

Freshwater fish diversity in an oil palm concession area in Mimika, Papua

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Abstract. Ohee HL. 2016. *Freshwater fish diversity in an oil palm concession area in Mimika, Papua. Biodiversitas 17: 665-672.* New Guinea's freshwater fish diversity may reach 400 species, twice the number of fish recorded in Australia. However, New Guinea's freshwater fishes are facing rapid and poorly-planned social and economic developments, which have accelerated both habitat loss and degradation, impacting its unique biodiversity and threatening natural ecosystems. This study documents freshwater fish diversity and threats due to habitat conservation from oil palm development in the Timika Region, Papua. Fishes were sampled in canals, creeks, streams and rivers in the concession area of Pusaka Agro Lestari Company (PT. PAL) using seine and hand nets and a spear gun. Twenty two freshwater fish species in 15 families and 15 genera were recorded from the area. One of them is an endemic species of Timika (*Glossamia timika*), one rainbowfish species with a restricted Southern New Guinea distribution, and 12 other native fishes. Land clearing leads to increase water turbidity and sedimentation, water temperature, and pollution which are potential threats to native fishes and their habitats. The fact that PAL's concession is part of distribution area of known distribution of *G. timika* in Timika vicinity, habitat conversion to palm oil elevates the threat to this species. Hopefully, PT. PAL will adopt necessary conservation measures to mitigate the potential impact during the land clearing, especially, if they leave riparian buffer regions intact to protect aquatic habitats when clearing land.

Keywords: Freshwater fish diversity, Mimika, oil palm plantation, threats

INTRODUCTION

New Guinea's freshwater fish diversity probably reaches 400 species, twice the number of fishes recorded in Australia (Richards and Suryadi 2002). Many new discoveries in New Guinea (Papua and Papua New Guinea) were made over the last 25 years as Papua's transportation systems were developed, and field research increased (Allen et al. 2008, Allen and Unmack 2008, 2012; Allen and Hadiaty 2011; Kadarusman et al. 2010, 2011, 2012). Papua supports a rich and diverse vertebrate fauna with about 1,240 species known from Papua, but only 250 species (20%) are endemic. In comparison, there are a total of 1,674 vertebrate species found throughout the entire island of New Guinea, about 1,130 (69%) are endemic (Allison 2007). However, the freshwater fishes of New Guinea and Australia are very unique, and are mostly secondary division fishes, having evolved from marine species, whereas other continents' freshwater fishes are primary division fishes (Allen 1991).

As with many parts of Indonesia, fish habitats in Papua are facing rapid habitat degradation and loss as a result of rapid human population growth, large-scale infrastructure development, pollution, domestic waste, and the establishment of new government centers (*kabupaten*). As a result of these threats, some freshwater fishes have been listed in the IUCN Red List with various conservation statuses, and some have become very rare.

The oil palm industry has contributed significantly to Indonesian economic growth, but unfortunately, oil palm also poses potential and direct threats on species and natural habitats, especially in low land areas, where most species richness is found in tropical regions. Lenzen et al. (2008) recorded 30% of global species threats are due to international trade. Consumers in developed countries cause threats on species due to their demands of commodities which are ultimately produced in a certain area in developing countries. It includes oil palm industry from Indonesia which exports its product to some developed countries, and it affects 294 species. Moreover, researchers have shown that, in fact, oil palm plantations harbor far fewer forest-dwelling species of either primary or logged forests (Koh and Wilcove 2012). Field studies have recorded larger scale development activities including logging, mining, plantations, roads and development of new government centers which all have a direct impact on rainbow fish habitat. For instance, 22 plantation companies operated in Papua covering around 540,000 ha and 0.05-21% (100-30,000 ha) with considerable overlap with various rainbow fish distributions (Ohee 2005).

Pusaka Agro Lestari Company (PT. PAL) is an oil palm plantation company operating in Mimika, Papua, with a concession of 35,759 ha. The company plans to establish 5,775 ha of its concession as conservation forest. Five thousand hectares have opened for the plantation and 500 ha of it are set aside to conserve plants and animals. It is very unfortunate this concession area overlaps with the

only known habitat for one endemic species in Timika/Mimika (*Glossamia timika*), thus any company activities will have direct impact on this habitat.

The fact that PT. PAL is willing to set aside some of the concession area for conservation is great news. However, what is needed is greater participation from government and conservation communities to assist the effort for optimal conservation of this important habitat. This study was designed to document fish species diversity in this concession area in relation to freshwater fish diversity in river systems in New Guinea. The goal is to understand the importance of this concession area in the context of Papuan diversity and how PT. PAL can contribute to reduce threats

to local species, especially local endemic species which are at greater risk of extinction.

MATERIALS AND METHODS

Field studies were conducted in February and November 2015 in PT. PAL’s concession area, Kuala Kencana and Iwaka Districts, Mimika, Papua. Fish samples were collected in 21 sampling sites in four states, PAL 1, PAL 2, PAL 3 and PAL 5 including canals, tributaries, streams, and rivers in the forest and plantation areas (Figure 1, Figure 2).

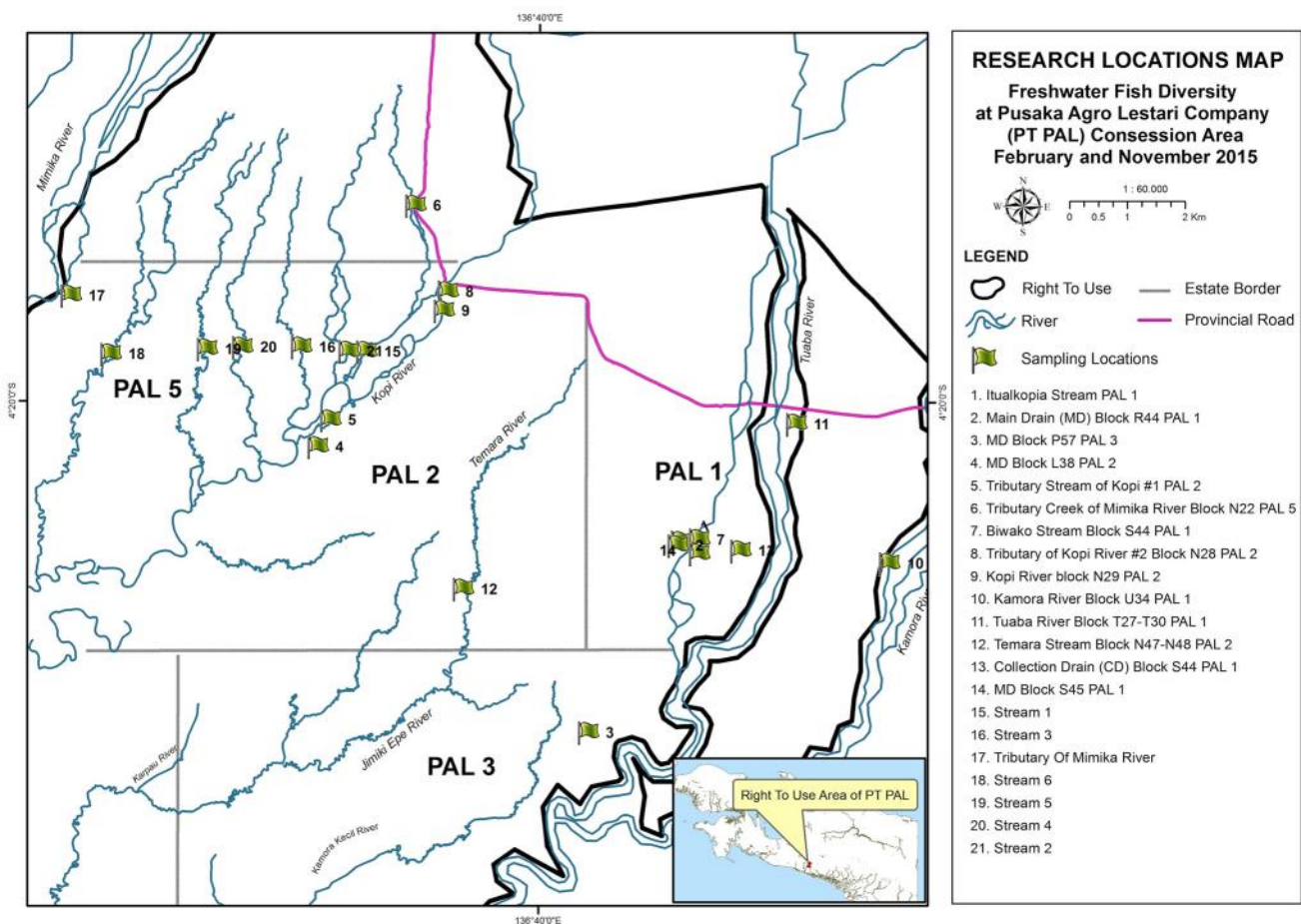


Figure 1. Sampling sites in at least three years old and newly open area plantation area in PT. PAL’s concession area, Mimika, Papua

Table 2. Fish collection/observation sites in PT. PAL’s concession areas

Location	Description
Site 1	Itualkopia Stream PAL 1; about 3.09 km SW of PT. PAL’s Base Camp; S 04° 21’ 19.1”, E 136° 41’ 17.6”; cleared 2 years ago; elevation about 60 m; a clear water stream (3-4 meters wide and 80 cm-2 meters deep); moderately fast flowing over sand and gravel, through open and closed canopy cover; dense wood debris and litter in bottom; 17.02.2015; seine net.
Site 2	Main Drain (MD) Block R44 PAL 1; about 3.5 km SW of PT. PAL’s Base Camp; S 40° 21’ 20.5”, E 136° 41’ 16.8”; cleared 2 years ago; elevation about 44 m; a warm and turbid pond over mud (1-1,5 m wide and about 50 cm deep); through open canopy cover; 17. 02.2015; seine net.

- Site 3 MD Block P57 PAL 3; about 6.78 km SW of PT. PAL's Base Camp; S 04° 23' 08.5", E 136° 40' 26.1"; cleared 1 year ago; elevation about 28 m; a stagnant turbid water canal over mud (around 1 m wide and 70 cm deep); dense of lichen; through open canopy cover; 17.02.2015; seine net.
- Site 4 MD Block L38, PAL 2; about 8.18 km W of PT. PAL's Base Camp; S 04° 20' 23.4", E 136° 37' 56.5"; cleared 1 year ago; elevation about 40 m; a slow clear water canal (about 1-2 m wide and 10 cm-1 m deep) with pools in some points over mud and gravel; dense of wood debris; lichen on gravel; through open canopy cover; 18.02.2015; seine net.
- Site 5 Tributary stream of Kopi River #1 PAL 2; about 8.10 km W of PT. PAL's Base Camp; S 04° 20' 15.3', E 136° 37' 58.9"; cleared 1 year ago; elevation about 59 m; a clear and slow flowing forest stream (about 2-5 m wide and at least 1 m deep) with more than 1 m pools over sand, gravel, rocks and boulders; wood debris and litter in bottom; through closed canopy cover; seine net, deep net and spear gun.
- Site 6 Tributary creek of Mimika River Block N22 PAL 5; about 7.35 km NW of PT. PAL's Base Camp; S 04° 28' 10.5", E 136° 38' 49.9"; newly cleared; elevation about 81 m; a clear slow flowing creek (about 1 m wide and <50 cm deep) over sand, gravel and rocks; water plants and lichen in the creek; through open canopy cover; 19.02.2015; seine net.
- Site 7 Biwako Stream Block S44 PAL 1; about 2.67 km SW of PT. PAL's Base Camp; S 04° 21' 11.0", E 136° 41' 29.8"; cleared 2 years ago; elevation about 81 m; a clear and moderately flowing stream (about 1-5 m wide and < 20 cm-4 m deep) with pond around 4 m over silt, sand, gravel and cobble; wood debris and litter in bottom; root of plants along the stream; through closed canopy cover; 19.02.2015; seine net.
- Site 8 Tributary of Kopi River #2 Block N28 PAL 2; about 6.3 km E of PT. PAL's Base Camp; S 04° 18' 58.99", E 136° 39"; cleared 1 year ago; elevation about 74 m; a clear and slow flowing tributary (about < 50 cm-3 m wide and < 50 cm-1,5 m deep) with some ponds over sand and gravel; dense of wood debris and litter in bottom; through open and closed canopy cover; 20.02.2015; seine net.
- Site 9 Kopi River Block N29 PAL 2; about 6.3 km E of PT. PAL's Base Camp; cleared 1 year ago; elevation about 74 meter; S 04° 18' 58.99", E 136° 39' 06.98"; a clear and moderate fast to very fast flowing river (about 10-50 m wide and less than 1 m deep) over gravel and cobble; through open canopy cover; 20.02.2015; seine net.
- Site 10 Kamora River Bloc U34 PAL 1; about 3.47 km arah SE of PT. PAL's Base Camp; S 04° 21' 31.9", E 136° 43' 27.4"; elevation about 81 meter; a clear and moderate fast to very fast flowing river (at least 100 m wide and 50 cm to at least 2 m deep) with some pools over sand, gravel and cobble; through closed canopy cover; 20.02.2015; seine net.
- Site 11 Tuaba River Block T27-T30 PAL 1; about 1.2 km S of PT. PAL's Base Camp; S 04° 20' 33.95, E 136° 42' 16.29"; cleared 2 years ago; elevation about 50 m; a clear water river (about 5-15 m wide and less than 1 m deep) over sand, gravel, cobble and boulder; through open canopy cover; 20.02.2015; seine net.
- Site 12 Temara Stream Block N47-N48 PAL 2; about 6.5 km E of PT. PAL's Base Camp; S 04° 21' 41.06", E 136° 39' 20.44"; cleared 1 year ago; elevation about 30 m; a moderate fast flowing steam stream (about 1-5 m wide and less than 1 m deep) over sand and gravel; dense pf wood debris; through open and closed canopy cover 21.02.2015; seine net.
- Site 13 Collection Drain (CD) Block S44 PAL 1; about 3.15 km SE of PT. PAL's Base Camp; S 04° 21' 20.7", E 136° 41' 16.4"; cleared 2 years ago; elevation about 51 m; a stagnant turbid water canal (about 1-3 m wide and to at least 1,5 m deep) over mud and sand; open canopy cover; 20.02.2015; seine net.
- Site 14 MD Block S45 PAL 1; about 3.02 km SW of PT. PAL's Base Camp; S 04° 21' 24.0", E 136° 41' 28.0"; cleared 2 years ago; elevation about 53 m; a clear and slow flowing pond and canal (about 1-3 m wide and 50-100 cm deep) over mud; dense wood debris and lichen on the rocks; through open canopy cover; 23.02.2015; seine net.
- Site 15 Stream 1; about 7.6 km W of PT. PAL's Base Camp; S 04° 19' 31.624", E 136° 38' 21.556"; newly cleared; elevation about 54.5 m; a clear water stream (1-8 meters wide and varied deep of water, at least 1 meter); moderate to fast flowing over gravel through open canopy cover; dense wood debris and litter in bottom in some spots; 3.11.2015; seine net.
- Site 16 Stream 3; about 8.8 km W of PT. PAL's Base Camp; 4° 19' 29.658" S; 136° 37' 44.762" E; newly cleared; elevation about 41.3 m; a clear, slower to moderate flowing water stream over gravel and mud in some spots (1-6 m wide and variety water deep, at least 1 meter, ponds in some spots); through closed canopy cover; dense wood debris and litter in bottom in some spots; 4.11.2015; seine net.
- Site 17 Tributary of Mimika River; about 12.8 km W of PT. PAL's Base Camp; 4° 19' 01.030" S; 136° 35' 35.497" E; newly cleared; elevation about 46.5 m; a stagnant to slow turbid water tributary over mud and gravel (1-5 m wide and less than 1 meter water deep); through relatively closed canopy cover; wood debris and litter in bottom; seine net.
- Site 18 Stream 6; about 12 km W of PT. PAL's Base Camp; 4° 19' 33.731" S; 136° 35' 57.849" E; newly cleared; elevation about 46.2 m; a clear water, slow to fast flowing stream (about 1-10 m wide and varied water deep, more than 1 meter) with some deep pools along the stream over gravel; wood debris and litter in some spots; through closed canopy cover; 5.11.2015; seine net, spear gun.
- Site 19 Stream 5; about 10.4 km W of PT. PAL's Base Camp; 4° 19' 30.832" S; 136° 36' 52.007" E; newly cleared; elevation about 52.3 m; a turbid and slow to moderate flowing forest stream (at least to 6 m wide and variety water deep with pools more than 1 meter deep) over sand, mud, gravel; dense wood debris and litter in bottom; through closed canopy cover; riparian vegetation was clearing along the streams, where some spots till close to the stream edge; 5.1.2015; seine net, spear gun.
- Site 20 Stream 4; about 7.9 km W of PT. PAL's Base Camp; 4° 19' 29.508" S; 136° 37' 11.627" E; newly cleared; elevation about 41.3 m; a turbid slow to moderate flowing stream (about at least 6 meter wide and 20-30 cm to more than 1 m water deep) over sand and gravel; through closed canopy cover; riparian vegetation was clearing along the stream and only 1-2 meters kept along the stream; 6.11.2015; seine net and spear gun.
- Site 21 Stream 2; about 6.3 km W of PT. PAL's Base Camp; S 4° 19' 32.754" S; 136° 38' 12.240" E; newly cleared; elevation about 58.1 m; a clear and moderate to fast flowing stream (about to 8 m wide and ± 50 cm to more than 1 m water deep) with some ponds over gravel and white sand in some spots; dense of wood debris and litter in bottom; through closed canopy cover; riparian vegetation was clearing along the stream and only 1-2 meters kept along the stream, some spots still has dense riparian vegetation till 100 meter of the edge of the stream; temperature 24.7°C, pH 7.2; 7.11.2015; seine net.

Fishes were mostly sampled with seine and hand nets, but in few locations, spear fishing was also used. A seine net with 3 m length, 1.23 m height and mesh size less than 1.25 cm was used. The seine net was used in shallow streams with 50-100 cm deep. The net was set up in U-shape by two people and dragged toward certain point, such as under tree roots or across a pond, or the net was put in the certain point location and 2-4 people try to chase fish toward the net. Fishes were identified according to Allen et al. (2000) and Allen (1991) and were preserved in 4% formaldehyde during the survey, and later were transferred to 70% ethanol and were stored in Conservation Department of PT. PAL in Mimika and Biology Department of Cenderawasih University in Jayapura, Papua. Fish diversity is descriptively compared to other freshwater ecosystem in New Guinea and potential threats in the area are discussed.

RESULTS AND DISCUSSION

Fish composition in PT. PAL's concession area

Twenty-two species from 15 families and 15 genera were recorded during the study. At least one species is endemic (*Glossamia timika*) of Timika region, in addition 19 native Papuan species and 2 exotic species were also captured (Table 1). *Glossamia timika* was very rare in the area, only five individuals were recorded from 4 locations: tributary of Mimika River (2 individuals); Bimako Stream (1 individual); tributary of Kopi River#1 (1 individual); and stream 1 at PAL 5 (1 individual). There is no single dominant species in the area. Rainbow fishes and gudgeons were represented by four and three species respectively, while other families were mostly represent by only one species (Table 1). Four unidentified species are common species to Papua, which are two pipefishes, a goby species and a rainbow fish. It needs to further identification to know the species, the distribution area and habitat of the species.

The number of species observed during this study is far less (22 species or 22.4%) than the recorded number of species from this areas (Table 3). Allen et al. (2000) studied this area and recorded 98 freshwater species including 4 endemic species. In addition, Allen et al. (2016) just described a new blue-eye species which is also endemic to this region, bringing the total of 5 endemic species. Thus, it seems likely that the number of species in the PAL concession area should be higher than what was recorded during this single survey. Clearly, the concession area provides important habitat for the survival of at least one of the 5 endemic species of Mimika.

Zoogeographic affinities of fish fauna of PT. PAL's concession area

Fishes in the Mimika region are part of the biogeographic of Southern New Guinea region which has fish fauna quite distinct from the Northern New Guinea region. For example, only *Oxyeleotris fimbriata* (Eleotridae) is broadly distributed on both sides of the Central Dividing Range. Endemic fish of this region is

Glossamia timika which is known only from Timika vicinity. Three other endemic fishes for this region, a gudgeon (*Oxyeleotris stagnicola*) and two Blue-eyes (*Pseudomugil ivantsoffi* and *P. pelucidus*), were not observed during field studies. Two of five known introduced species in this region which were come from Africa and South Asia are documented in the plantation area (Allen et al. 2000). Thirteen species (59%) recorded in this study are Southern New Guinean species, including two which also occur in northern Australia. Allen et al. (2000) recorded 35 fish species of Southern New Guinea which are also found in Northern Australia, because these areas used to have connections. An endemic and restricted Southern New Guinea species is Ogilby's Rainbowfish (*Melanotaenia ogilbyi*), which is distributed in the Timika region and the Lorentz River (Allen et al. 2000). This species is distributed abundantly in the Mimika area, especially in forest streams in PAL 5.

There are four rainbow fish species recorded in the area: *Melanotaenia* sp., *Melanotaenia ogilbyi*, *M. goldiei*, and *M. rubrostriatus*. Rainbow fishes (Melanotaeniidae family) are a secondary fish family-meaning that their ancestor comes from marine water-(Allen 1991) which are endemic to New Guinea and Australia. Due to the large number of species, rainbow fishes make a major contribution to the unique Papuan freshwater fish diversity and is an important key used to identify important areas for conservation (Polhemus et al. 2004). *Melanotaenia goldiei* and *M. rubrostriatus* have a wide distribution in Southern New Guinea, while *M. ogilbyi* is restricted to the Timika region and Lorentz River (Allen et al. 2000).

In comparison to some river systems in New Guinea, PT. PAL concession area has only one endemic species and fewer species overall (Table 4). However, this area is important for an endemic species *Glossamia timika*, a new species described in 2000 (Allen et al. 2000), which is only known in the vicinity of Timika. The Kopi and Mimika River systems, and other rivers closed to the systems in PT. PAL concession area are part of the range of *G. timika*. In addition, the area is also a home for the endemic Southern New Guinea Ogilby's Rainbowfish (*Melanotaenia ogilbyi*). It is abundantly distributed in most of streams and creeks, both in planted and forest's area of PT. PAL concession area. As well as, the region is home for *Pseudomugil luminatus*, a new described blue-eye species (Allen et al. 2016).

Threats and conservation

Oil palm plantations cause habitat degradation and species loss. Habitat degradation is the primary cause of extinction and endangerment globally. Deforestation due to oil palm expansions threatens to drive more species to extinction that did prior episodes of deforestation in countries such as the United States and United Kingdom (Koh and Wilcove 2012). Rubber, coffee, cocoa and palm oil have been affecting 294 species in Indonesia including *Panthera tigris*, the Sumatran serow, *Capricornis sumatraensis*, and Sir David's long beaked echidna, *Zaglossus attenboroughi* (Lenzen et al. 2008). In freshwater ecosystems, agriculture and land clearing have

Table 1. The fish fauna of PT. PAL's concession area, Mimika, Papua

Family/Common name/Species	Locations																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Endemic species																					
Apogonidae																					
Timika Mouth Almighty																					
<i>Glossamia timika</i>					R	R	R								R						
Native species																					
Ambassidae																					
Sailfin Glassfish Perchlet																					
<i>Ambassis agrammus</i>	O	O	O			O						O	O		R						
Ariidae																					
Salmon Catfish																					
<i>Neoarius leptaspis</i>					R														R		
Atherinidae																					
Kubuna Hardyhead																					
<i>Craterocephalus randi</i>	O		O	O	O		O		O						F	O				R	R
Eleotridae																					
Banded Mogurnda																					
<i>Mogurnda cingulata</i>						R	R		R		R			x							
Fimbriate Gudgeon																					
<i>Oxyeleotris fimbriata</i>					R						R										
Giant Gudgeon																					
<i>O. selheimi</i>										R											
Gobiidae																					
Concave Goby																					
<i>Glossogobius concavifrons</i>					O										R	R	R				
Unidentified Goby species						R															
Hemiramphidae																					
Fly River Garfish																					
<i>Zenarchopterus novaeguineae</i>					O										O	R			R	O	
Melanotaenidae																					
<i>Melanotaenia</i> sp.	O	O		O	O	O	O	O								R					
Goldie River Rainbowfish																					
<i>Melanotaenia goldiei</i>															O						
Ogilby's Rainbowfish																					
<i>Melanotaenia ogilbyi</i>	O		O	O	O	O			O					O	D	D	D	D	D	D	D
Red-Striped Rainbowfish																					
<i>Melanotaenia splendida rubrostriata</i>						O	O						O	O			R				
Mugilidae																					
Greenback Mullet																					
<i>Chelon subviridis</i>									O												
Plotosidae																					
Papuan eel Catfish																					
<i>Plotosus papuensis</i>									R												
Soleidae																					
Tailed Sole																					
<i>Leptachirus klunzingeri</i>																	R				
Syngnathidae																					
Pipefish 1								R													
Pipefish 2								R													
Terapontidae																					
Mountain Grunter																					
<i>Hephaestus habbemai</i>					O	O	O		O	O				O		O	O				O
Introduced species																					
Cichlidae																					
Mozambique Tilapia																					
<i>Oreochromis mossambicus</i>						O			O		O										
Channidae																					
Striped Snakehead																					
<i>Channa striata</i>						R							R								

Note: A = Abundant: very common in area; D = Dominant: the most common species in the area; F = Frequent : many per site, even more than 100; O = Occasionally: 5-30 per site; R = Rare: 3 or fewer per site.

Table 3. Fish community in Timika region, Papua, Indonesia

Family	Common Name	Species	Allen et al. (2000)	This study
Endemic and native species				
Ambassidae-Glassfishes	Sailfin Glassfish	<i>Ambassis agrammus</i>	x	x
	Giant Glassfish	<i>Parambassis gulliveri</i>	x	
Anguillidae-Freshwater Eels	Indonesian Shortfin Eel	<i>Anguilla bicolor</i>	x	
	Speckled Longfin Eel	<i>A. reinhardtii</i>	x	
Apogonidae-Mouth Almighties	Mouth Almighty	<i>Glossamia aprion</i>	x	
	Sande's Mouth Almighty	<i>G. sandei</i>	x	
	Timika Mouth Almighty	<i>G. timika*</i>	x	x
Ariidae-Fork Tailed Catfishes	Daniel's Catfish	<i>Cochlefelis danielsi</i>	x	
	Blue Salmon Catfish	<i>Neoarius graeffei</i>	x	
	Broad-Snouted Catfish	<i>N. latirostris</i>	x	
	Salmon Catfish	<i>N. leptaspis</i>	x	x
	Sharp-nosed Catfish	<i>Potamosilurus macrorhynchus</i>	x	
	Duckbilled Catfish	<i>Cochlefelis spatula</i>	x	
	Taylor's Catfish	<i>Cathorops taylori</i>	x	
	Giant Catfish	<i>Arius</i> sp.	x	
	Comb-Spined Catfish	<i>Cinetodus carinatus</i>	x	
	Thick-Lipped Catfish	<i>C. crassilabris</i>	x	
	Smallmouthed Salmon Catfish	<i>C. froggatti</i>	x	
	Spoon-Snouted Catfish	<i>Nedystoma novaeguineae</i>	x	
	Day's Catfish	<i>N. dayi</i>	x	
	Lorentz Catfish	<i>Cinetodus conorhynchus</i>	x	
Atherinidae-Hardyheads	Mountain Hardyhead	<i>Craterocephalus nouhuysi</i>	x	
	Kubuna Hardyhead	<i>C. randi</i>	x	x
Belonidae-Longtoms	Long tom	<i>Strongylura krefftii</i>	x	
Centropomidae-Giant Perches	Baramundi	<i>Lates calcarifer</i>	x	
Clupeidae-Herrings	Papuan river sprat	<i>Clupeoides papuensis</i>	x	
	West Irian River Sprat	<i>C. venulosus</i>	x	
	Yamur Bony Bream	<i>Nematalosa</i> sp.	x	
Cynoglossidae-Tongue Soles	Freshwater Tongue Sole	<i>Cynoglossus heterolepis</i>	x	
Engraulididae-Achovies	New Guinea Thryssa	<i>Thryssa scratchleyi</i>	x	
Eleotridae-Gudgeons	Striped-Cheek Gudgeon	<i>Bostrychus strigogenys</i>	x	
	Barred Gudgeon	<i>B. zonatus</i>	x	
	Greenback Gudgeon	<i>Bunaka gyrinoides</i>	x	
	Olive Flathead-Gudgeon	<i>Butis amboinensis</i>	x	
	Duckbill Sleeper	<i>B. butis</i>	x	
	Snakehead Gudgeon	<i>Giuris margaritacea</i>	x	
	Empire Gudgeon	<i>Hypseleotris compressa</i>	x	
	Banded Mogurnda	<i>Mogurnda cingulata</i>	x	x
	Aru Gudgeon	<i>Oxyeleotris aruensis</i>	x	
	Fimbriate Gudgeon	<i>O. fimbriata</i>	x	x
	Poreless Gudgeon	<i>O. nullipora</i>	x	
	Fewpored Gudgeon	<i>O. paucipora</i>	x	
	Giant Gauvina	<i>O. selheimi</i>	x	x
	Swamp Gudgeon	<i>O. stagnicola*</i>	x	
	Paniai Gudgeon	<i>O. wisselensis</i>	x	
	Gobiidae-Gobies	Golden tank Goby	<i>Glossogobius aureus</i>	x
Concave Goby		<i>G. concavifrons</i>	x	x
Tank Goby		<i>G. giuris</i>	x	
Munro's Goby		<i>Glossogobius</i> sp. 1	x	
Dwarf Goby		<i>Glossogobius</i> sp. 2	x	
False Celebes Goby		<i>Glossogobius</i> sp. 3	x	
Barred Mudskipper		<i>Periophthalmus argentilineatus</i>	x	
New Guinea Mudskipper		<i>P. novaeguineensis</i>	x	
Spotfin Goby		<i>Redigobius chrysosoma</i>	x	
Marbled Goby		<i>Schismatogobius marmoratus</i>	x	
Barcheek Goby		<i>Stenogobius psilosinionus</i>	x	
	unidentified goby species			x
Hemiramphidae-Garfishes	Long-Jawed River Garfish	<i>Zenarchopterus caudovittatus</i>	x	
	Fly River Garfish	<i>Z. novaeguineae</i>	x	x
Kurtidae-Nurseryfishes	Nurseryfish	<i>Kurtus gulliveri</i>	x	
Megalopidae-Tarpons	Indo-Pacific Tarpon	<i>Megalops cyprinoides</i>	x	
Melanotaeniidae-Rainbowfishes	Threadfin Rainbowfish	<i>Iriatherina wernerii</i>	x	

	Goldie River Rainbowfish	<i>Melanotaenia goldiei</i>	x	x
	Ogilby's Rainbowfish	<i>M. ogilbyi</i>	x	x
	Red-Striped Rainbowfish	<i>M. splendida rubrostriata</i>	x	x
	-	<i>Melanotaenia</i> sp.		x
Mugilidae-Mullet	Greenback Mullet	<i>Chelon subviridis</i>	x	x
Osteoglossidae-Bony Tongues	Australian Bonytongue	<i>Scleropages jardini</i>	x	
Plotosidae-Eel-Tailed Catfishes	Narrowfront Tandan	<i>Neosilurus ater</i>	x	
	Shortfin Tandan	<i>N. brevidorsalis</i>	x	
	Southern Tandan	<i>N. equinus</i>	x	
	Maria's Tandan	<i>Oloplotosus mariae</i>	x	
	Papuan Eel Catfish	<i>Plotosus papuensis</i>	x	x
	Merauke Tandan	<i>Porochilus meraukensis</i>	x	
	Obbe's tcatfish	<i>P. obbesi</i>	x	
Pseudomugilidae-Blue-eyes	Inconspicuous Blue-eye	<i>Pseudomugil inconspicuus</i>	x	
	Ivantsoff's Blue-eye	<i>P. ivantsoffi*</i>	x	
	New Guinea Blue-eye	<i>P. novaeguineae</i>	x	
	Swamp Blue-eye	<i>P. paludicola</i>	x	
	Red Neon Blue-eye	<i>P. luminatus*</i>	x	
	Transparent Blue-eye	<i>P. pellucidus*</i>	x	
Soleidae-Soles	Tailed Sole	<i>Leptachirus klunzingeri</i>	x	x
	Velvety Sole	<i>Brachirus villosus</i>	x	
Sparidae-Breams	Goldsilke sea bream	<i>Acanthopagrus berda</i>	x	
Sciaenidae-Croakers	Scale Croaker	<i>Nibea squamosa</i>	x	
Synbranchidae-Swamp Eels	Bengal Eel	<i>Ophisternon bengalense</i>	x	
Syngnathidae-Pipefishes	Belly Pipefish	<i>Hippichthys heptagonus</i>	x	
	Short-Tailed Pipefish	<i>Microphis brachyurus</i>	x	
	Barhead Pipefish	<i>M. leiaspis</i>	x	
	unidentified pipefish 1	-		x
	unidentified pipefish 2	-		x
Terapontidae-Grunters	Mountain Grunter	<i>Hephaestus habbemai</i>	x	x
	Röemer's Grunter	<i>H. roemeri</i>	x	
	Lorentz's Grunter	<i>Pingalla lorentzi</i>	x	
	Jamur Lake Grunter	<i>Variichthys jamoerensis</i>	x	
Toxotidae-Archerfishes	Spotted Archerfish	<i>Toxotes chatareus</i>	x	
Introduced species				
Clariidae-Air Breathing Catfishes	Philippine Catfish	<i>Clarias batrachus</i>	x	
Aplocheilidae-Killifishes	Blue Panchax	<i>Aplocheilus panchax</i>	x	
Cichlidae-Cichlids	Mozambique Tilapia	<i>Oreochromis mossambicus</i>	x	x
Anabantidae-Climbing Gouramies	Climbing Perch	<i>Anabas testudineus</i>	x	
Channidae-Snakeheads	Striped Snakehead	<i>Channa striata</i>	x	x

Note: * endemic species

Table 4. Comparison of fish faunas of various river systems in New Guinea

River system	Total species (excluding introductions)	Endemic species	Percent endemics
Fly, PNG*	103	5	4.8
Kikori, PNG*	100	14	14.0
Aikwa/Iwaka, Papua*	75	2	2.7
Lorentz, Papua*	60	2	3.3
Purari, PNG*	57	6	10.5
Sepik, PNG*	53	3	5.7
Ramu, PNG*	50	2	4.0
Wapoga, Papua*	46	3	6.5
Digul, Papua*	40	0	-
Mamberamo, Papua*	28	6	21.4
Gogol, PNG*	25	0	-
Lakekamu, PNG*	22	1	4.5
PT. PAL Concession Area, Mimika (this study)	20	1	5

Note: *) Allen et al. (2002)

increased sedimentation in wetlands and streams, which in turn leads to an overall loss of these aquatic habitats (Groom et al. 2006). Plantation Service of Papua Province reported 24 large plantations companies in 8 regencies in Papua Province in 2015 with total 477,462.10 ha. Frazier (2007) also documented data of plantations service of Papua and a researcher which showed large size of land reserved for oil palm plantations in Papua, which is 6,115,443 ha in 1999 and 2.8 million in 2003 in only 8 regencies of Papua. There is still possibility to extend oil palm plantation in Papua and to continually increase potential threats to habitats and species. As a result, species extinction especially in freshwater habitats will be difficult to prevent in plantation areas without strong conservation actions. Loss of riparian vegetation along streams and tributaries, the introduction of exotic species and the use of poisons are main threats in PT. PAL's concession area. During the survey in a newly opened area of the company concession, we recorded extensive land clearing along streams, which increases water turbidity and sedimentation,

changes stream discharge and increases water temperature. An additional threat comes from fertilizer and pesticides use in the plantation where it can flow into freshwater systems. This, in turn, will increase nutrients and lead to eutrophication with subsequent reductions of dissolved oxygen in the water. Forest conversion is the main threat not only for aquatic inhabitants, but to all species, as it has been suggested that 80-100% of mammal, reptile and bird species are lost when palm plantations are established on primary forest (Frazier 2007). Deforestation for oil palm resulted in erosion and increased water turbidity in Arang-arang Lake in Muaro Jambi, Sumatera (Asra 2009). Water turbidity decreases light penetration into the lake, which reduces photosynthesis and, thus, phytoplankton growth. Phytoplankton is the primer producer in the lake and very important for aquatic biota such as benthic invertebrates and fishes. Fertilizers and pesticides used in the plantation resulted in water pollution of the lake (Asra 2009). Koh and Wilcove (2012) stated that a prohibition on the conversion of primary or secondary forests to oil palm is urgently needed to take care of tropical biodiversity. Until that happens, oil palm might well be the single most immediate threat to almost all number of species.

The best conservation effort to protect endemic and native fishes is natural habitat protection. Therefore, threats to endemic and native fishes by deforestation and plantation should be minimized to decrease negative impacts. It is recommended that over clearing riparian vegetation, excessive fertilizer use, and fishing with poison should be better managed to conserve diversity of freshwater fishes. For instance, most of the impact from plantations would be eliminated if riparian vegetation buffer zones along any water body were at least 200 m wide from the water body edge. In addition, plantations should limit fertilizer use or use more environmental friendly fertilizers as well as developing waste management systems to control fertilizer loss from of the plantation to prevent them entering water courses. If these conservation efforts were enacted, then plantations would be able to support good habitat for the fishes, which needs clear, clean and fresh water environment.

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