Distribution and abundance of the arfak rainbowfish, Melanotaenia arfakensis Allen, 1990 in Prafi River system, Manokwari, West Papua: due to habitat degradation?

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Distribution and abundance of the arfak rainbowfish, *Melanotaenia arfakensis* Allen, 1990 in Prafi River system, Manokwari, West Papua: due to habitat degradation?

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Abstract. Arfak rainbowfish, *Melanotaenia arfakensis*, is one of the freshwater endemic fish in Manokwari, West Papua. The presence of the Arfak rainbowfish is currently experiencing many disturbances related to anthropogenic activities. This research, therefore, was conducted to describe habitat condition, distribution and abundance of the Arfak rainbowfish in the Prafi River system spatially. This study was conducted for 12 months on 12 sites in Nimbai and Aimasi Streams, the Prafi River system. The results showed that this species was mainly distributed in the upper reaches of the Nimbai and the Aimasi streams based on the frequency of occurrence (>90.9%) and relative abundance (≥25.5%). The lower fish occurrence and abundance was found at site of the sewerage and downstream. The highest value of the habitat utilization overlap index between Arfak rainbowfish and alien fish species was found in lower reaches. Decreasing habitat quality in lower reaches of the river causes limited distribution and decline in abundance of this species. To conserve this endemic fish population, it is necessary to maintain habitat condition in the upstream area and restore the damaged habitat in lower reaches of the Prafi River system.

Keywords: alien species, habitat degradation, habitat restoration, *Melanotaenia arfakensis*

1. Introduction

The river system facing a lot of disturbance by various anthropogenic activities which causes a decline in the habitat conditions of fish fauna that inhabit it. Various anthropogenic activities that have impact on river water conditions have been widely reported, for example with regard to the clearing of forest areas, including conversion of riparian zones on river banks, for plantations and agriculture (Mercer *et*

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al 2013, Mori *et al* 2015, dos Santos *et al* 2015, Lorion and Kennedy 2009, Lobón-Cerviá *et al* 2016), road infrastructure construction (Wang *et al* 2013) and dams (Mason 1991, Gehrke *et al* 1995, Neraas and Spruell 2001, Sá-Oliveira *et al* 2015), as well as mining activities (Mol and Ouboter 2004, Batsaikhan *et al* 2017). Various forms of changes in river systems such as increased turbidity of water due to input of suspended particles into river systems (Growns and Davis 1994, Sutherland *et al* 2002, dos Santos *et al* 2015), increased temperature as a form of reduced canopy cover at the edges of river (Lynch *et al* 1984, Rambo and North 2009). In addition, palm oil processing wastes that contain a lot of organic matter and suspended solids (Ma 2000) and dumped into river systems without management mechanisms will have a negative impact on river ecosystems, including fish communities (Devita and Tarumun 2012, Madaki and Seng 2013), among them the pH concentration decreases and the dissolved oxygen concentration becomes low even to anoxic conditions. The introduction of various alien fish species into river systems also adds pressure to native fish, with the interaction of food competition and predation on native fish (Allen 1991, Polhemus *et al* 2004). Decreasing habitat condition will disrupt fish physiology processes and also reduces fish ability to find food effectively (Sweka and Hartman 2003, Sutherland and Meyer 2007, Zamor and Grossman 2007). Furthermore, this condition will reduce the growth rate of fish (Sigler *et al* 1984, Northcote 1995), fish abundance and distribution (Berkman and Rabeni 1987, Rowe *et al* 2000, Mol and Ouboter 2004).

The Nimbai and Aimasi Streams are part of the Prafi River system, Manokwari, which are located in the northeastern part of the Vogelkop Peninsular (Bird's Head). As reported by Allen (1990, 1991) and Manangkalangi *et al* (2014), there is one endemic species in the Prafi River system, namely Arfak rainbowfish, *M. arfakensis* and 10 native fish species (Manangkalangi *et al* 2014). It is worried that various anthropogenic activities around the river system will lead to declining of river system condition for endemic and native fish, as indicated by Manangkalangi *et al* (2014) and have an impact on spatial distribution and fish abundance. This research, therefore, was conducted to describe habitat quality, distribution and abundance of Arfak rainbowfish in the Prafi River system spatially.

2. Materials and methods

2.1. Study sites
This study was carried out in two streams in the Prafi River system, namely Nimbai Stream and Aimasi Stream (figure 1 and table 1) covering twelve sites which located between 2nd order to 4th order (ritral) (Allen 1990, Manangkalangi *et al* 2009a, Manangkalangi *et al* 2014, Lefaan *et al* 2019). Fish sampling and measurement of water quality parameters were carried out monthly from May 2016 to April 2017. Analysis of fish samples was carried out at the Fisheries Laboratory, Faculty of Fisheries and Marine Sciences, University of Papua.

In the study sites, four habitat types were determined for sampling Arfak rainbowfish, native and alien fish species and aquatic environmental parameters (except for S5-S7 with small water bodies and slow flow conditions). The four habitat types including slow littoral, medium littoral, pool, and run areas (Copp 1992, Hawkins *et al* 1993).

### 2.2. Collection and identification of fish samples
The collection of fish samples was carried out on each habitat type using a combination of electric shock and hand net (net mesh size of 1 mm). Fish samples were then identified by combination based on morphological and genetic characters (COI gene markers). Morphological identification of all fishes was carried out with reference refers to Allen (1990, 1991), Kotellat *et al* (1993), Rainboth (1996), Robert (1989), Allen *et al* (2000), Pusey *et al* (2004), Kadarusman *et al* (2010), and Keith *et al* (2011, 2012, 2017). Several specimens were selected for tissue sampling.

A total of 41 tissue samples were collected. Examples of tissue obtained are then preserved with 96% ethanol and then used in the DNA extraction process. The DNA extraction was carried out at Genetic Laboratory, Faculty of Fisheries and Marine Sciences, Papua University. DNA extraction using the Mini Kit Promega Cat No. Genomic DNA extraction kit GT050. Molecular analysis was performed using primer forward Fish BCL (5'TCAACYAAT CAYAAAGATATGGCAC3') and primary reverse fish - BCH (5'ACTTCYGGGTGRCC-RAARAATCA') (Weight *et al* 2011). The PCR reaction was carried out in a volume of 50 μL, using a DNA template of 2 μL. Each reaction contained 1 μL DMSO, 2.5 μL each primer (10 mM), 25 μL Go Tag Green and 17 μL ddH2O.

The PCR reaction includes initial denaturation at 94°C for 15 seconds, denaturation at 94°C for 30 seconds, annealing at 50°C for 30 seconds, extension at 72°C for 45 seconds, and final 72°C for 5 minutes and this process occurs as many as 40 cycles. The PCR results were then electrophoretic to visualize PCR results. The positive amplified PCR results were sending and then sequenced by 1stBASE Malaysia to obtain a sequence of base pairs of nucleotide sequences.

2.3. Measurement of water quality parameters

In each habitat type, water quality measurements were taken with three replications. Water quality parameters were measured such as water temperature using a thermometer, turbidity with HI 93703 microprocessor turbidity meter, electrical conductivity (DHL) with HI98130, dissolved oxygen (DO) with Lutron DO-5510, total alkalinity by titration using HI3812 test kit HI-775, and pH with a HI98127 pH meter. The water velocity was measured using basic handheld stream flow meter Ward's.
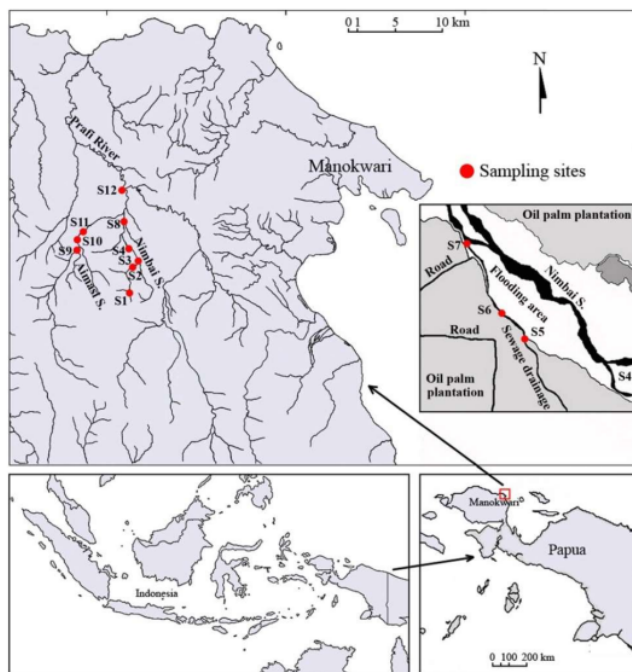
Figure 1. Map of study sites on the Nimbai and Aimasi Streams, Prafi River system, West Papua Province, Indonesia.

Table 1. Description of each research location.

Site	Remark	Coordinate	Altitude (m)*
S1[c,d]	Type of primary riparian vegetation (a segment of Nimbai Stream, 2nd order)	E 133°51'04.6" S 00°56'52.4"	195
S2[c,d]	Type of secondary riparian vegetation (segment of Nimbai Stream, 2nd order)	E 133°51'46.9" S 00°56'13.9"	125
S3[c,d]	Type of secondary riparian vegetation and near the settlement (a segment of Nimbai Stream, 2nd order)	E 133°51'47.8" S 00°56'00.8"	117
S4[c,d]	Palm oil plantation area (Nimbai Stream segment, 3rd order)	E 133°51'24.1" S 00°55'31.2"	103
S5[c]	Sewage drainage of palm oil processing (palm oil mill effluent, POME) to the Nimbai S.	E 133°51'19.5" S 00°55'30.4"	101
S6[c]	Sewage drainage of palm oil processing (palm oil mill effluent, POME) to the Nimbai S.	E 133°51'16.6" S 00°55'28.5"	101
S7[c]	Sewage drainage of palm oil processing (palm oil mill effluent, POME) to the Nimbai S.	E 133°51'13.2" S 00°55'22.7"	99
S8[c,d]	Palm oil plantation area and near the settlement (Nimbai Stream segment, 3rd order)	E 133°50'59.5" S 00°54'03.7"	74
S9[b]	Type of primary riparian vegetation (Aimasi Stream segment, 2nd order)	E 133°48'25.3" S 00°55'31.8"	173
S10[b]	Near the palm oil plantation area at upstream weir for irrigation (Aimasi S. segment, 3rd order)	E 133°48'28.2" S 00°55'18.8"	161
S11[b]	Near the palm oil plantation area at downstream weir for irrigation (Aimasi S. segment, 3rd order)	E 133°48'20.8" S 00°55'00.0"	154
S12[a,c,d]	Type of open riparian vegetation and near type locality of this species (Prafi River segment, 4th order)	E 133°50'52.1" S 00°52'04.0"	57

[a]Allen (1990), [b]Manangkalangi *et al* (2009a), [c]Manangkalangi *et al* (2014), [d]Lefaan *et al* (2019), * = above sea level

2.4. Data analysis
2.4.1. Identify fish samples. The sequencing results obtained were then edited and analyzed using the MEGA 6.06 (Molecular Evolutionary Genetics Analysis) application (Tamura *et al* 2011). The data was edited using Clustal W in the program to see diversity of nucleotide bases (Tamura *et al* 2011). DNA sequence analysis to determine the type was carried out with the Basic Local Alignment Search Tool (BLAST) at the National Center for Biotechnology Information (NCBI), the National Institute for Health, USA.

2.4.2. Frequency of occurrence and relative abundance. The frequency of occurrence at each site was calculated based on the presence of a species during the study period in a location (ranging between four and 12 observations). While the abundance of each species in all sites was calculated based on the individual proportion of a species, namely the number of individuals each type divided by the total individuals of all species. In this study, it is more specialized in the proportion of Arfak rainbowfish and all alien fish.

2.4.3. Overlapping index of habitat type utilization. The level of overlap of habitat utilization between Arfak rainbowfish and alien fish species was analyzed using the Morisita index (Smith and Zaret 1982, Krebs 1989), according to the formula:

$$C = \frac{2 \sum p_{ij} p_{ik}}{\sum^{n} p_{ij}[(n_{ij}-1)/(N_j-1)] + \sum^{n} p_{ik}[(n_{ik}-1)/(N_k-1)]} \qquad (1)$$

with C = Morisita index of overlapping niches between species j, and species k, p_{ij} = proportion of resource i is total resource utilized by species j, p_{ik} = proportion of resource i is the total resources utilized by species k, n_{ij} = the number of individuals from the species j that utilize the i-group resources, n_{ik} = the number of individuals from the k species that utilize the i-group resources, and N_j, N_k = the total number of individuals in each species in the example ($\sum n_{ij} = N_j$ and $\sum n_{ik} = N_k$).

2.4.4. Principle Component Analysis (PCA). To determine habitat characteristics between study sites and correlation of the Arfak rainbowfish with its habitat characteristics, the main component analysis was used (Bengen 2000). This analysis is used to display data in graphical form and the maximum information contained in a data matrix. The data matrix in this study consisted of 12 sites, 4-12 measurement times, and 8 physicochemical parameters of the waters. PCA using XLSTAT software on Microsoft Excel 2010.

3. Results and discussion

3.1. Composition of fish species

A total of 24 fish species from 23 genera and 17 families were collected during the study period (table 2). One endemic species was found namely Arfak rainbowfish (*M. arfakensis*) and as many as 15 other fish species belong to the native fish group, and the rest (8 species) belongs to the alien fish group.

Table 2. Composition of fish species at the study site.

No.	Taxa		Status
	Family	Species	
1.	Melanotaeniidae	*Melanotaenia arfakensis*	Endemic
2.	Ambassidae	*Ambassis* sp.	Native
3.	Anguillidae	*Anguilla marmorata*	Native
4.	Eleotridae	*Eleotris fusca*	Native
5.	Eleotridae	*Belobranchus segura*	Native
6.	Eleotridae	*Bunaka gyrinoides*	Native
7.	Eleotridae	*Hypseleotris* sp.[a]	Native
8.	Gobiidae	*Stiphodon semoni*	Native
9.	Gobiidae	*Sicyopterus cynocephalus*	Native
10.	Gobiidae	*Schismatogobius* sp.	Native
11.	Gobiidae	*Awaous ocellaris*[a]	Native
12.	Gobiidae	*Awaous grammepomus*	Native
13.	Kuhliidae	*Kuhlia marginata*	Native
14.	Mugilidae	*Cheilon melinopterus*	Native
15.	Rhyachthidae	*Rhyacichthys guilberti*	Native
16.	Syngnathidae	*Microphis* sp.	Native
17.	Anabantidae	*Anabas testudineus*	Alien
18.	Aplocheilidae	*Aplocheilus panchax*	Alien
19.	Channidae	*Channa striata*	Alien
20.	Cichlidae	*Oreochromis niloticus*	Alien
21.	Clariidae	*Clarias batrachus*	Alien
22.	Cyprinidae	*Barbodes binotatus*	Alien
23.	Poecillidae	*Gambusia affinis*	Alien
24.	Synbranchidae	*Monopterus albus*	Alien

The existence of an endemic species, *M. arfakensis* Allen (1990) at several locations in the Prafi River system has been genetically confirmed using COI gene markers. Also, some native fish species found in this study are the latest information compared to the results of previous studies in the same location (Manangkalangi *et al* 2014), namely *Awaous ocellaris*, *Eleotris fusca*, *Bunaka gyrinoides*, *Rhyacichthys guilberti*, *Chelon melinopterus*, *Anguilla marmorata*. For *R. guilberti*. Results of this study indicate the renewal of location information. Specifically, we discovered two genera which their identity could not be ascertained to the species level, namely *Schismatogobius* sp. and *Hypseleotris* sp.

The identification results also prove the existence of alien species in the Prafi river system, including *A. testudineus*, *A. panchax*, *C. striata*, *O. niloticus*, *C. batrachus*, *B. binotatus*, *G. affinis*, and *M. albus*. In addition to the eight alien fish species found in this study, based on the results of the study of Manangkalangi *et al* (2014) also found two other species (*O. mossambicus* and *C. gariepinus*), therefore there are ten alien species in the Prafi river system. The presence of alien species in the Prafi River system is thought to be related to anthropogenic activity such as cultivation to meet protein requirements in relation to transmigration programs (Polhemus *et al* 2004). Meanwhile *G. affinis* and *A. panchax* have been introduced as bio-controls for malaria mosquitoes since the 1930s (Allen 1991) and the 1990s (Allen *et al* 2000), respectively.

3.2. Interaction of Arfak rainbowfish, native fish, and alien fish

3.2.1. Distribution and frequency of occurrence. Information on distribution and frequency of occurrence of Arfak rainbowfish, native fish, and alien fish were shown in table 3. Although Arfak rainbowfish can be found in all research sites, it was mainly found in the upstream of Nimbai (S1-S4) and Aimasi Streams (S9-S11) with frequency of occurrence more than 90.9%. The lowest frequency of occurrence of endemic species (8.3-66.7%) was found at the sites of the POME sewerage (S5-S7) and downstream (S8 and S12). The presence of rainbowfish in several disturbing sites is thought to be physically transported from the upstream after rain occurred. In the native fish group, the distribution covers almost all study sites, except for sites in the POME waste drainage channel (S5-S6). At site S7, two native fish species (*S. cynocephalus* and *R. gulberti*) were found with a low frequency of occurrence (≤8.3%). The group of alien fish was generally found at the sites of the POME sewerage (S5-S7) and in the downstream sites (S8 and S12). In addition to these sites, three species of alien fish (*B. binotatus*, *O. niloticus*, and *A. panchax*) spread to sites in upper reaches of Nimbai and Aimasi S.

3.2.2. Relative abundance. The relative abundance of three fish groups in Nimbai Stream and Aimasi Stream are presented in table 4. In Arfak rainbowfish, higher relative abundance averages were found in upstream sites in both streams (S1-S4 and S9-S11), which was ≥ 25.5%. In the downstream sites and drainage of POME, this endemic fish was found with relatively low abundance (≤4.9%). The relative abundance of native fish was relatively same between upstream and downstream sites (i.e. with an average value ranging from 16.4-39.0%), except in sewerage that was found to be lower (≤0.8%). Different relative abundance patterns were shown by the alien fish group. This group was generally found abundantly at sites in the sewerage and downstream (on average 60.9-99.8%) and lower in locations at the upstream section (≤49.9%).

Plotting of relative abundance of Arfak rainbowfish on alien fish species in each location during the study period (4-12 times sampling) is shown in figure 2. This result indicates that the relative abundance of Arfak rainbowfish was inversely proportional to the abundance of alien fish. Arfak rainbowfish was mainly found with high abundance at upstream sites. Therefore, the interactions that occur were mainly related to several alien fish species that have a wide distribution and relatively high abundance, namely *B. binotatus*, *O. niloticus*, and *A. panchax*. A wide distribution of *B. binotatus* and *O. niloticus* from upstream to downstream and high abundance is also reported in the Opak River, Yogyakarta (Djumanto *et al* 2013).

3.2.3. Use of habitat types. Calculation of the overlapping index of utilization habitat types in the Nimbai Stream (S1-S4) and in the Aimasi Stream (S9-S11) between Arfak rainbowfish and alien fish are shown in table 5. Based on site, overlapping index values tended to higher at downstream. In terms of species, there was a high overlapping index in utilizing large habitat types of *M. arfakensis* and *B. binotatus* in all study sites. At downstream sites, more overlapping utilization of habitat types was found between Arfak rainbowfish and alien fish species.

High overlap of habitat types utilization in the lower reaches occurred between Arfak rainbowfish and alien fish. Besides being related to habitat, this finding shows the potential for competition related to the utilization of food and reproduction resources. For example, Manangkalangi and Kaliele (2011) found a high level of similarity in food composition (62.80-94.85%) between *M. arfakensis* and *G. affinis* in Nimbai S. Likewise, King (2004) reports that the same ontogeny and reproduction time strategies in *Melanotaenia fluviatilis* and *Gambusia holbrooki* in the Broken River, Australia. Aggressive and territorial characteristics of alien fish (for example, *O. mossambicus* and *O. niloticus*) during reproduction can interfere with successful spawning of *M. splendida* (Doupe *et al* 2009). Various interactions with these alien fishes were expected to affect the distribution and abundance of Arfak rainbowfish, especially in downstream of both streams.
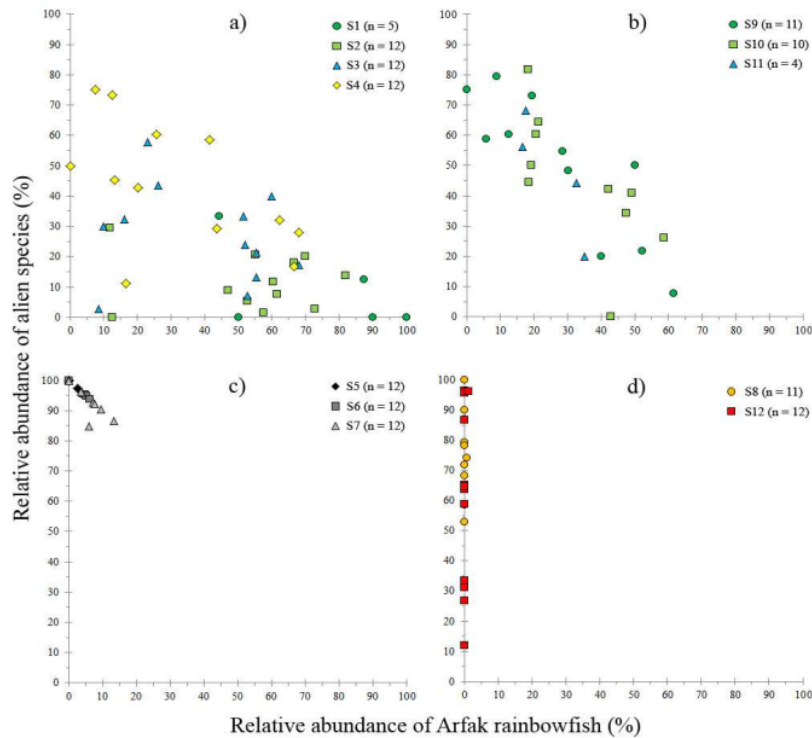

Figure 2. The relative abundance of Arfak rainbowfish and alien fish in the study sites. a) upstream of Nimbai S. (S1-S4), b) upstream of Aimasi S. (S9-S11), c) sewerage for POME waste to Nimbai S. (S5-S7) and d) downstream (S8 and S12).

Table 3. Distribution and frequency of occurrence (%) of fish species based on the study sites.

No	Species	Site												Range of occurrence frequency
		Nimbai S. (upstream → downstream)								downstream	Aimasi S. (downstream ← upstream)			
		S1	S2	S3	S4	S5	S6	S7	S8	S12	S11	S10	S9	
	Endemic fish													
1.	M. arfakensis	100	100	100	91.7	8.3	25.0	66.7	9.1	8.3	100	100	90.9	8.3-100.0
	Native fish													
2.	Ambassis sp.	-	-	-	-	-	-	-	-	8.3	-	-	-	0.0-8.3
3.	A. marmorata	-	16.7	8.3	25.0	-	-	-	-	8.3	25.0	20.0	-	0.0-25.0
4.	E. fusca	20.0	8.3	8.3	41.7	-	-	-	72.7	75.0	-	-	54.5	0.0-75.0
5.	B. segura	-	83.3	66.7	50.0	-	-	-	54.5	33.3	100.0	80.0	-	0.0-100.0
6.	B. gyrinoides	-	-	-	-	-	-	-	-	16.7	25.0	-	-	0.0-16.5
7.	Hypseleotris sp.	-	-	-	-	-	-	-	27.3	25.0	-	-	-	0.0-27.7
8.	S. semoni	-	83.3	75.0	58.3	-	-	-	72.7	66.7	25.0	50.0	54.5	0.0-83.3
9.	S. cynocephalus	40.0	91.7	91.7	83.3	-	-	8.3	72.7	91.7	100.0	90.0	72.7	0.0-100.0
10.	Schismatogobius sp.	-	8.3	16.7	16.7	-	-	-	9.1	33.3	25.0	-	-	0.0-33.3
11.	A. ocellaris	20.0	8.3	-	16.7	-	-	-	27.3	41.7	-	10.0	-	0.0-41.7
12.	A. grammepomus	20.0	8.3	-	8.3	-	-	-	54.5	50.0	-	10.0	-	0.0-54.5
13.	K. marginata	20.0	33.3	8.3	-	-	-	-	-	41.7	50.0	-	-	0.0-50.0
14.	C. melinopterus	-	-	-	8.3	-	-	-	18.2	8.3	-	-	-	0.0-18.2
15.	R. guilberti	20.0	41.7	16.7	25.0	-	-	8.3	-	-	100.0	20.0	9.1	0.0-100.0
16.	Microphis sp.	-	-	-	-	-	-	-	18.2	-	-	-	-	0.0-18.2
	Alien fish													
17.	A. testudineus	-	-	-	-	-	-	-	-	16.7	-	-	-	0.0-16.7
18.	A. panchax	-	16.7	33.3	75.0	66.7	75.0	41.7	90.9	100.0	-	-	-	0.0-100.0
19.	C. striata	-	-	-	-	-	-	-	9.1	16.7	-	-	-	0.0-16.7
20.	O. niloticus	-	8.3	8.3	50.0	75.0	66.7	75.0	100	25.0	50.0	-	-	0.0-100.0
21.	C. batrachus	-	-	-	8.3	16.7	8.3	8.3	-	-	-	10.0	-	0.0-16.7
22.	B. binotatus	40.0	91.7	100	100	100	83.3	91.7	100	100	100	90.0	100	40.0-100.0
23.	G. affinis	-	-	-	25.0	41.7	41.7	50.0	72.7	41.7	-	-	-	0.0-72.7
24.	M. albus	-	-	-	16.7	33.3	50.0	41.7	54.5	25.0	-	-	-	0.0-54.5
	Number of sampling	5	12	12	12	12	12	12	11	12	4	10	11	
	Number of native species	1-4	2-7	1-6	1-6	0-1	0-1	0-3	0-7	1-8	5-6	1-6	1-4	
	Number of alien species	0-1	1-2	1-3	1-5	2-5	1-6	1-6	2-6	2-4	1-2	0-2	1	
	Number of total species	1-4	4-9	3-9	3-10	2-5	1-6	1-7	3-11	4-12	6-8	2-8	2-5	

Table 4. Relative abundance (%) based on the study sites.

No	Species	Site												
				Nimbai S. (upstream → downstream)						downstream	Aimasi S. (downstream ← upstream)		
		S1	S2	S3	S4	S5	S6	S7	S8	S12	S11	S10	S9
	Endemic fish												
1.	*M. arfakensis*	44.4-100 (74.4)	11.8-81.8 (54.2)	8.6-68.0 (39.9)	0.0-68.0 (31.5)	0.0-2.6 (0.2)	0.0-6.3 (1.4)	0.0-13.3 (4.9)	0.0-0.7 (0.1)	0.0-1.3 (0.1)	16.7-35.0 (25.5)	0.0-58.7 (28.2)	0.0-61.5 (28.1)
	Native fish												
2.	*Ambassis* sp.	-	-	-	-	-	-	-	-	0.0-3.3	-	-	-
3.	*A. marmorata*	-	0.0-3.4	0.0-2.9	0.0-3.3	-	-	-	-	0.0-3.3	0.0-4.2	0.0-6.6	-
4.	*E. fusca*	0.0-11.1	0.0-5.9	0.0-4.3	0.0-11.1	-	-	-	0.0-14.6	0.0-17.4	-	-	-
5.	*B. segura*	-	0.0-12.5	0.0-19.4	0.0-33.3	-	-	-	0.0-4.9	0.0-4.4	1.6-25.0	0.0-100.0	0.0-20.0
6.	*B. gyrinoides*	-	-	-	-	-	-	-	-	0.0-8.0	0.0-1.9	-	-
7.	*Hypseleotris* sp.	-	-	-	-	-	-	-	0.0-5.3	0.0-11.7	-	-	-
8.	*S. semoni*	-	0.0-11.8	0.0-30.0	0.0-26.4	-	-	-	0.0-15.9	0.0-28.9	0.0-5.0	0.0-3.8	0.0-23.1
9.	*S. cynocephalus*	0.0-33.3	0.0-47.1	0.0-62.9	0.0-22.2	-	-	0.0-6.1	0.0-26.1	0.0-38.9	5.8-10.0	0.0-42.9	0.0-26.1
10.	*Schismatogobius* sp.	-	0.0-4.7	0.0-3.2	0.0-1.9	-	-	-	0.0-1.4	0.0-8.0	0.0-2.1	-	-
11.	*A. ocellaris*	-	0.0-1.3	-	0.0-1.4	-	-	-	0.0-1.8	0.0-11.1	-	0.0-1.3	-
12.	*A. grammepomus*	0.0-8.3	0.0-12.5	-	0.0-16.7	-	-	-	0.0-12.2	0.0-8.8	-	0.0-1.6	-
13.	*K. marginata*	0.0-11.1	0.0-37.5	0.0-3.8	-	-	-	-	-	0.0-13.3	0.0-5.8	-	-
14.	*C. melinopterus*	-	-	-	0.0-5.6	-	-	-	0.0-1.8	-	-	-	-
15.	*R. guilberti*	0.0-8.3	0.0-12.5	0.0-3.0	0.0-5.6	-	-	0.0-3.0	0.0-2.4	-	1.6-5.0	0.0-100.0	0.0-4.9
16.	*Microphis* sp.	-	-	-	-	0.0	0.0	-	-	-	-	-	-
	Relative abundance of native species	0.0-50.0 (16.4)	4.5-87.5 (34.2)	0.0-88.6 (33.2)	0.0-72.2 (25.0)	0.0 (0.0)	0.0 (0.0)	0.0-9.1 (0.8)	0.0-47.1 (24.9)	2.5-88.0 (39.0)	14.3-45.0 (27.4)	0.0-100.0 (34.8)	0.0-40.0 (21.9)
	Alien fish												
17.	*A. testudineus*	-	-	-	-	-	-	-	-	0.0-4.3	-	-	-
18.	*A. panchax*	-	0.0-9.1	0.0-20.0	0.0-24.1	0.0-66.7	0.0-100.0	0.0-100.0	0.0-66.7	8.0-75.6	-	-	-
19.	*C. striata*	-	-	-	-	-	0.0-2.2	-	0.0-2.0	0.0-2.2	-	-	-
20.	*O. niloticus*	-	0.0-1.3	0.0-1.4	0.0-0.8	0.0-14.3	0.0-2.2	0.0-4.8	2.4-24.6	0.0-3.7	0.0-1.9	0.0-2.6	-
21.	*C. batrachus*	0.0-33.3	0.0-29.4	2.9-46.2	3.3-51.8	5.6-89.7	0.0-90.5	0.0-88.5	3.6-69.6	2.2-71.7	20.0-66.7	0.0-81.8	7.7-79.4
22.	*B. binotatus*	-	-	-	0.0-43.3	0.0-50.0	0.0-48.6	0.0-41.7	0.0-31.9	0.0-16.9	-	-	-
23.	*G. affinis*	-	-	-	0.0-1.1	0.0-14.3	0.0-20.0	0.0-22.2	0.0-2.6	-	-	-	-
24.	*M. albus*	-	-	-	-	-	-	-	-	0.0-11.1	-	-	-
	Relative abundance of alien species	0.0-33.3 (9.2)	0.0-29.4 (11.6)	2.9-57.7 (26.9)	11.1-75.0 (43.5)	97.4-100.0 (99.8)	93.8-100.0 (98.6)	84.8-100.0 (94.3)	52.9-100.0 (75.0)	12.0-96.3 (60.9)	20.0-68.3 (47.2)	0.0-81.8 (37.0)	7.7-79.4 (49.9)

Note: the numbers in parentheses are average

Table 5. Index of overlapping habitat type utilization between Arfak rainbowfish and alien fish.

Alien species	Nimbai Stream				Aimasi Stream		
	Upstream → Downstream				Downstream ← Upstream		
	Site						
	S1	S2	S3	S4	S11	S10	S9
A. testudineus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A. panchax	0.00	0.00-0.65	0.00-2.86	0.00-2.63	0.00	0.00	0.00
C. striata	0.00	0.00	0.00	0,00	0.00	0.00	0.00
O. niloticus	0.00	0.00-0.61	0.00-0.92	0.00-2.08	0.00-1.58	0.00	0.00
C. batrachus	0.00	0.00	0.00	0.00-2.55	0.00	0.00-2.68	0.00
B. binotatus	0.00-2.00	0.00-2.56	0.00-2.50	0.00-2.48	0.67-2.25	0.00-2.72	0.00-2.67
G. affinis	0.00	0.00	0.00	0.00-2.55	0.00	0.00	0.00
M. albus	0.00	0.00	0.00	0.00-2.63	0.00	0.00	0.00

3.2.4. Physical and chemical characteristics of the location. The results of the measurement of physical and chemical parameters of the aquatic environment are shown in table 6. The results of the principal component analysis of the characteristics of water-physicochemical parameters and abundance of fish groups are shown in figure 3. These results indicate that there were sites grouping based on similarities in water-physic chemistry and group abundance fish. Sites in the upper reaches of S. Nimbai (S1-S4) and S. Aimasi (S9-S11) were characterized by higher oxygen concentrations, higher water flow rates, deeper water depths, and more alkaline water pH, the abundance of higher rainbow fish. Whereas the sites in the sewerage section (S5-S7) and downstream (S8 and S12) were characterized by high turbidity, total alkalinity, conductivity, and higher water temperature, and lots abundance of alien fish.

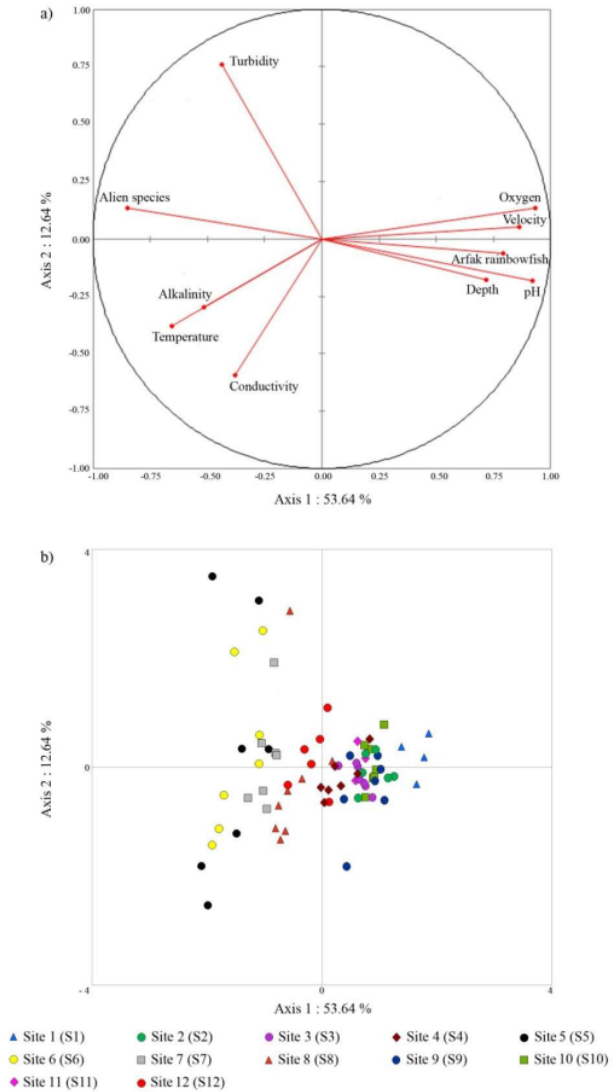**Table 6**. Physicochemical parameters of the Nimbai Stream and the Aimasi Stream.

Site	Temperature (°C)	Water velocity (m·sec.$^{-1}$)	Depth (cm)	Turbidity (NTU)	Dissolved Oxygen (m·L^{-1})	Total alkalinity (mg·L^{-1})	pH	Conductivity (µs·cm^{-1})
S1	22.6-25.5	0.10-3.30	10.3-91.0	0.05-6.14	7.00-8.40	63-117	7.82-8.18	0.037-0.148
S2	24.5-27.7	0.10-2.40	5.0-75.0	0.23-7.19	6.00-7.90	66-258	6.73-8.16	0.025-0.161
S3	24.4-28.0	0.00-2.00	10.0-72.0	0.13-4.78	6.10-7.80	75-240	7.12-8.27	0.140-0.165
S4	23.6-29.6	0.00-2.40	6.0-69.0	0.17-6.89	5.30-7.50	60-225	6.07-8.20	0.004-0.150
S5	26.4-30.3*	0.02-0.40	4.0-43.0	0.86-305.00*	3.60*-6.10	42-345	5.03*-6.13	0.056-0.842
S6	26.1-29.5	0.10-0.53	8.0-26.0	1.34-149.00*	3.90*-5.90	42-285	5.13*-6.45	0.047-0.656
S7	26.0-28.7	0.02-0.60	9.0-53.0	2.13-91.0	4.70-6.50	39-300	5.55-6.96	0.050-0.565
S8	24.4-32.6*	0.04-1.60	7.0-67.0	0.75-49.29	4.70-7.10	54-480*	6.24-7.80	0.018-0.542
S9	21.9-28.0	0.10-2.20	10.1-72.0	0.13-8.58	6.40-8.50	39-360	7.36-8.12	0.057-1.961
S10	23.1-27.8	0.09-1.67	7.0-80.0	0.77-9.52	5.50-8.30	39-153	7.60-8.12	0.031-0.115
S11	24.4-28.4	0.13-1.72	10.0-67.0	1.28-5.24	6.10-8.00	54-150	7.75-8.21	0.008-0.118
S12	25.0-30.3*	0.04-1.30	10.0-85.0	0.78-271.00*	5.20-7.60	30-180	5.60-7.96	0.010-0.642
Range[1]	22.6-29.6	0.00-3.30	5.0-91.0	0.05-91.00	4.70-8.40	30-360	5.55-8.21	0.008-1.961

Note:[1] Arfak rainbowfish found, * out of range Arfak rainbowfish found

The high distribution and abundance of Arfak rainbowfish in the upper reaches is thought to be related to habitat conditions that are relatively suitable for their life. Arfak rainbowfish have a relatively narrow tolerance range than other native fish and alien fish (see table 7). Therefore, the distribution and abundance were relatively low in disturbed sites (in the sewerage and downstream areas) thought to be related to their relatively limited tolerance for Physico-chemical parameters. In contrast to alien fish which generally can adapt to broader physical and chemical parameters, so it was more resistant to conditions that have been disturbed waters.

3.2.5 Implications of decreasing habitat quality on the distribution and abundance of Arfak rainbowfish. Habitat degradation in both streams has led to relatively limited distribution and decreased the abundance of Arfak rainbowfish, particularly downstream segments. This fact was related to changing riparian conditions which become exposed, causing an increase in water temperature, a decrease in the concentration of dissolved oxygen, and an increase in turbidity. This decline in quality is further compounded by the inclusion of palm oil processing waste that enters the Nimbai Stream system.

Moreover, the introduction of alien fishes and become relatively abundant in the downstream segment was though to adding the pressure to the Arfak rainbowfish population. This condition will cause habitat fragmentation and subsequently isolated this endemic fish population in upper reaches of the streams.

Figure 3. Graph of analysis of the main components of the physical-chemical characteristics of competition a) change the abundance of Arfak rainbowfish and alien fish with physicochemical parameters on axis 1 and 2, b) the distribution of research sites on axis 1 and 2.

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Table 7. Characteristics of physicochemical parameters of the habitat of Arfak rainbowfish and alien fish.

Species	Water velocity (m·sec.[-1])	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg·L^{-1})	pH
M. arfakensis[1,2,3,4,5,6]	0.00-3.30	21.9-29.6	<91,0	3.2-8.5	5.55-8.80
A. testudineus[6,10,]	0.09-1.13	26.2-29.6	0.78-3.80	6.2-6.3	6.42-7.20
A. panchax[4,6,]	0.00-0.73	23.6-32.0	0.18-305	3.6-7.7	3.60-8.29
C. striata[10,]	0.12-1.13	28.6-29.6			7.0-7.3
O. niloticus[10,]	0.12-1.13	28.6-29.6			7.0-7.3
C. batrachus[4,10]	0.12-1.13	25.5-31.8		2.2-6.9	5.66-7.95
B. binotatus[4,7,9, 10]	0.12-1.13	21.23-32.0		2.2-8.1	5.66-8.29
G. affinis[4,7,8]	-	11.9-28.0		2.2-10.6	5.66-7.95
M. albus[10,11,]	0.49	20.0-38.2			6.5-7.3

Note:[1]Tapilatu and Renyaan (2005), [2]Sabariah *et al* (2005), [3]Binur and Budirianto 2008, [4]Manangkalangi *et al* (2009a), [5]Manangkalangi *et al* (2014), [6]This study, [7]Berra *et al* (1975), [8]Al-Hafedh (2007), [9]Paller *et al* (2013), [10] Djumanto *et al* (3013), [11] Affandi *et al* (2003).

Habitat fragmentation is an important issue in the conservation of biological resources (Fahrig 2003, Monaghan *et al* 2005). This condition occurs naturally or as a consequence of various human activities, for example, road construction, logging, construction of dams, and agricultural land-use (Fahrig 2003). One example is forest fragmentation as a result of the expansion of poorly managed oil palms which is the major threat to biodiversity in Southeast Asia (Fitzherbert *et al* 2008, Koh and Wilcove 2008, Corley2009, Azhar *et al* 2011, Giam *et al* 2015).

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