Bone Estuary of Tomini Bay as habitat of "Nike" fish: sedimentation rate and physical-chemical water characteristics

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Abstract. The survival and sustainability of the Nike fish (amphidromous goby larva), one of the Tomini Bay fish species, with a high economic and ecological value commodity, must be maintained. Therefore, the water condition must be monitored, especially the sedimentation and environmental aspects of the estuary, a natural habitat for Nike fish. This study examined the daily sedimentation rate and the physical and chemical water characteristics of the Bone Estuary. Sampling for sediment and water quality in each station was carried out every three days during one cycle of the larva's appearance in September 2022. The sediment collection was carried out using a sediment trap at six stations deployed at the estuary depth. The daily sedimentation rate range was 871.32–19,670.98 g m^{-2} day^{-1}, with the highest and lowest rates occurring at Station 4 and Station 5, respectively. The average values of water depth, velocity, transparency, water surface temperature, pH, salinity, dissolved oxygen, turbidity, total dissolved solids, and conductivity of the estuary were 1.25±0.49 m, 0.44±0.25 m s^{-1}, 0.32±0.14 m, 29.37±0.88°C, 6.77±0.32, 1.33±2.44 ppm, 7.54±0.16 mg L^{-1}, 46.80±19.74 NTU, 1852.29±2994.66 ppm, and 3521.25±5942.92 µS cm^{-1}, respectively.

Key Words: Gorontalo, native species, precipitation, tides.

Introduction. Nike fish, as a high economic and ecological aquatic resource, has been concerned by the biological research: ecological conditions such as water quality (Salam et al 2016) and degradation of the natural habitat of fish were studied, together with the intensive exploitation by fishermen, since these aspects potentially influence the Nike fish's sustainability (Olii et al 2017; Olii et al 2019; Sahami et al 2019a; Sahami et al 2019b; Pasisingi et al 2020b; Pasisingi & Habibie 2020a; Sahami et al 2020; Pasisingi et al 2021; Sahami & Habibie 2021; Olii & Pasisingi 2022).

Nike fish's life cycle is unique as it is categorized as an amphidromous (Pasisingi & Abdullah 2018). Nike is a group of gobies in larvae stages composed of several species (Sahami et al 2019; Sahami et al 2020b) that live in seawater and migrate to grow up (Sahami & Habibie 2020) and spawn in freshwater. Nike's larval and juvenile population inhabit the estuary area. Larvae are an extremely vulnerable and critical life stage of the organism. Research on the importance of the estuary ecosystem, which functions as a sustainability area, and the extinction threat on the Nike fish of the Gorontalo Waters has never been reported.

An estuary area as the meeting point of fresh and marine waters is a highly strategic and critical area for the sustainability of aquatic organisms. Among the 24 estuaries of the Tomini Bay, the Bone Estuary is merely an ecosystem where Nike fish regularly appear every month. The estuary is administratively situated in the southern part of Gorontalo and is geographically inseparable of the Tomini Bay. External factors affecting the dynamics of the Bone Estuary can threaten the sustainability of Nike resources in Gorontalo waters, including physical changes in the area, concerning the sedimentation process and the physical and chemical conditions of the waters. This study aimed to determine the daily sedimentation rate and the physical and chemical water characteristics of the Bone Estuary waters, as a habitat for Nike fish.

Material and Method

Time and research sites. The sampling for monitoring the sedimentation rate and the measurement of physical-chemical water characteristics was performed in 6 stations in the Bone Estuary, Tomini Bay, Indonesia (Figure 1). Sediment samples and water quality parameters were taken and measured every three days from 7 to 28 September 2022, along with the Nike fish migration from saline to fresh waters.

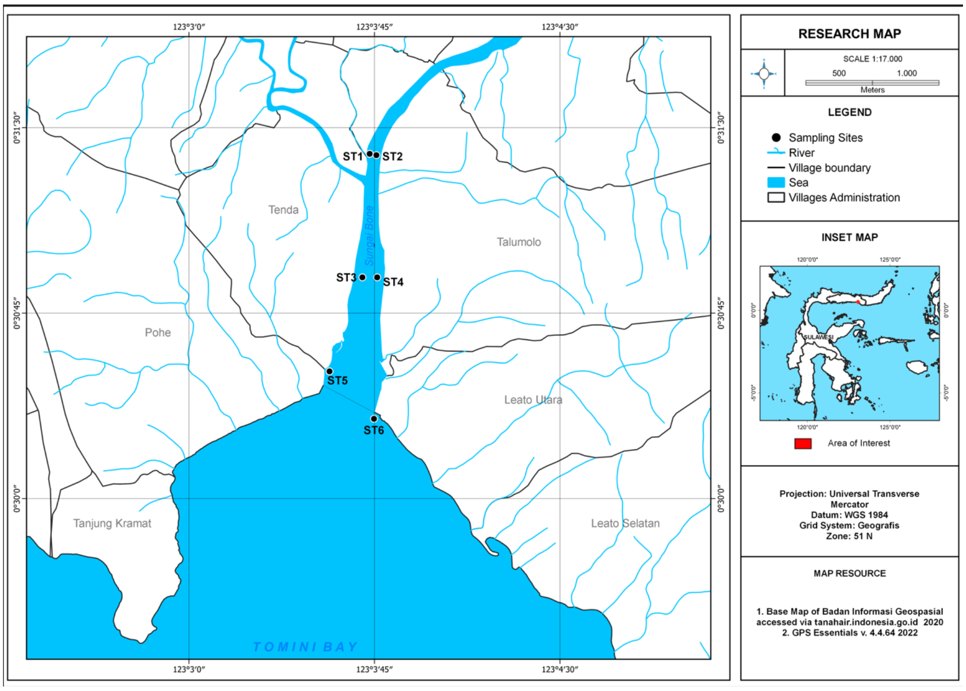
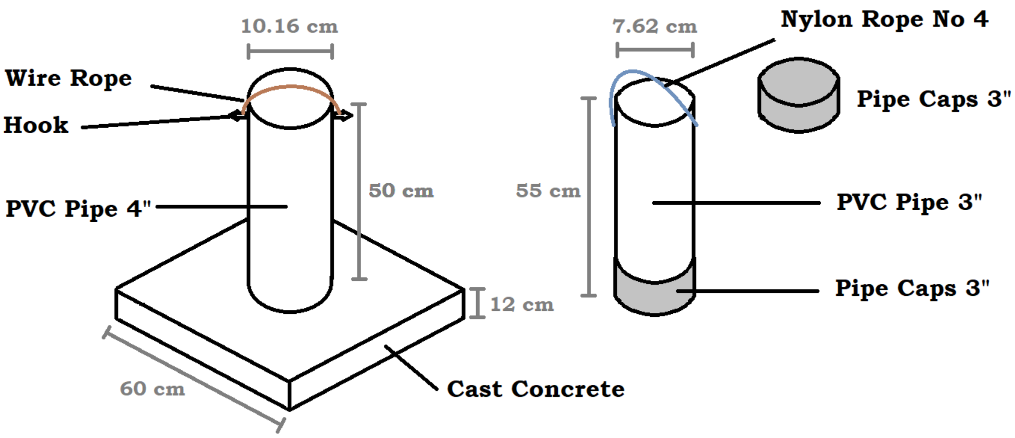


Figure 1. Stations for sedimentation rate and physical-chemical water quality sampling of Bone Estuary, Tomini Bay.

Sediment collection. Sediment was gathered from each sampling site along Bone Estuary using sediment traps (Figure 2) deployed in the depth of Bone Estuary waters. Six trap bases were placed at each station, while twelve trap columns were provided to be re-used when potting and lifting sediment from each trap base at each station every three days. During this research, 48 series of samples were compiled in total. The trapped sediment from the appropriate column was picked and stored in Ziplock plastic bags for laboratory analysis.



(a)

(b) (c)

Figure 2. Traps for monitoring sedimentation rate of Bone Estuary of Tomini Bay (a) dimension design; (b) concrete trap base (c) sediment trap columns.

A sampling of water parameters. The measurement of water quality parameters was carried out simultaneously with the sediment trap lifting. Depth was measured using a weighted scaled tie by dipping it into the bottom of the water. In situ parameters, including temperature and DO, were measured using the water quality smart sensor AR8210, pH was measured using a pH meter, salinity was measured using a refractometer, current velocity was measured using a drought float, and transparency was measured using a Secchi disc. The ex-situ turbidity parameter was measured using a turbidimeter, while TDS and conductivity were measured using a Portable E-1 TDS & EC meter. Daily tides data were obtained from a real-time recorder using the NAUTIDE Pro Ver. 3.1.11 application. In addition, daily precipitation was retrieved from https://bwssul2-gorontalo.net/ by averaging the precipitation data of the Bone River watershed.

Sediment analysis. Sediment samples from each station in the trap columns were placed in trays and labeled accordingly. The samples were dried under the sunlight. The sediment particle size was homogenized by grinding and discarding it from excess particles. Furthermore, each sediment sample was wrapped with aluminum foil and then placed into the oven at 110°C, for 24 hours. The aluminum foil wrap and each wrapped sediment (after drying) were weighed for the sample analysis data.

Data analysis

Sedimentation rate. The daily sedimentation rate measurement was calculated using the following formula (Srijati et al 2017):

Sedimentation rate = (A – B)/cross-sectional area of the pipe trap /duration of trap deploying at depths

Where:
A - weight of aluminum foil + sediment (g);
B - weight of aluminum foil (g);
π - 3.14;
r - radius of the sediment trap column (cm).

Water environmental parameters. Hydrological and physical-chemical water parameters were visualized in histograms to compare calculated parameter values among stations at every sampling time. Also, tides and precipitation data were analyzed descriptively in a graph.

Results

Sedimentation. Bone Estuary experienced various daily sedimentation rates ranging from 202.39-38554.09 g m^{-2} day^{-1} (Table 1). The appearance of Nike fish in the estuary occurred when the waters experienced a daily sedimentation rate of 871.32–19,670.98 g m^{-2} day^{-1}.

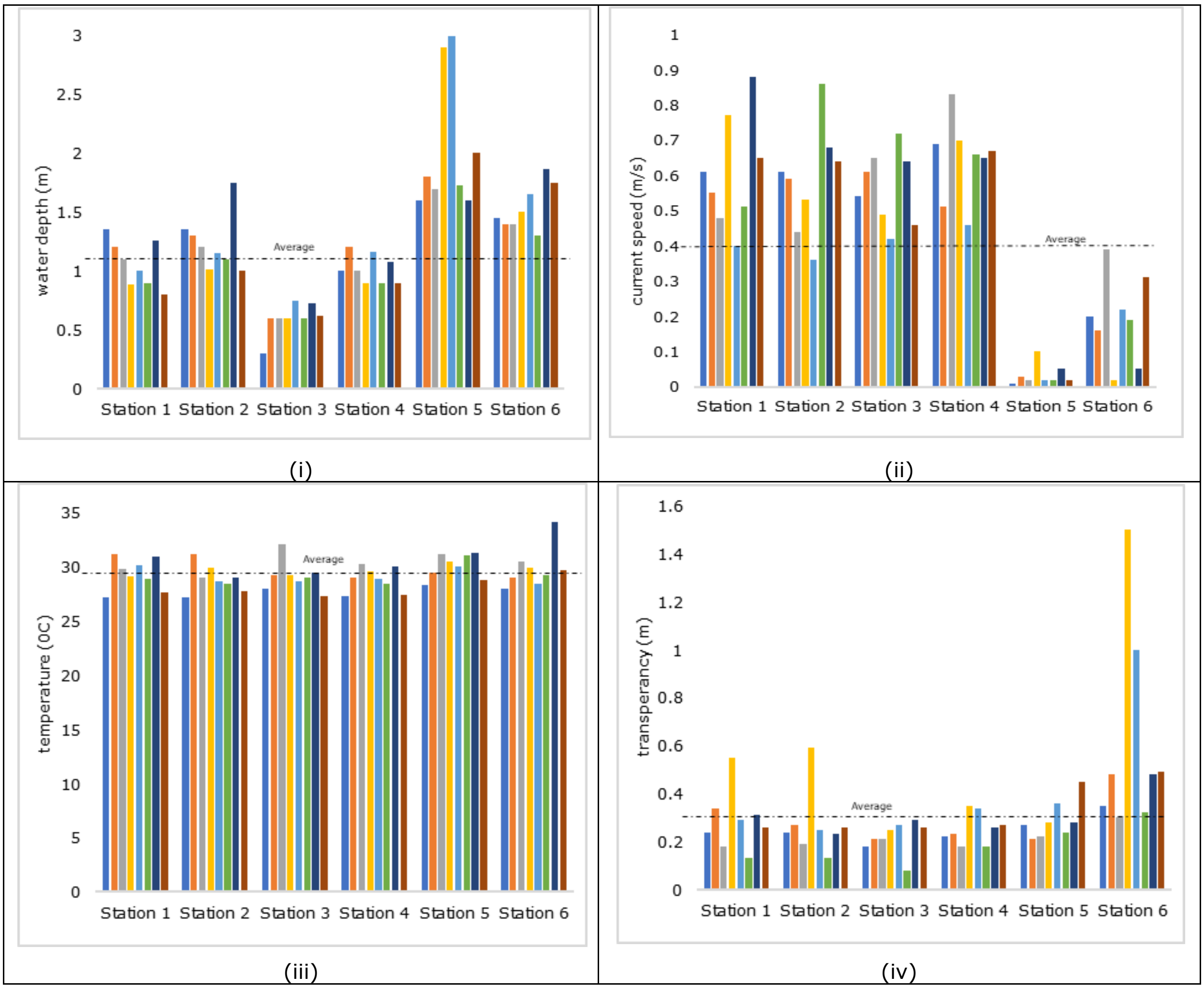
Table 1

Daily sedimentation rate of Bone Estuary

St	*Date of sampling*								*Average*
	7 Sep.	*10 Sep.*	*13 Sep.*	*16 Sep.*	*19 Sep.**	*22 Sep.**	*25 Sep.**	*28 Sep.*	*(g m^{-2} day^{-1})*
1	31,914.39	31,914.38	5,142.00	2,511.12	6,415.75	7,887.68	38,554.09	1,836.86	13,465.98
2	75,585.04	75,585.05	10,399.54	4,026.02	5,135.41	9,007.13	3,0972.46	2,571.27	19,670.98
3	49,732.65	52,442.14	18,120.12	8,231.03	3,264.00	14,329.76	20,603.27	2,728.87	17,102.74
4	78,070.76	26,672.74	5,522.09	4,940.15	4,159.30	11,111.10	17,533.24	4,413.98	10,621.80
5	891.83	610.27	157.23	3,660.37	645.19	164.36	78.25	1,741.79	1,008.21
6	1,449.81	1,689.32	301.66	2,719.18	202.39	140.78	226.52	819.43	871.32

St-station; 19–25 September* 2022-Natural appearance period of Nike fish in Bone Estuary.

Physical and chemical parameters. Depth and water quality parameters of Bone Estuary, the six stations during the seven days of observation of this study, were quite dynamic (Figure 3).



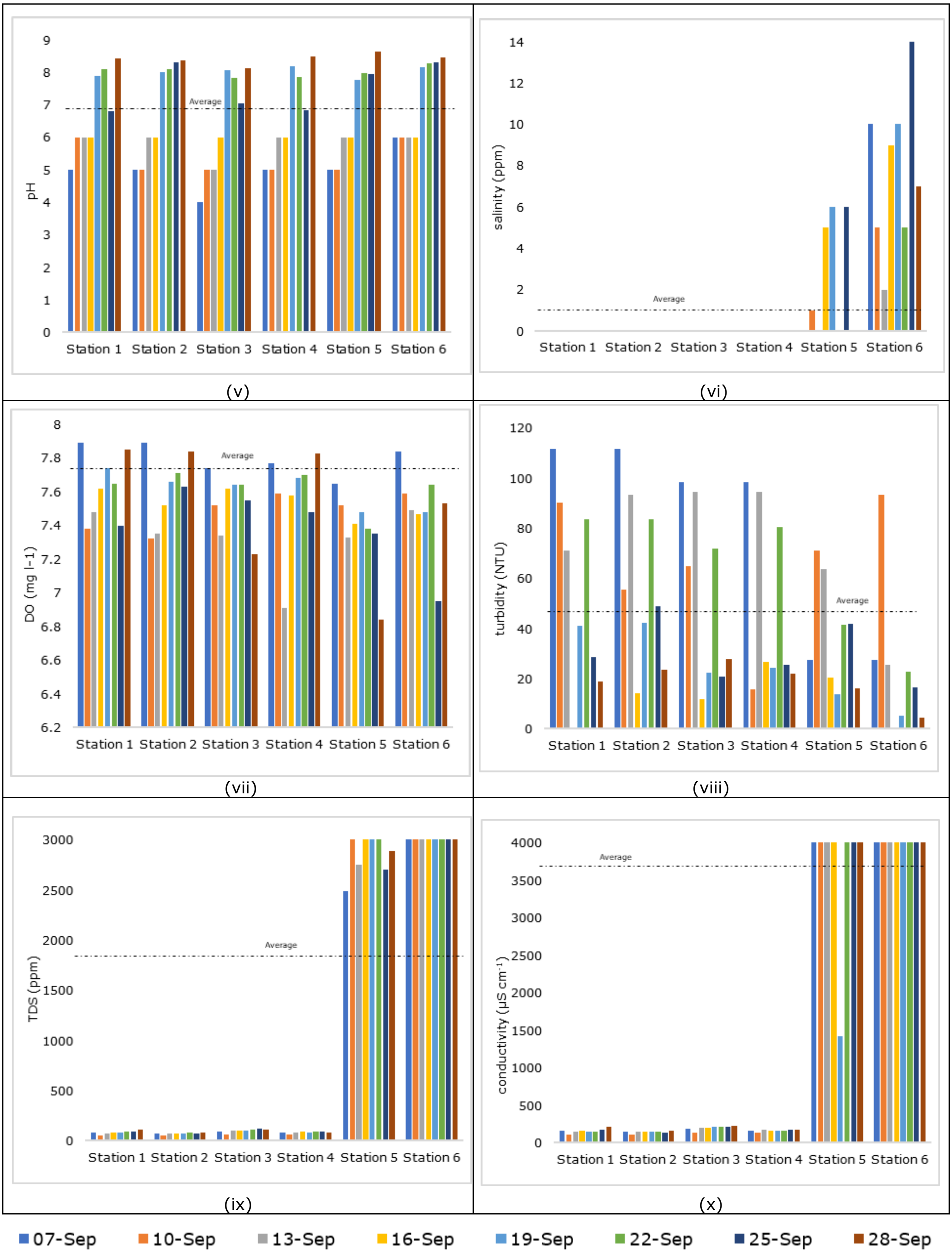


Figure 3. Water depth (i); current speed (ii); transparency (iii); water surface temperature (iv); water pH (v); salinity (vi); dissolved oxygen (vii); turbidity (viii) total dissolved solid (ix); conductivity (x).

The water depth range was 1.088–1.452 m. Physical parameters measured during the study include current speed (0.313–0.493 m s^{-1}), water transparency (0.180–0.587 m), surface temperature (27.67–30.82°C), salinity (0-14 ppm), turbidity (18.30–79.23 NTU), TDS (1353.0–2294.2 ppm), and conductivity (2705–3856 μS cm^{-1}). There are no extreme fluctuations in water physics at the station level, except for the transparency at Station 6, precisely on the 4^{th} observation day (16^{th} of September 2022) and salinity at Station 5 and Station 6. The water chemistry values, including pH (5.0–8.4) and DO (7.3–7.8 mg L^{-1}), recorded normal changes.

Tides and precipitation. The first appearance of Nike in September 2022, in the Bone Estuary, occurred in tide conditions of low amplitude, not at the highest tide peak (Figure 4). The appearance of the larvae in the Bone Estuary occurred when the water level was between 0.24 and 1.29 m.

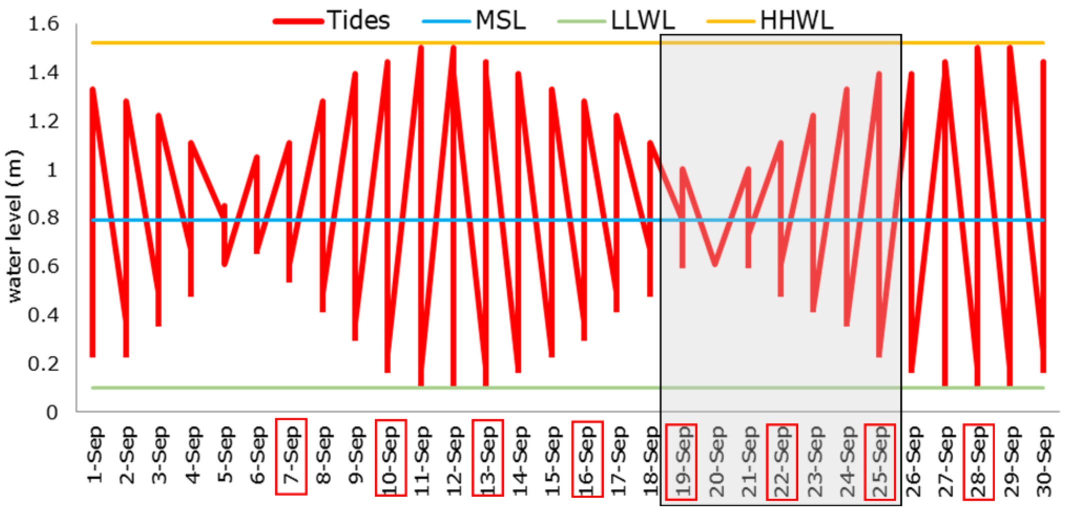


Figure 4. Daily tides of Bone Estuary (MSL-Mean Sea Level; LLWL-Lowest Low Water Level; HHWL-Highest High Water Level); gray area-the pattern of natural presence of Nike fish; sediment sampling was carried out on the date marked with the red box.

The average rainfall in September was 25.6 mm, with the highest intensity occurring on the 5^{th} of September 2022, while monitoring the sedimentation rate occurred in the average range of precipitation of 0–12.7 mm. Figure 4 shows that Nike fish appeared in the waters for seven consecutive days, in conditions of relatively low precipitation.

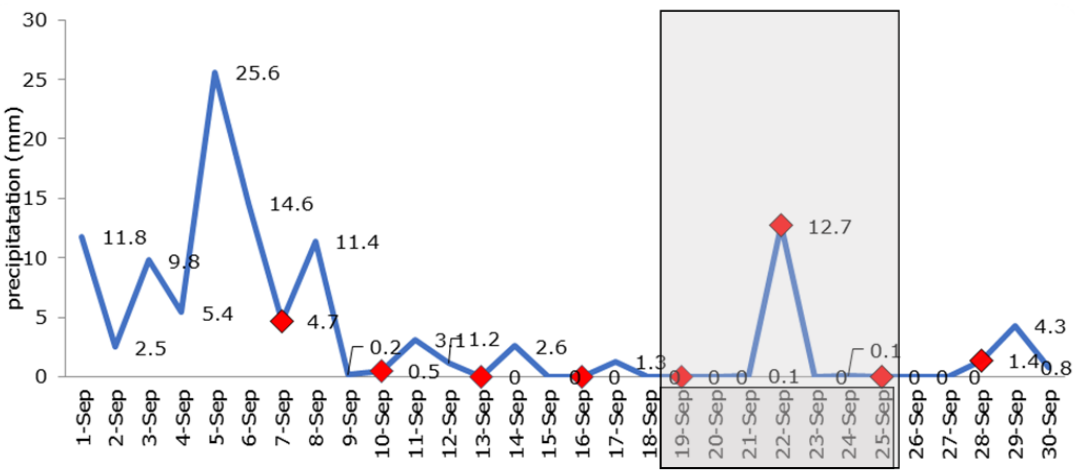


Figure 5. Average daily precipitation of Bone Estuary in September 2022 (precipitation during the sediment sampling is shown with red marks; the grey area marks the days of natural Nike fish presence).

Discussion. Sedimentation is a critical problem for human life and aquatic organisms (Roswaty et al 2014). Its daily rate in Bone Estuary shows a high condition compared to several areas (Table 2). The sedimentation process in waters can cause siltation and degradation of the water quality, due to the sediment particles carried by river flows and deposited around the estuary (Soeyanto & Arifiyana 2018). Sedimentation in the Bone Estuary can be considered a determining factor for the survival and success of the Nike fish migration. It will potentially cause alteration of the river elevation and estuary area, changing the trajectory of larval migration from the sea to the upper river. However, proving this hypothesis requires further detailed research.

Table 2

Comparison of the sedimentation rates of Bone Estuary and other areas

No	*Estuary area*	*Sedimentation rate (g m^{-2} day^{-1})*	*Reference*
1	Bone	871.32 – 19,670.98	This research
2	Socah	1,243.68 – 2,177.91	Rosyadewi & Hidayah 2020
3	Porong	2468.70 – 3907.17	Rosyadewi & Hidayah 2020
4	Musi	860.63 – 970.97	Barus et al 2020
5	Citayur	798 – 20530	Nabila et al 2021
6	Sambas	12614 – 27184	Saputra et al 2022
7	Langsa	269.4 – 2777.3	Erlangga et al 2022

The deposit rate from the first to third monitoring day in this study was relatively high compared to other sampling days at the same station. In detail, comparing sedimentation rates (Table 1) among the six stations revealed that the highest rate occurred at Station 4, on the 1st monitoring day (7th of September 2022). High precipitation rates occurred in early September, as shown in Figure 5. On the other hand, the lowest sedimentation rate occurred at Station 5, on monitoring day 7 (25th of September 2022), without precipitation at the sampling time, at a station area located far from the river. Consequently, the water discharge weakens the sediment transfer.

Estuaries are defined as semi-enclosed coastal bodies of water where the ocean water is diluted by land-derived freshwater discharges (Valle-Levinson 2011). The mixing of fresh water from rivers and sea in the estuary area causes changes in the physical oceanographic conditions (Rosyadewi & Hidayah 2020). Depth is a hydrological parameter that plays an essential role in providing space for the fish habitat. At Station 5, which has the highest average depth, there was recorded the lowest current velocity, since the station is far from the river, being located in an area of water that juts into the mainland; therefore, the horizontal movement of water masses, influenced by river currents, was hindered. A higher salinity was detected at Station 5 and Station 6, as these stations are close to the sea and far from freshwater intrusion. Water transparency values at Station 6 on the fourth day of observation (16th of September 2022) were relatively high compared to the other five stations. This is in addition to the absence of rainfall which has the potential to transport sediment particles. The low velocity is synchronized with the low turbidity occurring at the sampling stations located far from the effect of the Bone River's flow. There is an association between turbidity in the estuary and the river flow, which can be used to estimate the suspended particles concentration (Nguyen et al 2021). Furthermore, TDS and conductivity at Station 5 and Station 6 were relatively higher than at the stations located close to the Bone River, due to higher salinity levels. Salinity, TDS, and conductivity in the waters show a positive correlation (Naher et al 2017). Salinity is a dynamic environmental factor in estuaries, mainly associated with the influence of freshwater and seawater. Consequently, the other three factors, not directly affected by salinity, namely water temperature, pH, and DO, tended to be stable during the observation period.

Nike fish appeared in the waters when the estuary was in the lowest low tide and gradually moved towards the river as the water level increased. The tides transport the larvae passively to the Bone Estuary and then to upper locations along the river. Nike fish from Gorontalo waters, which empties into Tomini Bay, are also found in Paguyaman

Waters (Sahami & Habibie 2021) and in several areas of Sulawesi Island (Muthiadin et al 2020; Nurjirana et al 2019), although with a different local name. However, the larva frequency of occurrence day in other waters is not as high as their incidence in the Bone Estuary. So far, there are no scientific clarifications of the frequency differences of the larva's appearance. Nevertheless, several environmental parameters were predicted in explaining the variation in the frequency of appearance day of Nike fish in several regions, including parameters monitored in this study and any other external factors.

An estuary has high productivity since it continuously experiences organic and inorganic materials from land that flows through rivers and bordering waters (Rosyadewi & Hidayah 2020). This research merely reported the Bone Estuary water conditions before after and during the Nike fish's presence in the waters was detected. Therefore, the research data cannot accurately determine the key factors causing the emergence of Nike in the estuary. As a, the water parameters at different locations and periods should be compared in order to establish the main environmental parameters determining the Nike fish habitat. However, the extreme sedimentation rate in the estuary signals a significant threat to the sustainability of the amphidromous goby larva. According to (Rositasari & Rahayu 1994), an estuary is part of a marine sub-system comprising an assemblage of biota from the marine and freshwater. The main channel serves as an entry-exit gate for various types of fish and high-taxa invertebrates. These aquatic organisms take advantage of the richness of nutrients in the estuary area to carry out their growth through several phases of life. Therefore, it is necessary to examine and continuously observe the stability of the Bone Estuary as a critical habitat for Nike fish for implementing policies of habitat conservation.

Conclusions. Based on this monitoring study, Bone Estuary experienced a daily sedimentation ranging from 871.32 to 19,670.98 g m^{-2} day^{-1}. The measured hydrological, physical, and chemical characteristics of the estuary, as a critical habitat for Nike fish, include the water depth (1.25±0.49 m), current speed (0.44±0.25 m s^{-1}), transparency (0.32±0.14 m), water surface temperature (29.37±0.88°C), pH (6.77±0.32), salinity (1.33±2.44 ppm), DO (7.54±0.16 mg L^{-1}), turbidity (46.80±19.74 NTU), TDS (1,852.29±2,994.66 ppm), and conductivity (3,521.25±5,942.92 μS cm^{-1}).

Acknowledgements. This project is part of Higher Education Fundamental Research (PDUPT) fully funded by the Ministry of Education, Culture, Research, and Technology of Republic Indonesia (Kemdikbud-ristek) Year 2022 with the decree number of 225/E5/PG.02.00.PT/2022 and contract number of B/100/UN47.D1/PT.01.03/2022. The authors highly appreciate Ahmad Musyali, S.Pi. and Yelyan Rasyid, S.Pi. for their help in the field sampling and laboratory analysis.

Conflict of interest. The authors declare no conflict of interest.

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*** https://bwssul2-gorontalo.net/ Minister for Public Works and Human Settlements. Directorate General of Water Resources. Central Sulawesi River Region II Gorontalo.

Received: 03 October 2022. Accepted: 16 November 2022. Published online: 27 November 2022.
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How to cite this article:
Olii A. H., Pasisingi N., 2022 Bone Estuary of Tomini Bay as habitat of "Nike" fish: sedimentation rate and physical-chemical water characteristics. AACL Bioflux 15(6):3083-3092.