Mudskipper is amphibious fish that inhabited sandy beaches, mudflat, and mangrove areas. This fish is euryhaline because of its tolerance to varying salinity as well as pH, temperature, conductivity, and dissolved oxygen. This study aimed to identify the taxonomy status of mudskipper in Banua Pangka Mangrove Ecotourism, Seta-Seta Beach, and Masiae River, it was expected to be additional information used as a basis for management and benefit of the coastal ecosystem. The sampling method of this study was purposive sampling. Morphological identification was carried out by observing morphometric and meristic character. The result found two mudskipper species from three sampling sites, namely Periophthalmus argentilineatus and Periophthalmus freycineti. Water quality parameter values at three sampling locations were within the optimal range for mudskipper species according to the previous study. The temperatures ranged from 28-33 °C, the dissolved oxygen ranged from 2.04-6.74 mg/L, the pH ranged from 6.57-7.1, conductivity ranged from 3.47-41.2 mS/cm, and the salinity ranged from 1.7-2.58 ‰.

INTRODUCTION
Indonesia is the biggest archipelagic nation with a length of coastline at 95.181 km [1] and mangrove areas estimated at 3,244,018 ha, which is mainly distributed in Sumatera, Jawa, Kalimantan, Sulawesi, and Papua [2]. These mangrove areas are home to 35 % of fish in the world [2]. The Bone Gulf is one of the Indonesian waters located between South Sulawesi and Southeast Sulawesi, with a length of coastline at 1.128 km [3]. It bears mangrove areas, sandy beaches, and a coast planted with palm oil. The potential for large fishery resources is caused by being inhabited by various kinds of fish.

Mudskippers are one of the fish-inhabited coasts of the Bone Gulf. Mudskippers belong to the family Gobiidae and subfamily Oxudercinae, which comprises 10 genera and 40 species [4, 5]. Their habits on the exposed littoral surface are due to their ability to respire through humid skin, mucosal lining in the mouth, and throat [6]. They can adapt to various environmental conditions as well, including temperature, pH, salinity, and dissolved oxygen [6]. They can be found on mudflats, sandy beaches, and mangrove areas [5].

Mudskipper identification can be carried out by identifying morphological characters, including morphometric and meristic characters. Morphometric characters describe body shape measured in cm, like total length, snout length, etc [7, 8]. While meristic characters refer to the number of countable body structures, like the number of dorsal and pelvic fin rays, etc [7, 8]. Nugroho et al. [9] identified 23 morphometric characters and eight meristic characters toward mudskippers from the coast of Tarakan. They found four species, namely Periophthalmus malaccensis, Periophthalmus barbarous, Periophthalmus freycineti, and Boleophthalmus boddarti.

Mudskippers play an important role in the environment and humans. Due to being one of the coastal fish that can accumulate pollution of coastal water, mudskippers are used as bioindicators of various water pollution in the coastal ecosystem [6]. Besides, the abundance and distribution of mudskippers become an indicator of habitat health as well in the coastal ecosystem [6]. In a food chain, mudskippers are important prey for marine visitor species, such as shorebirds and others [10]. As a food source, mudskippers are consumed either as a protein source or as traditional medicine in some countries, such as India [11], Bangladesh, Thailand, the Philippines, China, and Taiwan [10]. However, their consumption is limited caused of their role as bioindicators in the coastal ecosystem.

Mudskippers are widely distributed on the coast of Sumatra, Jawa, Kalimantan, Sulawesi, Lesser Sunda, Maluku, and Papua [12]. Banua Pangka, Seta-Seta Beach, and Masiae River are mangrove coastal ecosystems inhabited by mudskipper in South Sulawesi. Banua Pangka is a mangrove ecotourism located in East Luwu.
regency adjacent to Fish Auction [13]. Mudskippers can be easily seen under mangroves, but there is no previous data or study about mudskipper in Banua Pangka. Seta-Seta beach is a tourist attraction that become one of the water conservation areas in South Sulawesi located in North Luwu Regency [14]. According to data from the Marine and Fisheries Ministry, Seta-Seta Beach is inhabited by 71 species of reef fish and no mudskipper data [14]. Masiae River is a river located on the coast of Wajo Regency [15]. In 2001, Haryono conducted a study of fish biodiversity in Masiae River and found no mudskipper [15].

Sulawesi has only 8 species mudskipper [12]. The lack of research was considered to correlate with the low number of mudskipper in Sulawesi [12]. This study aimed to give information on mudskippers’ identity from South Sulawesi to be the basis for management and benefaction.

**METHODS**

This study was conducted in May-July 2022. The type of this study is descriptive qualitative and quantitative, with a survey approach. Sampling sites were Banua Pangka Mangrove Ecotourism in East Luwu (2°37’08.6” S; 120°47’33.5” E), Foreang Seta-Seta Beach in North Luwu (2°40’57.9” S; 120°37’14.8” E), and upstream of Masiae river located at Paojepe Village in Wajo (3°47’15.2” S; 120°22’23.9” E) (Figure 1). The mudskipper collection stations were determined using a purposive sampling technique, based on the habitat of mudskipper in the mangrove area.

**A sampling of mudskippers.** Sampling was done using a hand fishing net (serokan) in low tide in the morning when they were outside of their burrows for feeding and doing other activities. Morphological identification comprised the observation of 23 morphometric characters (Figure 2). It was measured with a ruler and vernier caliper with an accuracy of 0.05 mm. The measured morphometric characters of mudskipper were TL: total length, SL: standard length, SnD2: snout to the second dorsal fin, D2: length of the second dorsal base, CpL: caudal peduncle length, SnD1: snout to the first dorsal fin, D1: length of the first dorsal base, SnP: snout to pectoral fin, HL: head length, SnL: snout length, E: eye diameter, HD: head depth, BD: body depth, CpD: caudal peduncle depth, CL: caudal fin length, P: pectoral fin length, SnPv: snout to pelvic fin, PvL: pelvic fin length, PFA: pelvic fin to anal fin, SnA: snout to anal fin, Ab: length of anal fin base, HW: head width, IO: interorbital length. Observation of meristic characters consisted of the number of first dorsal fin rays (D1), second dorsal fin rays (D2), pectoral fin rays (P), pelvic fin rays (Pv), anal fin rays (A), caudal fin rays (C),

![Figure 1. Sampling sites. Yellow = Banua Pangka, red = Seta-Seta beach, green = Masiae river](https://biotropika.ub.ac.id/)
Figure 2. The pattern of mudskipper morphometric measurement [18]

predorsal scale, longitudinal scale, and transverse-forward scale. The predorsal scale was counted from the posterior interorbital to the beginning of the first dorsal fin. The longitudinal scale was counted from the dorsoposterior of opercular membrane attachment, continued on a posteroverental diagonal to the pectoral fin tip, and straight to the posterior edge of the hypural plate or caudal fin attachment. The transverse-forward scale was counted from the dorsoanterior of the anal fin origin to the base of the first dorsal fin. Species determination was done by referring to Murdy [4], Takita et al. [16], and the Mudskipper [17].

Measuring of water quality parameter. Water sampling and measurement were conducted in the morning around 08.00 and in shallow depths around mangrove roots where mudskipper like to swim and climb. Water quality parameters measured in this study were temperature, pH, salinity, conductivity, and dissolved oxygen (DO). The temperature was measured on-site with an alcohol thermometer. pH, salinity, conductivity, and DO were measured with a water quality tester pen digital at the laboratory of the environmental agency of East Luwu and Luwu. Especially DO measurement at the laboratory of the environmental agency of Luwu, water from the sampling location was put into the 125 ml Winkler bottle. 1 ml MnSO4 and 1 ml NaOH were added to the bottle. The bottle was closed. It was shaken until the water became homogenous and a precipitate formed. The next step was titration at the laboratory.

Data analysis. All samples from three sampling locations were observed by focusing on morphometric and meristic characters, and coloration as well. Morphometric character data obtained were subjected to discriminant analysis using SPSS version 16.0 for Windows. It aimed to know the main distinguishing characters among samples. It was done in two steps. Step one was analyzing all morphometric characters and then step two was determining the main distinguishing characters. The main distinguishing characters were subjected to principal component analysis (PCA). It was aimed to determine the grouping of samples through character correlation. Meristic characters were observed and numerically categorized as binary data. It was analyzed in phenetic analysis to determine the cluster according to the similarity value of samples. The algorithm in the analysis is Unweighted Pair Group Method with Arithmetic Average (UPGMA). While similarity was analyzed by Simple Matching Method (SSm) in MVSP software.

RESULTS AND DISCUSSION

Identification of mudskipper. Oxudercinae has an elongated body. They have small to moderate heads. The eyes are on the dorsal of the head. The number of fin rays is as follows: first dorsal fin with 4-17 elements; second dorsal fin with 10-33 elements; anal fin with 9-31 elements; pectoral fin with 11-25; pelvic fin I,5. The body size is small to moderate. The body length is about ≤ 20 cm or 10 – 30 cm in SL [5, 19].

Mudskipper found at Banua Pangka, Poreang Seta-Seta Beach, and Paojepe village is two species, namely Periophthalmus argentilineatus
and *Periophthalmodon freycineti*. The following is the description of the mudskippers characters.

**Material examined.** 10 specimens of *Periophthalmodon freycineti* from the stream of Masiae River. Size ranges are 156-192 mm in SL (Figure 3).

**Characteristic.** The body is elongated. Mouth inferior. The isthmus lacked scale, but the snout scaled. D1 fin rays are IV-V (which V is rare). The length of D1 base is less than 10% SL. The number of D2 fin rays is I.12. D1 and D2 are not connected by any membrane. Pectoral fin rays are 14. The pelvic fin is I.5 and completely united with the frenum. The number of anal fin rays is I.12. Scale is cycloid. Number of caudal fin rays is 15. The longitudinal scale is 55-57, the predorsal scale is 16, and the transverse forward is 15-17.

**Coloration.** Dorsal and flanks are brown with numerous white spots on the head, especially around the snout, and on the flanks. The ventral body is white. A dark brown dorsal stripe extends from the eye to the caudal. 5-6 saddle-like brown bars extend vertically on the flank. D1 is brown with a white margin. D2 is brown to blackish with a white margin as well. The pectoral fin is yellowish to brownish at distal and dusky at proximal. Caudal fin is dark brown. The pelvic fin is white to hyaline.

**Distribution.** In Indonesia, Kalimantan, Sulawesi, Maluku, Lesser Sunda, and Papua [12].

While in Sulawesi, South Sulawesi (Sinjai, Lowu, Wajo), Central Sulawesi (Banggai, Palu, Poso), Southeast Sulawesi (Kendari, Konawe) [20, 21], and North Sulawesi (Likupang, Bajo, Bunaken Island, Mantehage Island, Wawontulap) [22].

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**Periophthalmodon freycineti**

*Figure 3. Periophthalmodon freycineti, SL= 192 mm, Masiae river, Keera, Wajo, South Sulawesi, Indonesia. A. rays of D1 and D2, B. five and four rays of D1, C. pelvic fin*
Periophthalmus argentilineatus

70.5 mm

Figure 4. Periophthalmus argentilineatus, SL = 57.2 mm, the first site was Banua Pangka, Wotu, East Luwu, South Sulawesi, Indonesia. The second site was Seta-Seta beach, Tanalili, North Luwu, South Sulawesi, Indonesia. A. rays of D1 and D2, B. pelvic fin

Analysis of morphometric characters. Even though specimens from Banua Pangka and Seta-Seta Poreang Beach were identified as Periophthalmus argentilineatus, they varied in the number of meristic characters. Therefore, the differentiation between them is interesting to analyze. In this analysis, specimens from Banua Pangka were named Periophthalmus argentilineatus BP. While specimens from Seta-Seta Poreang beach were named Periophthalmus argentilineatus PO. Specimen from Masiae river remain Periophthalmodon freycineti.

Measurement of 23 morphometric characters was done to ensure the taxonomical status of specimens. Range of standard length Periophthalmus argentilineatus BP is 57.91 mm ±4.750, Periophthalmus argentilineatus PO is 54.735 mm ±3.249, and Periophthalmodon freycineti is 181.6 mm ±10.511. In a previous study, Periophthalmodon freycineti in Tarakan was 153 mm in SL [9] and Periophthalmus argentilineatus specimens in Sekotong were 37.85-51.66 mm in SL. Morphometric and meristic characters were used in morphological identification because they were able to classify or separate taxa [19].

Data obtained from the measurement of morphometric characters were subjected to discriminant analysis. This analysis helps to find out the most distinguishing character which can differentiate interspecies. The result of the discriminant analysis showed four selected characters, namely A (length of the anal base), CpL (caudal peduncle length), PvL (pelvic fin length), SnD1 (distance from snout to D1) (Table 1). These characters were selected on Wilks’s Lambda test with a significance value of 0.000 which means significantly different.

The four selected characters were then analyzed on PCA using PAST program. PCA is a multivariate technic used to analyze some quantitative dependent variables which correlate with each other [23]. PCA is widely used to classify or separate taxa through the correlation of characters. The result of PCA showed that Periophthalmus argentilineatus BP and PO have grouped in quadrants II dan III, while Periophthalmodon freycineti was independently grouped in quadrants I and IV (Figure 5).

Relationship among Periophthalmus argentilineatus BP and PO, and Periophthalmodon freycineti as well as showed by a dendrogram constructed according to Euclidean distance. It showed that Periophthalmus argentilineatus BP and PO have grouped in one clad, while Periophthalmodon freycineti was independently grouped (Figure 6).

Analysis of meristic characters. Phenetic analysis of Periophthalmus argentilineatus BP, Periophthalmus argentilineatus PO, and Periophthalmodon freycineti based on 21 morphological characters using the UPGMA method was performed by NTSYS 2.02i program. The dendrogram formed showed Periophthalmus argentilineatus BP and Periophthalmus argentilineatus PO were grouped, while Periophthalmodon freycineti was independently grouped (Figure 7).
Table 1. Main distinguishing characters of mudskipper specimens

<table>
<thead>
<tr>
<th>Characters</th>
<th>Banua Pangka</th>
<th>Poreang</th>
<th>Paojepe</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9.36±0.764</td>
<td>8.905±0.768</td>
<td>40.7±2.201</td>
</tr>
<tr>
<td>CpL</td>
<td>11.975±1.180</td>
<td>10.525±0.972</td>
<td>32.63±2.020</td>
</tr>
<tr>
<td>PvL</td>
<td>7.312±0.831</td>
<td>7.315±1.560</td>
<td>30.45±1.257</td>
</tr>
<tr>
<td>SnD1</td>
<td>20.78±2.232</td>
<td>19.49±1.995</td>
<td>65.1±4.971</td>
</tr>
</tbody>
</table>

Figure 5. Clustering of mudskippers based on main distinguishing characters

Figure 6. Dendrogram of mudskippers based on main distinguishing characters

Figure 7. Dendrogram of mudskippers based on phenetic analysis

According to similarity value, *Periophthalmus argentilineatus* BP and *Periophthalmus argentilineatus* PO were similar by 100% (Table 2). It showed that the different numbers of some meristic characters did not separate them to be one species. While *Periophthalmodon freycineti* with more different meristic characters from other specimens showed a 38.1% of similarity value.

Table 2. The similarity of mudskippers based on phenetic analysis

<table>
<thead>
<tr>
<th></th>
<th>BP</th>
<th>PO</th>
<th>PAO</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PO</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>PAO</td>
<td>38.1</td>
<td>38.1</td>
<td>100</td>
</tr>
</tbody>
</table>
Habitat environment of mudskipper. Mudskipper specimens were found in Banua Pangka, Seta-Seta Beach, and Masiae River. Banua Pangka is a mangrove ecotourism that is close to Fish Auction. Seta-Seta Beach is a sandy beach with mangrove vegetation and wide fishponds around. While upstream of Masiae River is a narrow river located around a residential area and ±2 km away from the shoreline. Mangrove vegetation at those locations consisted of Sonneratia sp., Rhizophora sp., Hibiscus sp., Pandanus sp., and Nypa sp.

Those three locations have different substrates. Banua Pangka had a mudflat as a mangrove vegetation floor. Mudskippers seemed to ‘walk’ on mudflats among mangrove roots, plastic waste from ecotourism visitors, and shipwrecks that belong to local fishermen. Seta-Seta Beach had a mudflat as a mangrove vegetation floor and sandy substrate at the beach. In low tide, mudskipper ‘walked’ on sandy beaches or mudflats among mangrove roots. While in high tide, mudskipper climbed to higher places that were not submerged in seawater, like rocks and higher mangrove roots. Upstream of Masiae River had a mudflat substrate. As a part of the intertidal area, this upstream would be submerged in high tide and vice versa. Mudskippers seemed to ‘walk’ on a mudflat in low tide, but they seemed to swim or climb to a higher place in high tide.

Those locations were influenced by anthropogenic activities. Banua Pangka, Seta-Seta Beach, and upstream of Masiae River were used as ‘traffic lanes’ of the boat containing fish or seaweed. Banua Pangka and Seta-Seta Beach received plastic waste from visitors and upstream of Masiae river received household waste. Especially Seta-Seta Beach, Hindu people used to worship there.

Water quality parameter. Mudskipper life is supported by good-quality water. The parameters of water quality measured in this study were temperature, pH, salinity, conductivity, and DO (dissolved oxygen). The result is in the Table 3 as follows.

Water temperatures at three locations ranged from 28-33 °C. In a previous study, the temperature of Kairatu waters in Maluku inhabited by the same species ranged from 30.01-30.05 °C [24]. While the temperature of the beach of southeast India inhabited by the same species ranged from 23.5-35.5 °C [25]. Water temperature is closely related to DO. An increase in water temperature causes a decrease in DO and an increase in DO demand [26]. An optimal temperature keeps the mudskipper actively moved. While at low temperature, mudskipper tends to hide in their burrows [27]. According to the previous study, water temperatures at three locations were optimal for mudskipper.

The result of the pH measurement showed pH at three locations ranged from 6.59-7.1. pH in Kairatu waters was 7.3-7.5 [24]. Some of the optimal pH for mudskipper was 4-11 [15], 5.8-6.5 [25], and 6.5-7.3 [28], pH value is an index of hydrogen ions (H⁺) that shows the balance of acids and bases. pH is an indicator of chemical balance which is important for aquatic organisms [29]. pH values at study sites were optimal for mudskipper based on the previous study.

Salinity in Banua Pangka and Seta-Seta Beach inhabited Periophthalmodon argentinellatus was 2.27 ppt and 2.58 ppt. Salinity in waters inhabited by the same species was 5-7 ppt in Kairatu Maluku [24] and 27-28 ppt in the Ambon mangrove area [30]. Salinity on the southeastern coast of India inhabited genus Periophthalmodon was 24.3-34.4 ppt [25]. While salinity in the south China sea inhabited by the same genus reached the lowest salinity up to 3 ppt [31].

Upstream of Masiae River inhabited Periophthalmodon freycineti showed its salinity at 1.7 ppt. Fly river, Papua New Guinea, inhabited same species showed 0-5 ppt and >10 ppt [32]. Periophthalmodon septenarius inhabited mangrove area in Peninsular Malaysia with a salinity of 1-3 ppt in high tide [33]. Mudskippers are considered euryhaline because they can live in various salinity [34, 35]. Periophthalmodon minutus was kept in burrows during the dry season in Australia with a salinity of 75 ppt [16]. According to salinity in Banua Pangka, Seta-Seta Beach, and upstream of Masiae River, those waters were included in freshwater (oligohaline) [36, 37] and still in the optimal salinity range for mudskipper.

<table>
<thead>
<tr>
<th>No</th>
<th>Locations</th>
<th>Temperature (°C)</th>
<th>pH</th>
<th>Salinity (%/ppt)</th>
<th>Conductivity (mS/cm)</th>
<th>DO (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Banua Pangka</td>
<td>31.1</td>
<td>7.1</td>
<td>2.27</td>
<td>38.2</td>
<td>6.74</td>
</tr>
<tr>
<td>2</td>
<td>Seta-Seta Beach</td>
<td>33</td>
<td>6.57</td>
<td>2.58</td>
<td>41.2</td>
<td>6.12</td>
</tr>
<tr>
<td>3</td>
<td>Masiae River</td>
<td>28</td>
<td>7.09</td>
<td>1.7</td>
<td>3.47</td>
<td>2.04</td>
</tr>
</tbody>
</table>
Conductivity in Banua Pangka, Seta-Seta Beach, and Masiae River was 38.2 mS/cm, 41.2 mS/cm, and 2.04 mS/cm respectively. While the ideal conductivity for fish growth was <750 mS/cm [15]. According to the ideal conductivity value, conductivity in those three locations was still in the ideal range for mudskippers. Conductivity represents a liquid ability to conduct electricity which depends on ion concentration and temperature. Conductivity is closely related to salinity, therefore high salinity will increase conductivity. In the estuary, high tide increases conductivity value, and vice versa [36, 37].

DO in three locations was 2.04 – 6.74 mg/L. Maro River and Payumb Beach in Merauke inhabited mudskipper showed the value of DO 1.85 and 1.82 mg/L respectively [34]. DO shows dissolved oxygen levels needed for the respiration and metabolism process [28]. The decrease in DO was due to an increase in temperature and salinity [38]. Roman et al. [26] stated that <2 mg/L DO in water was the category of hypoxia. It degraded the quality of the aquatic ecosystem [39] in terms of growth, mobility, reproduction, recruitment, and fish mortality [40]. Fish avoid hypoxia areas by either moving horizontally or vertically to the edge of that area [40]. Mudskippers take refuge in burrows during high tides and high temperatures to avoid hypoxia [16]. According to the result of the measurement, the value of DO in three locations was in an optimal range for the mudskipper.

CONCLUSION

In this study, two species were found in Banua Pangka mangrove ecotourism, Seta-Seta Beach, and upstream of Masiae River, namely *Periophthalmus argentilineatus* and *Periophthalmodon freycineti*. The most distinguishing characters from the discriminant analysis were A (length of the anal base), Cpl (caudal peduncle length), Pvl (pelvic fin base length), and SnD1 (length of the snout to first dorsal fin). In addition, temperature, pH, salinity, conductivity, and DO were in an optimal range for mudskipper, with the ranges of 28-33 °C, 6.57-7.1, 1.7-2.58 ppt, 3.47-41.2 mS/cm, and 2.04-6.74 mg/L respectively.

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