of less than 3 kg/yr.

The freshwater ichthyofauna of the Australian region, which includes Australia, mainland New Guinea, and associated island groups, is unique because the dominant groups of primary freshwater fish (Ostariophysi) are not represented (Roberts 1978). This has been confirmed by a number of ichthyological surveys of several major rivers on the New Guinea mainland, including the Fly (Roberts 1978), Laloki (Berra et al. 1975), Angabanga (Hyslop 1996), and Purari Rivers (Haines 1983) to the south; the Gogol (Parenti and Allen 1991), Ramu (Allen et al. 1992), Upper Yuat (Jenkins 1997), and Sepik Rivers (Allen and Coates 1990) to the north; as well as rivers in Irian Jaya (Allen and Boeseman 1982).

The ostariophysan fishes account for almost seven-eighths of the world's primary freshwater fishes (Darlington 1957), so the absence of the group from the New Guinea mainland has left the freshwater ichthyofauna depauperate (Haines 1983) and limited in capacity for freshwater fisheries production (Coates 1985).

It is well known that faunal diversity on islands (including the freshwater fauna) is naturally depressed, depending in part on island area (MacArthur 1972) and the distance of the island from the nearest continental land mass (Usinger 1963). The combined effects of reduced area, remote location, and the absence of ostariophysan fishes suggest severe reduction of the freshwater ichthyofauna of the Papua New Guinea island groups.

It is surprising that there has been relatively little freshwater ichthyological study of the New Guinea islands except for records provided by Munro (1967), Kailola (1975), and Allen (1989, 1991) for both marine and

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freshwater fishes. Gressitt (1982) excluded freshwater fishes from his treatment of the ecology of New Guinea, and Choy (1986) concluded that freshwater ecology in the Pacific Islands had been largely overlooked.

Environmental issues associated with industrial development in Papua New Guinea have imposed a requirement for management and political decisions in the absence of detailed knowledge of local freshwater environments. An example on the Papua New Guinea mainland is the Ok Tedi copper and gold mine (Allen 1991) and the Bougainville Copper mine on Bougainville Island (Ellis 1988). Bougainville Copper Limited operated the large open-cut porphyry copper mine on Bougainville Island (6° 00′ S, 155° 30′ E) from 1972 until 1989, when civil unrest forced premature mine closure. The mine was situated at an altitude of 900 m in Panguna in the headwaters of the Jaba River in the Crown Prince Range of Bougainville Island, North Solomons Province, Papua New Guinea (Figure 1).

During the period 1972–1989, and with government approval, Bougainville Copper Ltd. discharged tailings at rates up to 140,000 t/day into the Jaba/Kawerong River system. The tailings were discharged into the headwaters of the Kawerong River, and approximately 60% of the input entered the sea 35 km downstream. Sedimentation on this scale severely changed the morphology of the river and resulted in total loss of ichthyofauna in the main channel and partial loss in tributaries. The Jaba River tributaries were not directly influenced by sedimentation, but were isolated from the sea by high suspended-solid loading in the main channel.

To evaluate the extent of this impact and to assist Bougainville Copper Ltd. with ongoing negotiations for loss of natural resources resulting from its operations, ichthyological surveys of five streams on Bougainville Island were conducted during the period 1975–1988.

The purpose of this paper is to document the freshwater ichthyofauna of Bougainville Island in a biogeographical context and provide information about a largely unknown resource on a remote tropical Pacific Island. The importance of freshwater fishes as a source of high-quality protein to the indigenous inhabitants of the island is also assessed.

Study Area

CSIRO (1967) described the landforms of Bougainville and Buka Islands. The islands lie at the northern extremity of the Solomon Island Archipelago on the western edge of the Pacific Plate (Briggs 1987). The two islands together are 238 km (150 miles) long by 63 km (40 miles) wide, with a total area of 8568 km^2 (3475 square miles). The climate is wet tropical with an annual rainfall of approximately 3000 mm (Ruppin 1988). Recent volcanism has covered Bougainville Island with a mantle of ash often more than 1 m deep (Speight 1967), which, together with continuing tectonic instability and rainfall, has produced both high relief and a high rate of erosion and deposition.

The configuration of Bougainville has inhibited development of very large stream catchments (Speight 1967), the largest being the Luluai catchment (464 km^2). The rivers are short (generally <35 km long) and torrential. The headwaters and upstream areas of the rivers within the Crown Prince Range are boulder-strewn torrents passing into pool and riffle zones as stream gradient decreases. On the coastal lowlands the streams become meandering, swiftly flowing, generally single-channel rivers. All the rivers surveyed are nontidal; river flow is unidirectional at the mouth, and the salt water mixing zone is offshore. Ryan (1991) described streams of similar morphology in Fiji.

Detailed hydrological information is only available for the Jaba/Kawerong system, which has a catchment area of 440 km^2 and a mean annual discharge of 44 m^3 sec^{-1} (Ruppin 1988).

MATERIALS AND METHODS

Fish were collected from a total of 22 sites distributed along five rivers: the Pinei, Arakawau and Luluai Rivers on the eastern side of the Crown Prince Range, and the Mariropa and Pangara Rivers on the western side (Figure 1). The Pangara River collections in-

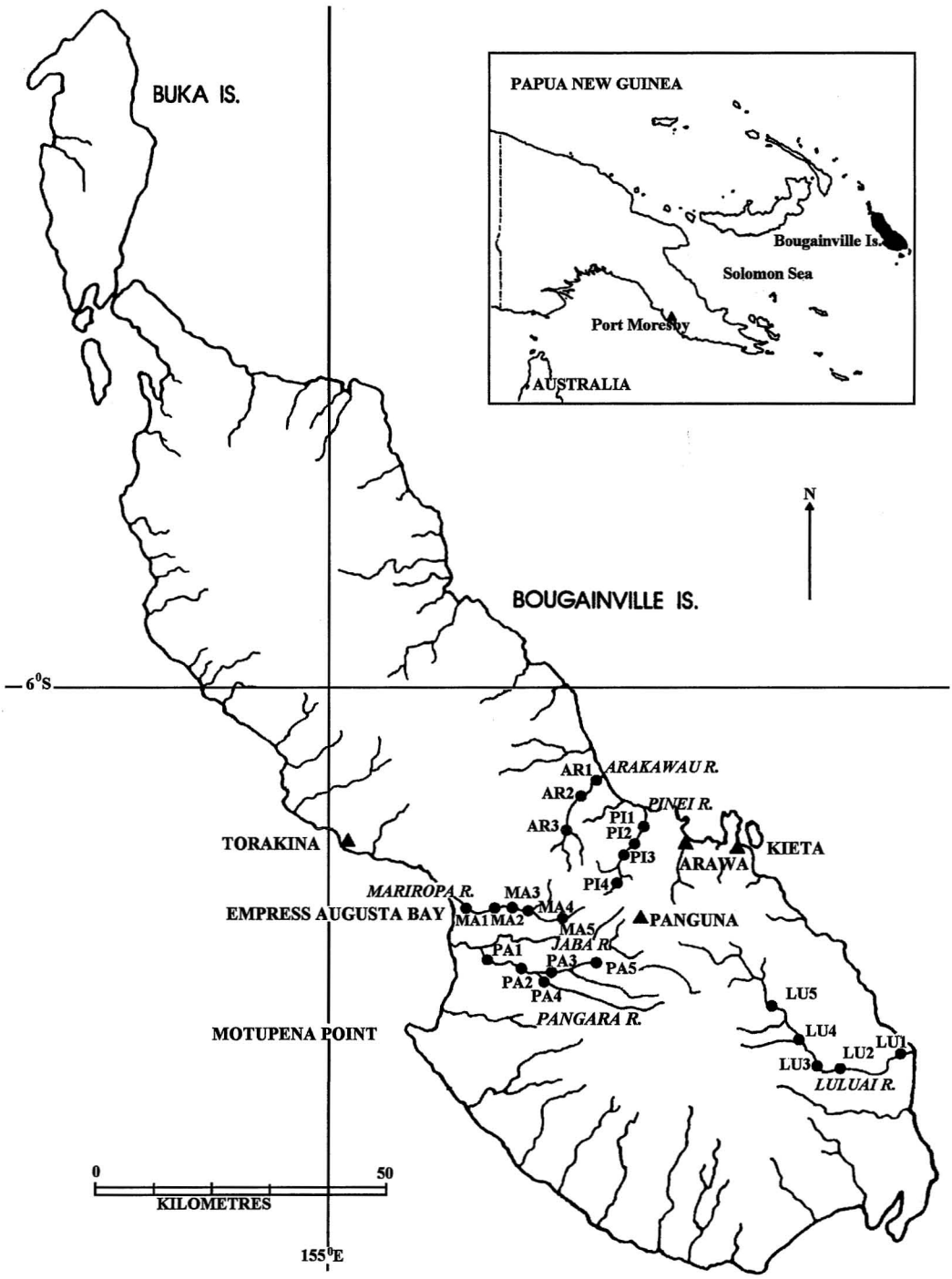

FIGURE 1. Bougainville Island showing river sampling locations and position of Panguna mine site in the headwaters of the Jaba River.

TABLE 1

SURVEY DATES AT FIVE RIVERS ON BOUGAINVILLE ISLAND DURING THE PERIOD 1975–1988

RIVER	1975	1976	1977	1978	1981	1982	1984	1986	1987	1988
Pinei		X		X	X		X	X	X	X
Arakawau		X			X		X		X	X
Luluai		X	X		X		X		X	
Pangara	X	X			X	X	X		X	X
Mariropa	X	X			X				X	

cluded visits to two tributaries (the Orei [site PA4] and Nunopa Rivers [sites PA3 and PA5]) in the upper reaches of its catchment. At least three sites were sampled in each river, one site in each major river zone: the upper boulder rapid zone, the middle pool and riffle zone, and the lower single-channel zone.

Each river was surveyed on several occasions between 1975 and 1988 (Table 1). Fish were collected using a variety of methods, including 100-mm multifilament gill net (30 by 3.2 m), 10-mm knotless bait seine net (20 by 5 m), 37-mm monofilament gill net (20 by 1 m), white lights and knives, diving and spearing, hook and line (angling and set lines), and fish traps (drums).

The fishing methods used by local landowners are mainly traditional (white lights and knives, spears, and hook and line). Gill netting and seine netting are rarely, if ever, conducted.

Captured fish were identified to species wherever possible, and the standard length and weight of individual fish were recorded. A complete reference fish collection was stored at Bougainville Copper Ltd.'s Panguna mine site at the time of mine closure. Only a small selection of duplicate specimens was lodged at the Queensland Museum, Brisbane.

RESULTS AND DISCUSSION

A species checklist and the sites at which they have been recorded are shown in Table 2. A complete list of fishes including dates and authors of original descriptions is available from the authors on request. *Lutjanus fuscescens* also was recorded previously from Bougainville Island by Allen and Talbot (1985) as were *Stenogobius hoesei* (Watson 1991), *Sicyopterus* sp. 2 (Allen 1991), and *Awaous ocellaris* (Watson 1992). Several of the other species in Table 2 (*Caranx sexfasciatus, Sicyopterus ouwensi,* and *Rhyacichthys aspro*) were also recorded by Kailola (1975), leaving 51 new records from the surveys reported here. All of these new records refer to species that require access to marine or brackish environments to complete their life histories.

Sites have been grouped into those representative of the lower reaches (approximately 0–5 km from the mouth), middle reaches (approximately 6–10 km upstream), and upper reaches (approximately 11–20 km from the mouth). Longitudinal zonation is apparent, with the largest number of species (47) being recorded from the lower reaches and fewer species (30–32) from the middle and upper reaches.

Some species such as the eel (*Anguilla marmorata*), grunter (*Mesopristes cancellatus*), flagtails (*Kuhlia marginata* and *K. rupestris*), and some representatives of the Gobiidae and Eleotridae occur throughout the river systems. Others occur mainly in the lower reaches: the tarpon (*Megalops cyprinoides*), glass perchlets (*Ambassis miops* and *A. nalua*), sawfish (*Pristis microdon*), trevallys (Carangidae), and snappers (Lutjanidae). The upper reaches are inhabited by the majority of representatives of the Gobiidae and Eleotridae in addition to the eels and flagtails.

Most of the fish that attain larger size (and are therefore prized as food) inhabit the lower reaches of the streams (e.g., the tarpon,

TABLE 2: A CHECKLIST OF THE FRESHWATER ICHTHYOFAUNA ON BOUGAINVILLE ISLAND SHOWING

	LOWER REACHES							MIDDLE REACHES						
TAXA	AR1	LU1	MA1	MA2	MA3	PA1	PI1	AR2	LU2	LU3	MA4	PA2	PI2	PI3
Pristidae														
Pristis microdon			1		1									
Megalopidae														
**Megalops cyprinoides*	1	1		1		7								
Anguillidae														
Anguilla marmorata	2	2			4		6			2		9		2
Opichthidae														
Lamnostoma orientalis		1												
Engraulidae														
Stolephorus tri		47												
Syngnathidae														
**Microphis brevidorsalis*														
**Microphis leiaspis*					2						2		1	
Ambassidae														
Ambassis urotaenia	15													
**Ambassis interruptus*				6	5									
Ambassis macracanthus	4	13		21	86		7	1	1		2			
Ambassis miops	14	9					1						1	
Ambassis nalua				144	392		7				1			
Terapontidae														
**Terapon jarbua*							1							
**Mesopristes argenteus*	1	1			1		2				2			
**Mesopristes cancellatus*		2			4		3	1	3	3			1	1
Kuhliidae														
**Kuhlia marginata*	3	28			83		3	1	17	6	7	2	51	13
**Kuhlia rupestris*		3					3	3	13	2			4	6
Carangidae														
Caranx sexfasciatus		2					2							
Trachinotus russelli		1												
Leiognathidae														
**Leiognathus equulus*		3												
Lutjanidae														
**Lutjanus argentimaculatus*		2			1	1	4				1			
Lutjanus fulviflamma							1							
**Lutjanus fuscescens*	1	7					6							
Gerridae														
Gerres filamentosus				1	1			1						
Pomadasyidae														
Pseudopristipoma nigra		2												
Mullidae														
Upeneus vittatus							1							
Toxitidae														
Toxotes jaculatrix				2										
Scatophagidae														
**Scatophagus argus*		1					4				1			
Cichlidae														
Oreochromis mossambicus						96						772	40	2
Mugilidae														
**Cestraeus goldiei*					1							1		
**Crenimugil heterocheilus*		18	1	5	17	2			23				7	
**Liza subviridis*	3	2		10	6		10						6	
Valamugil buchanani				7										
Valamugil seheli		1												
Polynemidae														
**Polydactylus plebeius*		2												

IZE RANGE AND RELATIVE ABUNDANCE (SITE LOCATIONS ARE SHOWN IN FIGURE 1)

TAXA	UPPER REACHES								TOTAL NO.	SIZE RANGE (SL IN MM)
	AR3	LU4	LU5	MA5	PA3	PA4	PA5	PI4		
Pristidae										
Pristis microdon									2	1,000–1,200
Megalopidae										
**Megalops cyprinoides*									10	190–471
Anguillidae										
Anguilla marmorata	4		6		2			1	40	300–1,350
Opichthidae										
Lamnostoma orientalis									1	217
Engraulidae										
Stolephorus tri									47	28–81
Syngnathidae										
**Microphis brevidorsalis*						6			6	81–96
**Microphis leiaspis*					1				6	117–156
Ambassidae										
Ambassis urotaenia									15	54–61
**Ambassis interruptus*									11	39–46
Ambassis macracanthus	1								136	29–131
Ambassis miops									25	38–87
Ambassis nalua									544	31–80
Terapontidae										
**Terapon jarbua*									1	210
**Mesopristes argenteus*									7	73–265
**Mesopristes cancellatus*	3		5	2				1	29	86–360
Kuhliidae										
**Kuhlia marginata*	85	2	77	36			12	14	440	32–168
**Kuhlia rupestris*	15	3	13	1				1	67	39–285
Carangidae										
Caranx sexfasciatus									4	88–131
Trachinotus russelli									1	62
Leiognathidae										
**Leiognathus equulus*									3	21–53
Lutjanidae										
**Lutjanus argentimaculatus*									9	152–400
Lutjanus fulviflamma									1	93
**Lutjanus fuscescens*									14	129–500
Gerridae										
Gerres filamentosus	2								5	61–109
Pomadasyidae										
Pseudopristipoma nigra									2	30–39
Mullidae										
Upeneus vittatus									1	120
Toxitidae										
Toxotes jaculatrix									2	201–216
Scatophagidae										
**Scatophagus argus*									6	93–210
Cichlidae										
Oreochromis mossambicus	2		4		431	645	749	1	2742	9–225
Mugilidae										
**Cestraeus goldiei*				2					4	122–405
**Crenimugil heterocheilus*			3						76	58–412
**Liza subviridis*	1							1	39	36–295
Valamugil buchanani									7	117–210
Valamugil seheli									1	191
Polynemidae										
**Polydactylus plebeius*									2	470

TABLE 2 (continued)

TAXA	LOWER REACHES							MIDDLE REACHES						
	AR1	LU1	MA1	MA2	MA3	PA1	PI1	AR2	LU2	LU3	MA4	PA2	PI2	PI3
Gobiidae														
**Awous melanocephalus*				53	34	1	4	2	9		4	5	46	3
**Awous ocellaris*									1				6	1
**Glossogobius celebius*	1			1	1	1	1	7	6	1	3	1	1	1
Glossogobius giuris	1			1	8			1				1		
Goby sp.	1			2										
**?Schismatogobius* sp.														
**Sicyopterus ouwensi*						1	1	2	6	4		21	3	7
**Sicyopterus* sp. 2 (Allen 1991)									2					
**Sicyopterus* sp. A									2					
**Sicyopterus* sp. B													13	
**Sicyopterus* sp. C														
**Stenogobius hoesei*					1			1	2				1	
**Stiphodon elegans*														
**Stiphodon* sp.														
Eleotridae														
Belobranchus belobranchus														
Butis butis								1						
**Hypseleotris guentheri*				160	254			3			1	126		
**Ophieleotris aporos*		1		1	22	49	3	4	5		1	19	49	15
Ophiocara porocephala	5													
**Oxyeleotris gyrinoides*				1	2	10	3	3	3			33	6	1
Oxyeleotris sp.					1			1				12	13	1
Rhyacicthyidae														
**Rhyacichthys aspro*					1			1		1		1		9
Tetraodontidae														
Chelanodon patoca		1												
Total no. of species	13	23	2	17	23	9	21	16	14	7	11	13	17	13

* Lodged at Queensland Museum, Brisbane, Australia.

eels, and snappers). Food fish are less plentiful in the middle and upper reaches of the streams. However, these larger species are not abundant (total number captured: tarpon, 10; eels, 40; and snappers, 24), indicating that the rivers are probably not a plentiful source of fish for the local inhabitants.

Allen (1991) reported that the freshwater fauna of New Guinea (Papua New Guinea and Irian Jaya) consisted of 329 species, of which 13 were introduced forms and 102 were marine species with life history stages requiring salt water. In contrast a total of 58 species (5960 individuals) was collected from Bougainville (18% of the mainland fauna), the most abundant being the introduced African species *Oreochromis mossambicus* (tilapia), which accounted for 45% of the catch (2742 individuals). Tilapia and carp (*Cyprinus carpio*) were introduced to the island in 1959 by the Department of Agriculture, Stock, and Fisheries in an attempt to increase food production (Glucksman et al. 1976). Carp were not collected in this series of surveys and seem not to have become established. However, tilapia escaped from ponds in the catchments of several rivers and were very abundant in the Pangara River. The Pangara catchment is isolated from the sea as a result of tailings disposal in the Jaba River. Because of this isolation, some important piscivorous species are absent from the Pangara catchment: the grunters (*Mesopristes cancellatus* and *M. argenteus*), the jungle perch (*Kuhlia rupestris*), and the one-spot perch (*Lutjanus fuscescens*). Tilapia has proliferated in the absence of these predators.

The native ichthyofauna as an assemblage is typical of the Tropics, being composed of a reasonably large number of species (57) none

TAXA	UPPER REACHES								TOTAL NO.	SIZE RANGE (SL IN MM)
	AR3	LU4	LU5	MA5	PA3	PA4	PA5	PI4		
Gobiidae										
**Awous melanocephalus*	3		3		2	2	2	1	174	20–130
**Awous ocellaris*					1				9	13–84
**Glossogobius celebius*	6		4	2					37	57–180
Glossogobius giuris	3			1					16	42–136
Goby sp.	2								5	41–96
**?Schismatogobius* sp.							1		1	
**Sicyopterus ouwensi*	73	1	117	2	24	4	7	40	313	39–122
**Sicyopterus* sp. 2 (Allen 1991)	1			1					4	39–122
**Sicyopterus* sp. A	1		1	3		3	12	2	24	62–65
**Sicyopterus* sp. B	14					1	4	7	39	34–67
**Sicyopterus* sp. C			1						1	34–40
**Stenogobius hoesei*	1								6	58–72
**Stiphodon elegans*				1					1	
**Stiphodon* sp.				1					1	40
Eleotridae										
Belobranchus belobranchus	1		1						2	82–142
Butis butis									1	87
**Hypseleotris guentheri*					1	1	53	26	625	32–65
**Ophieleotris aporos*	15		8	1		1	4	4	202	48–230
Ophiocara porocephala									5	59–122
**Oxyeleotris gyrinoides*	12			2	3		1		80	75–266
Oxyeleotris sp.	6						1	1	36	44–141
Rhyacicthyidae										
**Rhyacichthys aspro*	12	3	36	2				5	71	61–198
Tetraodontidae										
Chelanodon patoca									1	134
Total no. of species	22	4	14	14	8	8	11	14	58	

of which is particularly abundant. Ten species account for 84% of the catch, and most of these, except for the flagtails (*K. marginata* and *K. rupestris*), belong to smaller bait-sized representatives of the families Ambassidae, Gobiidae, and Eleotridae. Forty of the 57 native species are rare (less than 20 individuals for each of these species captured from all surveys).

There also seems to be no freshwater fish endemic to Bougainville Island, although endemicity might be revealed by revision of the Gobiidae and Eleotridae. Most of the species belong to the categories defined by Lowe-McConnell (1975) as (1) representatives of marine families (e.g., the tetradont puffers); (2) diadromous fishes (e.g., the anguillid eels); and (3) occasional visitors that are euryhaline representatives of marine families (e.g., Pristidae, Carangidae, and the Mugilidae).

In this regard, the freshwater ichthyofauna of Bougainville Island is consistent with that of the Australian region, but more depauperate because of the absence of representatives from the families Plotosidae, Ariidae, Melanotaenidae, Clupeidae, Osteoglossidae, Atherinidae, Lobotidae, Apogonidae, Soleidae, Hemiramphidae, Belonidae, Kurtidae, and Cynoglossidae, a total exceeding 100 species (Roberts 1978, Allen and Boeseman 1982, Allen 1991).

Munro (1967) listed about 220 species of native freshwater fish from Papua New Guinea alone, and McDowall (1981) considered that there are about 165–170 species of freshwater fish in Australia. The low number of native fish species on Bougainville confirms expectation and results from a combination of remote location, small area, and recent geological development. The 57 native species on Bougainville Island are more consistent with the 80 species reported from Fiji

by Ryan (1980 and 1991), but the Fiji Island group extends over 4 degrees of latitude, whereas Bougainville extends over just 2 degrees of latitude, from 5° to 7° S.

Most of the species recorded from Bougainville are widely distributed throughout the Indo-Pacific (see Weber and de Beaufort 1953, Fowler 1959, Masuda et al. 1984, Smith and Heemstra 1986). For example, *Lutjanus argentimaculatus* and *Lutjanus fulviflamma* extend from eastern Africa to the western Pacific including Fiji, Samoa, and New Caledonia, and *Lutjanus fuscescens* is found in freshwaters of China, the Philippines, Indonesia, and Papua New Guinea (Allen and Talbot 1985). Bougainville Island is the easternmost record for this species to date.

Although Bougainville lies west of the andesite line, it can probably be considered an oceanic island in the zoogeographical sense of having acquired its freshwater ichthyofauna by overseas dispersal. Many of the marine euryhaline genera represented (e.g., *Butis, Megalops, Gerres, Pristis, Scatophagus,* and *Ambassis*) confirm Pacific Plate marginal records listed by Springer (1982). The dominance of Gobiidae and Eleotridae combined (21 of 57 species [37%]) is also consistent with patterns presented by Ryan (1991) for Fiji, Vanuatu, and Samoa. The presence of the amphidromous sicydiine gobies *Stiphodon* from the Pacific and *Sicyopterus* from the Indo-Pacific reflects Bougainville's transitional position between these two major regions and reinforces the link between ocean basins and biogeography suggested by Parenti (1991).

However, the island has also been influenced by the added effects of volcanism and plate tectonic activity. Weber (1973) confirmed earlier reports by Stoddart (1969) of widespread mass mortality of reef corals in the central Solomon Islands. Stoddart considered that a contributing factor in coral mortality was tectonic activity resulting in noneustatic changes in sea level. Therefore, in addition to remote location and limited niches associated with island biogeography (Simmons 1979), evolution of the ichthyofauna on Bougainville has included adaptation to the influence of sea level changes on the morphology of streams and the effects of volcanism on water quality. Volcanic ash production coupled with high rainfall, high river discharge, and turbidity are additional factors that would not favor development of a prolific freshwater ecology.

Fish Yield

There is no commercial freshwater fishery on Bougainville. However, because mining activities have disrupted some of the streams, an assessment of the potential for freshwater fish production has been attempted to determine the extent of fish loss.

Coates (1985) prepared estimates of fish yield for the Sepik River, mainland Papua New Guinea, and concluded that a realistic fish yield figure for the Sepik might be 3000–5000 t/yr. The catchment area of the Jaba River is 440 km^2 (Ruppin 1988), 0.56% that of the Sepik (catchment area 78,000 km^2 [Coates 1985]). Discharge figures provide a similar ratio (Jaba River mean discharge, 40 m^3 sec^{-1}; Sepik River average discharge, 8000 m^3 sec^{-1}). Based on the ratio of catchment areas and discharge, the yield from the Jaba River would be unlikely to exceed 25 t/yr (range, 17–28 t/yr), provided the same species were present. A more realistic yield figure for the Jaba River will be less than this because the ichthyofauna is even more depauperate than that of the Sepik.

The average catch rate from the 100-mm gill net in Bougainville streams was 9.5 g/m^2 per set, which is approximately 60% of the catch rate (12.7–22.6 g/m^2 per set) quoted by Coates (1985). If 60% is applied as a modifying factor to account for the depauperate ichthofauna of Bougainville rivers, then a realistic fish yield for the Jaba River might be 10–17 t/yr. These estimates can be further reduced by at least 30% to eliminate the contribution made by tilapia to the catch in the Sepik (Coates 1985), resulting in a yield for native species in the Jaba River of 7–12 t/yr. A similar figure is obtained (< 6 t/yr) if the world average for freshwater fish yield (1.0–1.5 g/m^2 [Lowe-McConnell 1975]) is applied to the combined water surface area

of the channels within the Jaba River system (approximately 4×10^6 m^2).

The population density of the Jaba catchment was 10.45 persons/km^2 (basin area, 440 km^2; population, 4600), whereas the population density of the Sepik was only 1.15 persons/km^2 (basin area, 78,000 km^2; population, 68,000 [Coates 1985]). It is quite possible that the population density of the Jaba system (being nine times that of the Sepik) exceeds the biological capacity of the river to support even a subsistence fishery, so that an average per-capita fish consumption rate of <3 kg/yr is likely.

In conclusion, these preliminary estimates of fish yield, taken in conjunction with population figures, appear to support the observation made by Oliver (1973) that fishing is an "occasional pastime which does not add significantly to diet."

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