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Evaluation of *Argulus indicus* on striped snakehead (*Channa striata*) in Towuti Lake, South Sulawesi, Indonesia

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Abstract. *Amriana, Sari DK, Sriwulan, Anshary H. 2022. Evaluation of* Argulus indicus *on striped snakehead (*Channa striata*) in Towuti Lake, South Sulawesi, Indonesia. Biodiversitas 23: 1353-1360.* Fish parasites are frequently present in wild freshwater fish populations, but data are limited on their distribution and impacts. This research aimed to investigate the severity of parasitic *Argulus* infestation on striped snakeheads (*Channa striata*) caught in Towuti Lake based on prevalence, intensity, and the bacteria associated with *Argulus* parasitizing *C. striata*. The research was conducted from March 2018 to February 2019 at Towuti Lake, South Sulawesi Province, Indonesia. Striped snakehead samples were captured using fish traps and gillnets. Samples of bacteria associated with *Argulus* were collected from four striped snakeheads (three infested and one non-infested control). Bacteria from *Argulus* attachment sites were identified through Vitek-2 Compact biochemical tests. *Argulus* prevalence on striped snakeheads was in the range 73.3-96.7%, with a mean intensity range of 2.18-14.43 and mean abundance 1.67-13.47. Water quality parameters measured in Towuti Lake remained within the Indonesian standards for freshwater fish habitat. The bacteria in striped snakehead mucus comprised two species in control (*Staphylococcus xylosus*, *Pantoea* sp.) and seven species in the parasitized fish (*Micrococcus luteus, Bacillus mycoides, Acinetobacter baumannii, Sphingomonas paucimobilis, Pantoea* sp., *Aerococcus viridans, Staphylococcus arlettae*). This study found a very high prevalence of striped snakehead infestation with parasitic *A. indicus* at low to medium intensity levels. The study also showed that *A. indicus* infestation was accompanied by and likely stimulated pathogenic bacteria, which can cause skin infections in fish. Therefore, *A. indicus* could be considered a threat to striped snakehead populations in Towuti Lake.

Keywords: Fish lice, infection, parasite, pathogen, wild fish

INTRODUCTION

Towuti Lake in Luwu Timur District, South Sulawesi Province, Indonesia is the largest lake in the Malili ancient lake system and the second largest lake in Indonesia (Russell et al. 2020). The fish community in this lake comprises both native and introduced species, most of which are caught for subsistence and/or for sale, making an important contribution to the livelihoods and welfare of people living around the lake (Nasution et al. 2015). Parasites can be a threat to freshwater fish populations (Radkhah 2018). Parasites spend at least part of their life-cycle infesting hosts organisms on which they depend for meeting their energy needs as well as shelter (Stewart et al. 2017). In lakes, fish parasites can have negative impacts on fish stocks and the sustainability of fishing (Alsarakibi et al. 2014). Fish population dynamics can be affected, and parasites can cause rapid declines in host fish population abundance (McPherson et al. 2012). Parasites tend to be small, a factor contributing to the availability of resources such as food and habitat, while the host can provide protection from the external environment, facilitating the growth and reproduction of parasites in relatively protected micro-habitats (Walker et al. 2011).

Ectoparasites of the genus *Argulus* are branchiuran crustaceans, with at least 153 species reported worldwide (Walter and Boxhall 2021). Known as fish lice, these parasites have caused epidemics in many regions of the world, as *Argulus* can adapt to environmental change and survive even in extreme conditions (Alsarakibi et al. 2014). Low host specificity enables *Argulus* to infest a wide variety of marine and freshwater host fishes (Radkhah 2018). Infestation with *Argulus* can reduce the aesthetic appeal of the host and thereby reduce customer demand, as seen in the recreational fishery for trout at Stillwater in England (Taylor et al. 2006). *Argulus* parasites can attach themselves to fish using their hooked stylets and modified suckers and obtain nutrition by sucking the blood of the host (Stewart et al. 2017). Together with the toxins or digestive enzymes secreted through the pre-oral stylet and labial spines, these actions can reduce the abundance of red blood cells and haematocrit concentration, leading to anemia, as well as causing wounds and stimulating an increase in white blood cell production (Walker et al. 2011). The growth rate and condition factor of infested fish may also be considerably reduced (Kumar et al. 2016). *Argulus* can cause declines in wild fish population abundance due to the primary infestation as well as secondary infections with other pathogens such as bacteria, fungi and viruses for which the parasite acts as a vector (Stewart et al. 2017; Radkhah 2018).

In Indonesia, *Argulus* infestation is a serious concern in freshwater aquaculture (Farizqi and Nugroho 2021) and has also been reported in several Indonesian wild fish populations. Cases include infestation of the mahseer *Tor tambra* in Aceh Province (Muchlisin et al. 2014); freshwater eel *Anguilla marmorata* in Poso Lake, Central Sulawesi Province (Amrullah et al. 2019); the clown loach *Chromobotia macracanthus* in the Kelekar River, South Sumatra Province (Robin 2007); and tilapia (*Oreochromis* sp.) in Limboto Lake, Gorontalo Province (Ali et al. 2013). A recent study by Amriana et al. (2021a) found an Argulid parasite infesting wild fish in Towuti Lake, South Sulawesi Province, and identified this parasite as *A.s indicus*. Further study found *A. indicus* infesting four species in Towuti Lake: the striped snakehead *C. striata*, the three-spot cichlid *Cichlasoma trimaculatum*, the climbing perch *Anabas testudineus* and the Nile tilapia *Oreochromis niloticus* (Amriana et al. 2021b).

Although the Argulid parasite in Towuti Lake has been identified, there is a lack of information on the threat posed to the fish living in the lake, in particular the striped snakehead (*C. striata*), which is the prime fisheries commodity in Towuti Lake. Information of importance for estimating the severity of the *Argulus* infestation and its effects on the host fish include the prevalence, intensity and abundance of the parasite. It is also important to identify potentially pathogenic bacteria on the fish skin associated with the parasite, which could cause secondary infections in *A. indicus* infested hosts. The purpose of this study was to investigate the threat posed to wild striped snakehead *C. striata* populations in Towuti Lake based on Argulid parasite prevalence, intensity and associated bacteria.

MATERIALS AND METHODS

Ethics statement

This research was conducted with the approval of the Hasanuddin University Health Research Ethics Committee for the use of experimental animals in research (Protocol No. 13720093017). All stages in this research followed the Animal Ethics Guidelines issued by the Ministry of Health of the Republic of Indonesia.

Study site and sampling methods

The study was conducted from March 2018 to February 2019 in Towuti Lake, Luwu Timur District, South Sulawesi Province, Indonesia. Striped snakehead *C. striata* specimens from Towuti Lake were obtained from local fishermen using fish traps and gillnets. Specimens (n: 360) were collected from three stations: Tominanga, Bakara and Larona (Figure 1). The striped snakeheads were caught in the littoral zone of the lake at depths of 1-2 m in the swampy or marshy wetland ecosystems found around the edge of the lake. This habitat is characterized by aquatic vegetation, including floating plants, grasses or sedges, and some trees.

The samples from each station were kept in separate containers. Each fish was measured, weighed, and inspected for the presence of Argulid parasites. The parasites were recorded based on the attachment site with four body compartments used: the head, the gills, the fins, and the body surface (skin). *Argulus* were collected with tweezers and placed in labeled sample bottles filled with 70% ethanol. After this examination, the samples were placed in a cool-box and taken to the Fish Parasite and Disease Laboratory, Faculty of Marine Science and Fisheries, Universitas Hasanuddin for further analysis.

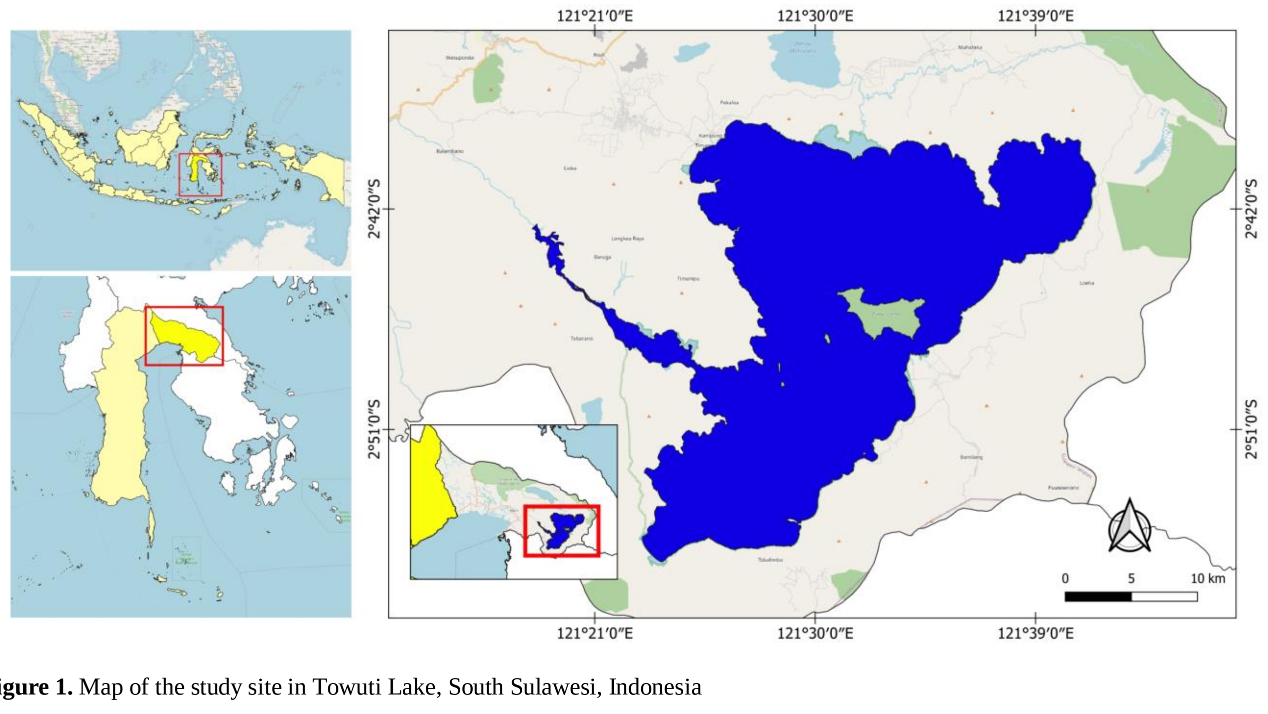

Figure 1. Map of the study site in Towuti Lake, South Sulawesi, Indonesia

Isolation of bacteria from striped snakehead samples

Four striped snakehead specimens were collected in February 2019, comprising three specimens with *A. indicus* infestation and one specimen with no visible infestation (normal condition) as a control. Mucus was collected from the infested fish at the *A. indicus* attachment sites using a spatula and placed in a 1.5 mL microtube to which 1 mL physiological solution was added. The sample tube was vortexed for 1 min, then the contents was poured into a tube containing 9 mL physiological solution. After vortexing, 1 mL of the solution was transferred to a second tube and the process was repeated until there were four tubes. Sub-samples of 100 μL were taken from the 3rd and 4th tubes and spread evenly over TSA agar media with an L stick. This procedure was repeated three times for each sample. The inoculated agar media were then incubated in an incubator for 24 hours at 37°C.

The dominant bacterial colonies were observed and characterized based on morphological criteria. Samples of the dominant colonies were transferred to fresh media using the quadrant method and incubated for 24 hours at 37°C. The morphology of the colonies formed was observed in order to identify and separate the dominant bacteria. Bacterial strains were isolated, ready for further examination using the streak plate method on blood agar media (BAM).

Staining was used to prepare the bacteria for identification. One ose needleful was collected aseptically from each bacterial colony and placed on a glass slide. The sample slides were dried and fixed over a Bunsen burner. Once fully dry, 2-3 drops of crystal violet were added to each slide and left for 1 min before rinsing under running water and allowing the slide to dry. Iodine solution was then dripped onto the slide and left for 1 min before rinsing under running water and allowing the slide to dry. Once dry, the slide was washed with 70% ethanol for 30 s and left to dry. Safranin solution was added and left standing for 2 min before rinsing under running water and drying the slide. The slide was then observed under a microscope and the color and shape of the stained bacteria was recorded.

The following stage of the identification process used the Vitek-2 Rapid Identification of Microorganism biochemical assay. This analysis used a KIT card for Gram-negative (GN) bacteria, Gram-positive (GP) bacteria and *Bacillus*. Bacteria were classified based on the Gram staining assay results. A sample of bacteria from each pure strain isolates was collected using a sterile swab and suspended in a single-use tube filled with sodium chloride (NaCl) until the standard turbidity of 0.48-0.56 on the McFarland scale (measured with a DensiCHECK) was reached. Vitek-2 64-Well identification cards were inoculated with the microorganism suspensions by placing the test tubes containing the microorganism suspensions into a special rack (cassette) and placing the identification card in the neighboring slot while inserting the transfer tube into the corresponding suspension tube. The filled cassette was then loaded into the Vitek-2 Compact unit. The results of the identification process were available in under 24 hours. For each group of bacteria, calibration and quality control procedures were performed for the Gram-negative, Gram-positive and *Bacillus* bacterial identification cards, based on the Gram staining results.

Water quality sample collection

Water quality data were collected from three stations around Towuti Lake (Tominanga, Bakara and Larona). Water quality parameters were measured at monthly intervals at the same time as collecting fish specimens. Parameters measured were: water temperature, pH, dissolved oxygen (DO) and five-day biochemical oxygen demand (BOD_5) based on the Class III water quality standards for aquaculture (Government of Indonesia 2001). Temperature and pH were measured and recorded in situ using a digital pH meter (Hanna HI98129). Water samples for DO measurement were prepared in the field through adding 2 mL NaOH Ki and 2 mL $MgCl_2$ to 100 mL water samples in a Winkler bottle. Water samples for BOD_5 measurement were collected in 100 mL Winkler bottles, and samples for BOT measurement were collected in 600 mL bottles. All water samples were placed in a fiberglass box filled with gel ice for transport to the laboratory. DO, BOT and BOD_5 were measured in the laboratory using Winkler titration (USEPA 1997). Dissolved oxygen (DO) was measured on the same day the samples were collected, while BOD_5 was measured 5 days later.

Data analysis

Prevalence (percentage of fish examined that were infested with *Argulus*), mean intensity (mean number of *Argulus* found on an individual fish specimen, including all parasites found on the host head, gills, fins and body/skin) and mean abundance (the number of all *Argulus* parasites found divided by the total number of fish specimens examined) were calculated following the procedures recommended by Bush et al. (1997) in GraphPad Prism 9.1.1.

RESULTS AND DISCUSSION

Results

The prevalence of parasitic *A. indicus* on striped snakeheads in Towuti Lake varied between months over the observation period (Figure 2). Prevalence was high in all months, ranging from 73.3 to 96.7%.

Argulus indicus intensity and abundance on striped snakeheads in Towuti Lake also varied over the study period (Figure 3). The mean intensity of *Argulus* infestation ranged from 2.18 to 14.43 parasite/fish, while mean abundance ranged from 1.67 to 13.47 parasite/fish.

Water quality parameters at the sampling sites (Table 1) varied between the stations and over the study period. Water temperature air in Towuti Lake ranged from 26.7 to 31.5ºC; pH was in the range 7.00-8.04, with dissolved oxygen in the range 3.88-7.36 ppm and BOD_5 in the range 0.052-5.44 ppm. All parameters measured during this study remained within the ranges considered normal under the Indonesian Government Regulation No.22/2021 on freshwater standards for fisheries and aquaculture.

Biochemical assays of the bacterial isolates from striped snakehead mucus (Table 2) show that the bacteria present included bacteria from three groups: Gram-negative, Gram-positive and Bacillus.

The Vitek-2 biochemical assay of bacterial isolates identified 8 species of bacteria (Table 3).

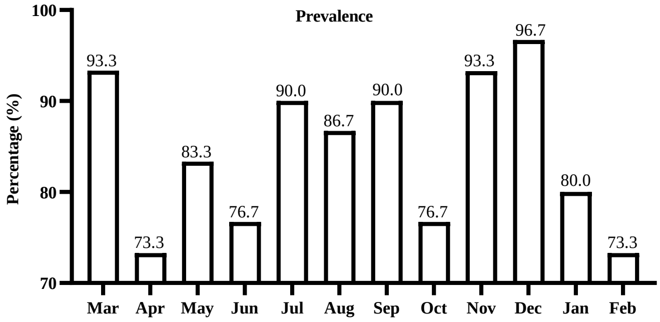

Figure 2. Prevalence of infection of the parasite *Argulus indicus* on striped snakehead *Channa striata*

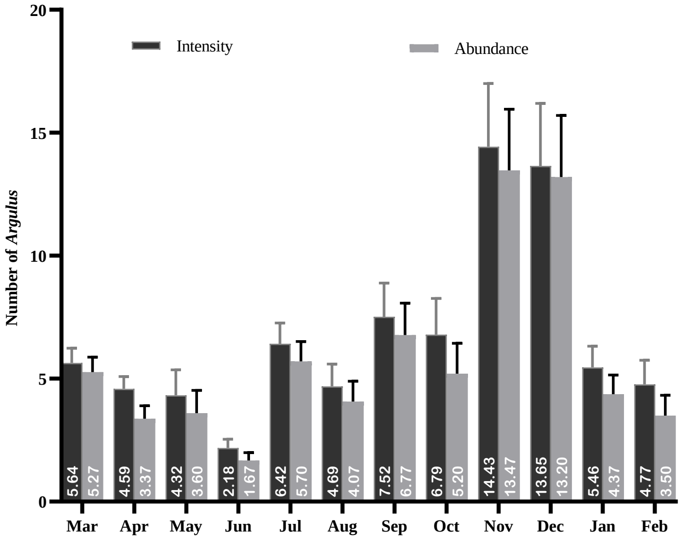

Figure 3. Mean intensity and mean abundance of the parasite *Argulus indicus* on striped snakeheads in Towuti Lake, South Sulawesi, Indonesia

Table 1. Water quality parameters at the Towuti Lake, South Sulawesi, Indonesia fish sampling stations

Station/source	Temperature (°C)	pH	DO (ppm)	BOD_5 (ppm)
Tominanga	26.7-29.5	7.08-8.04	3.88-7.36	0.52-4.48
Bakara	27.3-30.3	7.00-7.76	5.76-6.72	1.60-4.08
Larona	28.5-31.5	7.22-7.85	4.80-7.13	0.64-5.44
Water quality standard[a]	-	6-9	>3	≤6
Range tolerated by *Argulus* sp[b]	10-43	4-7	2.9-10.5	0.9-6.04

Note: [a]Government of Indonesia (2021); [b]Alsarakibi et al. (2014)

Table 2. Vitek-2 biochemical assay of bacterial isolates from striped snakehead mucus

Gram negative isolates						
Biochemical assay		**Sample code**				
		2	**5**	**6**	**7**	**10**
2	APPA	-	-	+	-	-
3	ADO	-	-	-	-	-
4	PyrA	+	-	+	+	-
5	IARL	-	-	-	-	-
7	dCEL	-	+	-	+	+
9	BGAL	+	-	-	+	-
10	H2S	-	-	-	-	-
11	BNAG	-	-	-	-	-
12	AGLTp	-	-	-	-	-
13	dGLU	+	+	+	+	+
14	GGT	+	-	-	+	-
15	OFF	+	-	-	+	-
17	BGLU	-	-	-	-	-
18	dMAL	+	-	+	+	-
19	dMAN	+	-	-	+	-
20	dMNE	+	+	-	+	+
21	BXYL	-	-	-	-	-
22	BALap	-	-	-	-	-
23	ProA	-	-	-	-	-
26	LIP	-	-	-	-	-
27	PLE	-	-	-	-	-
29	TyrA	+	+	-	-	+
31	URE	-	+	-	-	-
32	dSOR	-	-	-	-	-
33	SAC	+	-	+	+	-
34	dTAG	-	-	-	-	-
35	dTRE	+	-	+	+	-
36	CIT	+	+	-	-	+
37	MNT	-	+	-	-	-
39	5KG	-	-	-	-	-
40	ILATk	+	+	-	+	+
41	AGLU	-	-	-	-	-
42	SUCT	+	+	-	+	+
43	NAGA	-	-	-	-	-
44	AGAL	-	-	-	-	-
45	PHOS	+	-	-	-	-
46	GlyA	-	-	-	-	-
47	ODC	-	-	-	-	-
48	LDC	-	-	-	-	-
53	IHISa	-	-	-	-	-
56	CMT	+	+	+	+	+
57	BGUR	-	-	-	-	-
58	0129R	+	-	+	+	+
59	GGAA	-	-	-	-	-
61	IMLTa	-	-	-	-	-
62	ELLM	-	-	-	-	-
64	ILATa	-	-	-	-	-

Gram positive isolates					
Biochemical assay		**Sample code**			
		1	**3**	**8**	**9**
2	AMY	-	-	-	-
4	PIPLC	-	-	-	-
5	dXYL	+	+	-	-
8	ADH1	+	+	-	-
9	BGAL	-	+	+	-
11	AGLU	-	+	-	-
13	APPA	-	-	-	-
14	CDEX	-	-	-	-
15	AspA	-	-	-	-
16	BGAR	-	-	-	-
17	AMAN	-	-	-	-
19	PHOS	+	+	-	-
20	LeuA	-	-	-	-
23	ProA	-	-	-	-
24	BGURr	+	-	-	-
25	AGAL	-	-	-	-
26	PyrA	+	+	+	-
27	BGUR	+	-	-	+
28	AlaA	-	-	-	-
29	Tyra	-	-	-	-
30	dSOR	-	-	-	-
31	URE	+	-	-	-
32	POLYB	-	+	-	-
37	dGAL	-	-	+	-
38	dRIB	-	-	-	+
39	ILATk	-	-	-	-
42	LAC	+	+	+	+
44	NAG	-	-	-	-
45	dMAL	-	-	+	+
46	BACI	+	+	-	-
47	NOVO	+	+	+	+
50	NC6.5	+	+	+	+
52	dMAN	+	+	+	+
53	dMNE	+	-	+	-
54	MBdG	+	-	-	-
56	PUL	-	-	-	-
57	dRAF	-	+	-	-
58	O129R	+	-	+	+
59	SAL	+	+	-	-
60	SAC	+	+	+	+
62	dTRE	+	+	+	+
63	ADH2s	-	-	-	-
64	OPTO	+	+	+	+

Bacillus isolate		
Biochemical assay		**Sample code**
		4
1	BXYL	-
3	LysA	-
4	AspA	-
5	LeuA	+
7	PheA	-
8	proA	-
9	BGAL	-
10	PyrA	+
11	AGAL	-
12	AlaA	+
13	TyrA	-
14	BNAG	-
15	APPA	+
18	CDEX	-
19	dGAL	-
21	GLYG	-
22	INO	-
24	MdG	-
25	ELLM	-
26	Mdx	-
27	AMAN	-
29	MTE	+
30	GlyA	+
31	dMAN	-
32	dMNE	-
34	dMLZ	-
36	NAG	+
37	PLE	-
39	IRHA	-
41	BGLU	-
43	BMAN	-
44	PHC	+
45	PVATE	+
46	AGLU	-
47	dTAG	-
48	dTRE	+
50	INU	-
53	dGLU	+
54	dRIB	+
56	PSCNa	-
58	NaCl 6.5%	+
59	KAN	+
60	OLD	-
61	ESC	-
62	TTZ	+
63	POLYB_R	+

Table 3. Bacteria identified from infested and parasite-free (control) striped snakehead mucus

Isolate code	**Sample group**	**Gram staining result**	**Microorganism identified**
Isolate 1	Control	Cocci Gram Positive	*Staphylococcus xylosus*
Isolate 2		Bacilli Gram Negative	*Pantoea* sp.
Isolate 3	Infested	Cocci Gram Positive	*Micrococcus luteus*
Isolate 4		Bacilli Gram Positive	*Bacillus mycoides*
Isolate 5	Infested	Bacilli Gram Negative	*Acinetobacter baumannii*
Isolate 6		Bacilli Gram Negative	*Sphingomonas paucimobilis*
Isolate 7		Bacilli Gram Negative	*Pantoea* sp.
Isolate 8	Infested	Cocci Gram Positive	*Aerococcus viridans*
Isolate 9		Cocci Gram Positive	*Staphylococcus arlettae*
Isolate 10		Bacilli Gram Negative	*Acinetobacter baumannii*

Discussion

Based on previous research in Towuti Lake, the striped snakehead *C. striata* was the fish most severely affected by *A. indicus* infestation, in terms of prevalence, intensity and abundance (Amriana et al. 2021b), indicating that striped snakeheads in Towuti Lake were vulnerable to infestation, and could be a major host for *A. indicus* in this lake. This study observed the temporal trends over one year in the infestation of Towuti Lake striped snakeheads with *A. indicus*. The *Argulus* prevalence criteria of Hoffman (1998) in Fira et al. (2021) classify prevalence in the range 70-89% as usually present and 90-98% as almost always present. These levels can be considered severe. Despite fluctuations, *Argulus* prevalence of infestation remained relatively high throughout the year, in the moderate category for seven months and the severe category for five months (Figure 2). In terms of parasite intensity and abundance (Figure 3), the infestation was in the light (1-5) to moderate (6-55) range based on Hoffman (1998) in Fira et al. (2021). The severity of a parasite infestation in terms of its impact on the host can be evaluated based on the prevalence, mean intensity and abundance of the parasite (Bush et al. 1997). Prevalence, as the proportion of potential hosts infected, is commonly used to describe parasitic relationships, including the ecological and evolutionary factors which affect the relationship between host and parasite. Prevalence levels such as those observed in the Towuti Lake striped snakehead population indicate that infestation is (or has become) the norm, affecting the majority of potential host fish. Despite the light to moderate intensity and abundance of the parasite, the high prevalence indicates that parasitic *A. indicus* could be a threat to the striped snakehead population in Towuti Lake.

The severity of infestation with *Argulus* in a given waterbody will be influenced by the condition of the host as well as the reproductive and recruitment capability of *Argulus*, both of which will be influenced by many factors, including environmental conditions such as the substrate and water temperature (Alsarakibi et al. 2012; Sahoo et al. 2013; Alsarakibi et al. 2014). In general, *Argulus* parasites can survive in waters with a wide range of physical and chemical parameters, and some species of *Argulus* are known to tolerate temperatures as low as 3ºC and as high as 43ºC (Walker et al. 2011; Hunt and Cable 2020). Argulosis has frequently been seen as a seasonal disease, especially in subtropical regions. For example, Alsarakibi et al. (2012) found that *A. japonicus* was most abundant from the end of the summer to early autumn, while very few fish lice were found during the winter. Temperature can affect *Argulus* distribution during certain seasons. However, the tropical climate in Indonesia brings very little seasonal variation in temperature, so Argulid infestations could be expected to occur all year round, during both the wet and dry seasons.

According to data from the Meteorological, Climatological and Geophysical Agency (2018), Towuti Lake is situated in a zone without a clear distinction between the wet and dry seasons. The water quality data are consonant with other studies on Lake Towuti, showing a lack of major seasonal fluctuations, in particular with respect to temperature (Hasberg et al. 2019). Water temperature in the lake remained within the range 26-31ºC over the entire year during which observations were made. This temperature range is suitable for the hatching of *Argulus* eggs and to promote subsequent recruitment of *Argulus* (Sahoo et al. 2013). All other water quality parameters measured in Towuti Lake also remained within ranges suitable for both the host and the parasite (Table 1), so that biotic factors can be considered favorable for *A. indicus* infestation of striped snakeheads throughout the year, even though the severity fluctuated to some extent.

Argulid parasites can serve as a transmission pathway for other pathogens to attack the host fish (Radkhah 2018). *Argulus* parasites pierce the skin of the fish both as a means of attachment and as part of the feeding process; the puncture wounds that result can be made considerably worse through actions by the fish such as rubbing against hard and/or rough surfaces in attempts to remove the parasites (Walker et al. 2011; Wafer et al. 2015; Radkhah 2018). These wounds can then become pathways for secondary infection by pathogens such as bacteria, fungi and viruses to enter and infect the body of the host fish, causing a decline in fish health, with symptoms including bloody rashes, ulceration, and septicaemia and can be fatal (Kumar et al. 2016; Radkhah 2018). The bacteria identified in the mucus of striped snakeheads from Towuti Lake infested with *A. indicus* included several opportunistic bacteria (*Micrococcus luteus, Bacillus mycoides, Acinetobacter baumannii, Sphingomonas paucimobilis, Aerococcus viridans, Staphylococcus arlettae* and *Pantoea* sp.), which are considered as pathogens that can cause disease in fish and/or humans, although infection with some of these bacteria does not appear to have been reported as yet in freshwater fishes.

The bacterium *Acinetobacter baumannii* is well known as a pathogen that can pose serious risks to human health when present in the freshwater environment (Kozińska et al. 2014) but has also been reported as an opportunistic pathogen affecting rainbow trout and carp in Polish fish farms and can infect several other species of fish. This bacterium has low host specificity, can tolerate and even thrive in a wide range of environments, and can cause morbidity and mortality in fish.

Micrococcus luteus has been shown to cause disease in farmed rainbow trout and brown trout, leading to mortality rates as high as 50% in Poland from 2014 to 2016 (Pękala et al. 2018). The symptoms of infection with *M. luteus* can include exophthalmia, swelling of the abdomen and/or kidneys, melanization (darkening) or unusual pigmentation of the skin, pale gills and spleen, petechiae and focal lesions on the skin of infected fish. *Bacillus mycoides* is also considered a pathogen and can cause ulceration of the skin of infected fish; in 2017, an outbreak of disease caused by *B. mycoides* resulted in 60% mortality of farmed *Micropterus salmoides* in Guangdong Province, China (Cao et al. 2018). *Bacillus mycoides* belongs to the *Bacillus* group and can produce virulence factors, including enterotoxins, phospholipases, and endotoxins. *Aerococcus viridans* is also a pathogen known to affect fish. For example, in 2018 and 2019 disease caused by infection with *A. viridans* caused extensive financial losses in the Egyptian tilapia aquaculture sector with morbidity and mortality rates of 20-25%. Research has shown that mortality in fish purposively infected with *A. viridans* can be as high as 91% by 6 days after injection (Elgohary et al. 2021).

Pantoea sp. is an opportunistic pathogen that can be found in water, soil, plants and the digestive tracts of humans and animals (Dutkiewicz et al. 2016). *Pantoea* sp. infection has been reported in mahseer (*Tor* spp.) kept in earthen ponds in Cijeruk, Indonesia (Sugiani et al. 2019). In zebrafish (*Danio rerio*) the clinical symptoms of *Pantoea* sp. infection can include excessive mucus production and ulcers on the belly, dorsal region and operculum; these ulcers can develop into deep open wounds in the skin and body of the infected fish, exposing the underlying musculature (Rahayu et al. 2020). *Staphylococcus arlettae* has been found on the skin of terrestrial animals and in the environment (Yu et al. 2019). There are few references regarding this bacterial species, and none were found regarding *S. arlettae* infection in fish. *Sphingomonas paucimobilis* is known as a pathogen that can infect humans (Mustafa et al. 2017), but there is very little information on the presence or the effects of *S. paucimobilis* in fish.

Several of the bacteria isolated from fish skin mucus at *A. indicus* attachment sites are known to be opportunistic fish pathogens. These bacteria could cause secondary infections with a deleterious effect on the condition of the parasitized fish. This association of pathogenic bacteria with *A. indicus* parasites strongly indicates that the parasite can act as a vector for or stimulate bacteria which could cause serious disease in the host fish. The combination of high prevalence and association with pathogenic bacteria strongly suggest that infestation with parasitic Argulids will have negative impacts on the striped snakehead (*C. striata*) population in Lake Towuti and most likely at other sites. To test this hypothesis, further research is required on the impact of *A. indicus* infestation on the fish host immune system.

Fish parasites, and in particular Argulids, are a matter for growing concern in both captive and wild fish populations, and specific plans to control *Argulus* populations have been suggested (Kumar et al. 2016; Radkhah 2018). While many treatments applicable in a controlled (e.g. aquaculture) setting is not feasible or advisable in natural environments such as lakes, biological control methods include the placement of egg-laying boards to which female Argulids would be attracted and which can be removed and sterilized at appropriate intervals, especially during peak *Argulus* reproductive periods (Gault et al. 2002; Sahoo et al. 2013). The results of this study indicate that mitigation measures are considered advisable to reduce the negative impact of *Argulus* on the valuable striped snakehead stocks in Lake Towuti. Based on the literature regarding the control of Argulid infestations (Radkhah 2018), recommendations for mitigation by the local community and government actors include the use of egg-laying boards and reducing the availability of other suitable substrates for *Argulus* egg-laying, avoiding further introductions of non-native species to the lake, and biosecurity measures including quarantine and treatment of fish infested with *Argulus.*

This study shows that parasitic infestation with the fish louse *A. indicus* can be considered a potential threat to the striped snakehead *C. striata* population in Towuti Lake. Prevalence is high as almost all fish observed were infested, generally at mild to moderate intensity. The study also shows that *A. indicus* infestation can be associated with pathogenic bacteria, which could affect the skin integrity of striped snakeheads, indicating that the parasites can act as a vector for and/or a stimulus for these pathogenic bacteria. Appropriate management measures could mitigate Argulid infestation on the striped snakehead and other fish in Towuti Lake.

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