

# [biodiv] Submission Acknowledgement

1 pesan

Ahmad Dwi Setyawan via SMUJO <support@smujo.com> Balas Ke: Ahmad Dwi Setyawan <editors@smujo.id> Kepada: Melki Melki <melki@unsri.ac.id>

Melki Melki:

16 Februari 2025 pukul 14.11

Thank you for submitting the manuscript, "Unveiling the Secrets of the Giant Mudskipper: A Comprehensive Analysis of Morphology and Population Dynamics at Sungsang, South Sumatra" to Biodiversitas Journal of Biological Diversity. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Submission URL: https://smujo.id/biodiv/authorDashboard/submission/21288 Username: melki

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.



# [biodiv] Editor Decision

1 pesan

 Smujo Editors via SMUJO <support@smujo.com>
 22 Februari 2025 pukul 14.04

 Balas Ke: Smujo Editors <editors@smujo.id>
 Kepada: Melki Melki <melki@unsri.ac.id>, Fadhilah Dzakiyyah Ananta <FD\_ananta@gmail.com>, Isnaini <Isnaini@mipa.unsri.ac.id>, Fitri Agustriani

 <fitri\_agustriani@yahoo.com>, Rezi Apri <rezi\_apri@unsri.ac.id>, Hartoni <hartoni@mipa.unsri.ac.id>, Ellis Nurjualisti Ningsih <ellis.nurjualisti@gmail.com>, Jeni Meiyerani

 <jenimeiyerani24@gmail.com>

Melki Melki, Fadhilah Dzakiyyah Ananta, Isnaini, Fitri Agustriani, Rezi Apri, Hartoni, Ellis Nurjualisti Ningsih, Jeni Meiyerani:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia". Complete your revision with a Table of Responses containing your answers to reviewer comments (for multiple comments) and/or enable Track Changes. We are waiting for your revision in the system (https://smujo.id/biodiv), do not send it via email.

Our decision is: Revisions Required

Reviewer A:

Dear Author(s),

Thank you very much for your submission. Unfortunately, you still did not revise some of my reviews before. Here are my review.

-Abstract is too brief. An abstract is required (about 200-300 words).

- Running title is about 5-7 words. Please add it after Keywords
- -The introduction is too brief. An introduction is required (about 600-700 words).
- The discussion is too brief to be published in the journal. Please add more
- For non mother tongue, a Certificate of Proofreading from USA, UK, Canada or Australia is needed.
- All manuscripts must be written in clear and grammatically correct English (U.S.).

-Please write all the citations and references based on the author's guidelines (https://smujo.id/biodiv/guidance-for-author), include DOI. Kindly see the example below: e.g.,

Mukkun L, Kleden YL, Simamora AV. 2021. Detection of Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) in maize field in East Flores District, East Nusa Tenggara Province, Indonesia. Intl J Trop Drylands 5: 20-26. DOI: 10.13057/tropdrylands/t050104.

- The usage of "et al." in long author lists will also be accepted. For example, if the number of authors is more than 20, then it is permissible to use "et al."; if there are less than 20, writing all the authors' names is recommended.

Kindly check and correct accordingly Thank you

Recommendation: Revisions Required

\_\_\_\_\_

Biodiversitas Journal of Biological Diversity

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.

#### - The reviewer A comment: Abstract is too brief. An abstract is required (about 200-300 words)

#### Autor's response

We revised the abstract and added a sentence at the lines 13 to 18, as follow:

"Mudskipper fish are also found in the Sungsang coast, an estuary of the Musi River that is fed by river water from three provinces in Indonesia: South Sumatra, Lampung, and Bengkulu. The objective of this study was to analyze the morphology and population dynamics of mudskippers along with their environmental parameters in Sungsang coastal, South Sumatra. For this study, mudskipper specimens were collected from five sampling sites along the Sungsang coast and analyzed for morphometric characteristics, length-weight relationships, and their correlations with key environmental parameters like temperature, pH, and dissolved oxygen".

#### - The reviewer A comment: Running title is about 5-7 words. Please add it after Keywords

Autor's response

We added running title at the line 28, as follow:

"Running title: Morphology and Population Dynamics of Mudskipper"

# - The reviewer A comment: The introduction is too brief. An introduction is required (about 600-700 words)

#### Autor's response

We revised the introduction section and added a sentence on lines 46 to 66 with the word count of the introduction 654, as follow:

"Giant mudskippers are distinguished by their unique morphologies, which facilitate movement in both aquatic and terrestrial environments. Their pectoral fins are specialized for navigating on land, a crucial adaptation for survival in the intertidal zone (Pace and Gibb 2009; Zhou et al. 2023). The anatomical structure of these fins is not only important for movement, but also reflects the evolutionary transition from aquatic to terrestrial life (Ziadi-Künzli et al. 2024). For example, the robust fin morphology allows mudskippers to generate thrust on land, which is crucial for escaping predators and foraging for food (Pace and Gibb 2009). Furthermore, studies have indicated that pelvic fin morphology varies among mudskipper species, affecting their climbing behavior and overall movement (Hidayat et al. 2022).

The giant mudskipper is a bioindicator species, which means that its presence or absence can indicate the ecological health of its habitat. Its presence and abundance in the Sungsang estuary are an indication of environmental conditions, especially related to heavy metal pollution (Santoso et al. 2020; Santoso et al. 2024). Furthermore, the population structure of mudskippers in the region has been the subject of study, yielding insights into their reproductive biology and fecundity, which are influenced by seasonal changes and environmental factors (Ridho et al. 2021). The timing of spawning activities, for example, is correlated with the southwest monsoon, which affects resource availability and habitat conditions (Simon et al. 2012).

The biodiversity of fish species in the Sungsang estuary, including the giant mudskipper, is influenced by a variety of environmental factors. Numerous studies have documented the species diversity and community composition in this region, emphasizing the importance of mangrove ecosystems as critical habitats for mudskippers and other aquatic species (Fauziyah et al. 2019). However, the ongoing threat of human activities, such as deforestation and pollution, poses a significant threat to the ecosystem, thereby impacting mudskipper populations and their role. Consequently, conservation efforts are imperative to safeguard the habitat and ensure the long-term sustainability of mudskippers in South Sumatra (Septinar et al. 2023)."

#### - The reviewer A comment: The discussion is too brief to be published in the journal. Please add more

#### Autor's response

We revised the result and discussions section and added a sentence, as follow:

lines 150 to 158:

"and a more pronounced range of 24.4 to 34.4 ppt (Taniwel et al. 2020). The significance of these salinity levels is underscored by the observation that mudskippers are euryhaline, indicating their capacity to withstand a broad spectrum of salinities (Looi et al. 2021). However, pronounced fluctuations in salinity can exert an influence on their physiological processes and selection of habitat (Looi et al. 2021).

Temperature, salinity, and dissolved oxygen (DO) levels represent critical physical parameters that exert a significant influence on the viability and longevity of giant mudskippers. These fish exhibit a remarkable capacity for adaptability in response to fluctuating environmental conditions, as evidenced by their increased oxygen uptake rates in response to elevated temperatures (Pattaratumrong and Pompha 2024). Furthermore, they employ behavioral strategies to mitigate exposure to extreme conditions."

#### lines 170 to 177:

"Giant mudskippers display a distinctive body shape that is adapted for both swimming and terrestrial locomotion. Their bodies are generally elongated and laterally compressed, a trait that facilitates movement in both water and on land (Pattaratumrong and Pompha 2024). The total length of these creatures can exhibit significant variation based on environmental factors and habitat conditions. For instance, studies have documented lengths of up to 25 cm in certain specimens, attributed to variations in habitat type and food availability (Zhou et al. 2023). In addition to morphometric measurements, giant mudskippers exhibit specific meristic traits that can be used to differentiate them from other mudskipper species. For instance, the dorsal fin composition, including the number of spines and soft rays, exhibits variation among populations, suggesting adaptations to local environmental conditions (Nor et al. 2023)."

#### lines 213 to 215:

"The Musi River estuary is home to a diverse array of mudskipper species, which exhibit various adaptations to their mangrove habitat. For instance, studies have documented the reproductive biology and feeding habits of mudskippers in this region, emphasizing their role in the local food web (Ridho et al. 2019; Ridho et al. 2021)."

#### lines 232 to 235:

"Condition factors, which are used as an indicator of fish health, have been shown to vary with environmental conditions. This indicates that abiotic factors, such as temperature and salinity, as well as biotic factors, such as prey availability, significantly affect the growth patterns of these fishes (Dewiyanti et al., 2022; Dinh et al., 2022)."

# - The reviewer A comment: For non mother tongue, a Certificate of Proofreading from USA, UK, Canada or Australia is needed.

#### Autor's response

I do not have the required Certificate of Proofreading, but I have carefully reviewed the document for grammar, clarity, and coherence. Additionally, I have sought feedback from proficient English speakers to ensure its quality.

# - The reviewer A comment: All manuscripts must be written in clear and grammatically correct English (U.S.).

#### Autor's response

The manuscript has been carefully reviewed to ensure clear and grammatically correct English. However, if there are any specific concerns, we are happy to make further revisions as needed

# - The reviewer A comment: Please write all the citations and references based on the author's guidelines (https://smujo.id/biodiv/guidance-for-author), include DOI.

#### Autor's response

All citations and references have been formatted according to the author's guidelines. Please let us know if any specific adjustments are needed.

# - The reviewer A comment: The usage of "et al." in long author lists will also be accepted. For example, if the number of authors is more than 20, then it is permissible to use "et al."; if there are less than 20, writing all the authors' names is recommended

## Autor's response

The usage of 'et al.' in long author lists has been applied according to the author's guidelines. If there are any specific concerns, we are happy to make further adjustments.



# [biodiv] Editor Decision

1 pesan

Smujo Editors via SMUJO <support@smujo.com>

Balas Ke: Smujo Editors <editors@smujo.id>

27 Februari 2025 pukul 15.50

Kepada: Melki Melki <melki@unsri.ac.id>, Fadhilah Dzakiyyah Ananta <FD\_ananta@gmail.com>, Isnaini <Isnaini@mipa.unsri.ac.id>, Fitri Agustriani <fitri\_agustriani@yahoo.com>, Rezi Apri <rezi\_apri@unsri.ac.id>, Hartoni <hartoni@mipa.unsri.ac.id>, Ellis Nurjualisti Ningsih <ellis.nurjualisti@gmail.com>, Jeni Meiyerani <jenimeiyerani24@gmail.com>

Melki Melki, Fadhilah Dzakiyyah Ananta, Isnaini, Fitri Agustriani, Rezi Apri, Hartoni, Ellis Nurjualisti Ningsih, Jeni Meiyerani:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia". Complete your revision with a Table of Responses containing your answers to reviewer comments (for multiple comments) and/or enable Track Changes. We are waiting for your revision in the system (https://smujo.id/biodiv), do not send it via email.

Our decision is: Revisions Required

## 

## Reviewer A:

Please review the modifications made to this paragraph for accuracy and relevance to the topic; if the author disagrees, it is better to ignore it. Please ensure that any rejected revisions we recommend are rewritten according to the previous version (do not accept the changes) or written as the author (s) intended. Table 3 shows the average weight at 83.9 g, which should be 85.4 g. Please check

Figure 2 shows the relationship between total length and body weight data. The text should follow standard US English, using commas for thousands and above and dots for decimals in all Tables, figures, and explanations.

Plagiarism is under 5% without references, and the shading sentences need more attention. This study was edited with minor corrections on grammar structures and non-influential wording that must be approved. Word deletion, insertion, and paraphrasing were incorporated into the manuscript, maintaining its thought and flow.

These statements below do not necessarily require a response that would enrich the analysis and are for counterargument purposes.

How would you address concerns that focusing on morphological adaptations might overlook other factors influencing the population dynamics of the Giant Mudskipper, such as predation or competition with other species?

Have you considered that the ecological health signified by the presence of mudskippers could also be impacted by external factors like climate change or habitat destruction, which may not be directly related to the species itself?

What would you say to someone who argues that relying on morphometric characteristics alone is insufficient to fully assess the health of the mudskipper population in relation to broader environmental dynamics?

What specific environmental factors influence the geographical distribution of the Giant Mudskipper in the Sungsang coastal region?

How do seasonal changes affect the population dynamics of the Giant mud skipper in this habitat?

What are the potential impacts of human activities on the health and sustainability of the Giant mud skipper population in the mangrove ecosystem? In response to critics who suggest that environmental factors influencing mudskipper morphology might not be the only variables at play, it's essential to acknowledge that while environmental factors are significant, they often interact with genetic, behavioral, and ecological variables. To address these concerns, I would emphasize the need for a multifaceted research approach that incorporates these additional variables. By employing a comprehensive methodology—such as long-term observational studies, controlled experiments, and genetic analysis—we can better discern the relative contributions of various factors to mudskipper morphology and bolster the validity of our conclusions. Considering the potential variability in responses among different mudskipper species to similar environmental parameters is an important aspect of ecological research. While our findings may be contextualized within the specific species studied, it's essential to explore comparative studies across various mudskipper species. This approach could highlight species-specific adaptations and responses, ultimately contributing to a broader understanding of evolutionary ecology. Future research could focus on examining a variety of mudskipper species in similar environments to assess and contrast their morphological adaptations.

When addressing concerns regarding the reliability of the sample size and its representation of the population dynamics of the Giant Mudskipper, I would underscore the importance of statistical power and sampling methods. A robust sample size is vital for ensuring that our findings are statistically significant and reflective of the broader population. I would also explain the rationale behind our sampling strategy, which involves random selection and stratification to mitigate bias. Additionally, it would be beneficial to conduct further studies with larger sample sizes or replicate the study in different habitats or conditions to reinforce the reliability of our findings.

Recommendation: Revisions Required

-----

**Biodiversitas Journal of Biological Diversity** 

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.

3 lampiran

Mathematical Article Text-1153824-1-4-20250225 REV.docx 457K

A-21288-Others-1153824-1-4-20250225.docx 36K

A-21288-Others-1153824-1-4-20250225.xlsx 14K

#### **COVERING LETTER**

Dear Editor-in-Chief,

I herewith enclosed a research article,

- $\overrightarrow{\mathbf{V}}$  The submission has not been previously published, nor is it before another journal for consideration (or an explanation has been provided in Comments to the Editor).
- The submission file is in OpenOffice, Microsoft Word (DOC, not DOCX), or RTF document file format.
- $\overrightarrow{\mathbf{v}}$  The text is single-spaced; uses a 10-point font; employs italics, rather than underlining (except with URL addresses); and all illustrations, figures, and tables are placed within the text at the appropriate points, rather than at the end.

The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines.

- $\boxed{\mathbf{V}}$  Most of the references come from current scientific journals (c. 80% published in the last 10 years), except for taxonomic papers.
- Where available, DOIs for the references have been provided.
- When available, a certificate for proofreading is included.

#### SUBMISSION CHECKLIST

Ensure that the following items are present:

The first corresponding author must be accompanied with contact details:

E-mail address

- Full postal address (incl street name and number (location), city, postal code, state/province, country)
- Phone and facsimile numbers (incl country phone code)

#### All necessary files have been uploaded, and contain:

- Keywords
- Running titles
- All figure captions
- All tables (incl title and note/description)

#### Further considerations

 $\underline{\mathbf{V}}$  Manuscript has been "spell & grammar-checked" Better, if it is revised by a professional science editor or a native English speaker

- $\fbox{\sc \ }$  References are in the correct format for this journal
- ✓ All references mentioned in the Reference list are cited in the text, and vice versa
- Colored figures are only used if the information in the text may be losing without those images
- Charts (graphs and diagrams) are drawn in black and white images; use shading to differentiate

#### Title:

| Author(s) name:   |   |
|---|---|
| MELKI <sup>1*</sup> , FADHILAH DZAKIYYAH ANANTA <sup>1</sup> , ISNAINI <sup>1</sup> , FITR<br>NURJUALISTI NINGSIH <sup>1</sup> , JEN        | RI AGUSTRIANI, REZI APRI <sup>1</sup> , HARTONI <sup>1</sup> , ELLIS<br>JI MEIYERANI <sup>1</sup> |
| Address   |   |
| (Fill in your institution's institution's name and address, your p  | personal cellular phone and email)  |
| <sup>1</sup> Department of Marine Science, Universitas Sriwijaya. Jl. R   | aya Palembang-Prabumulih Km. 32, Indralaya  |
| 30862, South Sumatra, Indonesia. Tel./Fax. +62-71   | 1-580086, <sup>•</sup> email: <u>melki@unsri.ac.id</u> .  |
| <b>For possibility publication on the journal:</b><br>(fill in <i>Biodiversitas</i> or <i>Nusantara Bioscience</i> or <i>mention the ot</i> | hers)   |
| <ul> <li>Biodiversitas Journal of Biological Diversity</li> </ul>   | Nusantara Bioscience  |
| Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia   | Asian Journal of Agriculture  |
| Asian Journal of Ethnobiology   | Asian Journal of Forestry   |

Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia

Asian Journal of Natural Product Biochemistry Asian Journal of Tropical Biotechnology

International Journal of Bonorowo Wetlands Cell Biology and Development International Journal of Tropical Drylands

Indo Pacific Journal of Ocean Life

#### Novelty:

(state your claimed novelty of the findings versus current knowledge)

This study presents the first comprehensive analysis of Periophthalmodon schlosseri morphology and population dynamics in the Sungsang coastal region, an area with limited prior research

#### Statements:

This manuscript has not been published and is not under consideration for publication to any other journal or any other type of publication (including web hosting) either by me or any of my co-authors. Author(s) has been read and agree to the Ethical Guidelines.

#### List of five potential reviewers

(Fill in names of five potential reviewers that agree to review your manuscpt and their email addresses. He/she should have Scopus ID and come from different institution with the authors; and from at least three different countries)

1. Prof. Dr. Ir. Hefni Effendi, M. Phil. (Scopus ID 54922085400). Email: hefni\_effendi@yahoo.com (Indonesia)

2. Prof. Che Abd Rahim Mohamed (Scopus ID 6603993675). Email: carmohd@ukm.edu.my (Malaysia)

3. Tran Hau Duc, PhD (Scopus ID 54968137900). Email: hautd@hnue.edu.vn (Vietnam)

4. Prof. Dr. Ir. Feliatra, DEA (Scopus ID 6506798004). Email: feliatra@lecturer.unri.ac.id (Indonesia)

5. Dr. Maria Massora, M.ScM. Sc (Scopus ID 57554919700). Email: m.massora@unipa.ac.id (Indonesia)

#### Place and date:

Indralaya, South Sumatra, 15 February 2025

Sincerely yours,

(fill in your name, no need scanned autograph) Melki

## Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia

#### MELKI<sup>1</sup><sup>\*</sup>, FADHILAH DZAKIYYAH ANANTA<sup>1</sup>, ISNAINI<sup>1</sup>, FITRI AGUSTRIANI, REZI APRI<sup>1</sup>, HARTONI<sup>1</sup>, ELLIS NURJUALISTI NINGSIH<sup>1</sup>, JENI MEIYERANI<sup>1</sup>

<sup>1</sup>Department of Marine Science, Universitas Sriwijaya. Jl. Raya Palembang-Prabumulih Km. 32, Indralaya 30862, South Sumatra, Indonesia. Tel./Fax. +62-711-580086, <sup>v</sup>email: melki@unsri.ac.id.

Manuscript received: DD MM 2025. Revision accepted: DD MM 2025.

Abstract. The Giant Mudskipper (*Periophthalmodon schlosseri*) is one of the most abundant mudskipper species, playing a vital role in the biomass of mangrove cosystems. Mudskipper fish are also found in the Sungsang coast, an estuary of the Musi River that is fed by river water from three provinces in Indonesia: South Sumatra, Lampung, and Bengkulu. The objective of this study was to analyze the morphology and population dynamics of mudskippers along with their environmental parameters in Sungsang coast and analyzed for morphometric characteristics, length-weight relationships, and their correlations with key environmental parameters like temperature, pH, and dissolved oxygen. The analysis of fifty-five specimens revealed an average total length of 20.08 cm, a standard length of 17.34 cm, and an average weight of 85 + 43.09 g. The growth pattern exhibited positive allometry (b>3), suggesting that as these fish grow, their body weight increases at a faster rate than their length. Condition factor analysis indicated that the fish sampled were healthy and in good nutritional condition. The principal component analysis (PCA) further highlighted a strong association between dissolved oxygen and pH levels with the morphometric characteristics of the mudskippers, explaining 55.47% of the variation on the F1 axis and 24.70% on the F2 axis, <u>This</u> robust correlation between environmental factors and morphometric characteristics underscores the reliability of our findings. These rindust provide crucial insights into the ecological health of the Giant Mudskipper and its dependence on specific environmental factors in the magrove habitat are of utmost importance.

Key wordsKeywords: Environmental parameter, Length-weight relationship, Morphometric, Mudskipper, Sungsang coast

Running title: Morphology and Population Dynamics of Mudskipper

#### INTRODUCTION

The mangrove ecosystem is a significant area due to its role in providing a habitat for a wide variety of aquatic and terrestrial biota. This ecosystem is important from a variety of angles, including its environmental functions, such as protecting estuaries and coastlines from storms, stabilizing the shore, and reducing coastal soil erosion and flooding. Additionally, it serves as a nursery habitat and breeding ground for a wide range of biota, and it provides sources these that include essential commodities for both subsistence and commerce (Arulnayagam et al. 2021; Su et al. 2021; Jordan and Fröhle 2022; Waleed et al. 2024).

During periods of low tide, mangrove swamps and tidal flats formed in creeks, estuaries, and coastal waterways provide a habitat for mudskippers (Mai et al. 2019; Ridho et al. 2019; Santoso et al. 2020; Darojat et al. 2023; Nathaniel et al. 2024). These creatures possess a variety of physiological, morphological, and behavioral adaptations that enable their unique lifestyle as amphibians, spending significant periods of time away from the water (You et al. 2018; Tran et al. 2020; Corush and Zhang 2022; Steppan et al. 2022). The geographical distribution of each species is influenced by various factors, including food availability, habitat selection, human disturbance, and others Various factors, including food availability, habitat selection, human disturbance, and others influence the geographical distribution of each species. A notable example is the giant mudskipper (*P. schlosseri*), which contributes significantly to the biomass value of the mangrove ecosystem (Zulkifli et al. 2012; Dewiyanti et al. 2022).

Giant mudskippers are distinguished by their unique morphologies, which facilitate movement in both aquatic and
 terrestrial environments. Their pectoral fins are specialized for navigating on land, a crucial adaptation for survival in the
 intertidal zone (Pace and Gibb 2009; Zhou et al. 2023). The anatomical structure of these fins is not only important for
 movement, but also reflects the evolutionary transition from aquatic to terrestrial life (Ziadi-Künzli et al. 2024). For example,
 the robust fin morphology allows mudskippers to generate thrust on land, which is crucial for escaping predators and foraging
 for food (Pace and Gibb 2009). Furthermore, studies have indicated that pelvic fin morphology varies among mudskipper
 species, affecting their climbing behavior and overall movement (Hidayat et al. 2022).

The giant mudskipper is a bioindicator species, which means that its presence or absence can indicate the ecological health of its habitat. Its presence and abundance in the Sungsang estuary are an indication of environmental conditions, especially related to heavy metal pollution (Santoso et al. 2020; Santoso et al. 2024). Furthermore, the population structure of mudskippers in the region has been the subject of study, yielding insights into their reproductive biology and fecundity, which are influenced by seasonal changes and environmental factors (Ridho et al. 2021). The timing of spawning activities, Formatted: Highlight

Formatted: Font color: Light Blue

**Commented [A1]:** Please review the modifications made to this paragraph for accuracy and relevance to the topic; if the author disagrees, it is better to ignore it. Please ensure that any rejected revisions we recommend are rewritten according to the previous version (do not accept the changes) or written as the author (s) intended.

Formatted: Font color: Light Blue

Formatted: Font color: Light Blue

**Commented [A2]:** Please review the modifications made to this paragraph for accuracy and relevance to the topic; if the author disagrees, it is better to ignore it.

| 60 | for example, is correlated with the southwest monsoon, which affects resource availability and habitat conditions (Simor | n e |
|----|--|-----|
| 61 | al. 2012).   |     |

62 The biodiversity of fish species in the Sungsang estuary, including the giant mudskipper, is influenced by a variety of 63 environmental factors. Numerous studies have documented the species diversity and community composition in this region, 64 emphasizing the importance of mangrove ecosystems as critical habitats for mudskippers and other aquatic species (Fauziyah 65 et al. 2019). However, the ongoing threat of human activities, such as deforestation and pollution, poses a significant threat 66 to the ecosystem, thereby impacting mudskipper populations and their role. Consequently, conservation efforts are 67 imperative to safeguard the habitat and ensure the long-term sustainability of mudskippers in South Sumatra (Septinar et al. 68

#### 2023)

69

70

A number of studies have been conducted on the foraging behavior of mudskippers in South Sumatra, encompassing research on their dietary habits (Ridho et al. 2019), gonad length and fecundity (Ridho et al. 2021), and range extension of P. septemradiatus (Iqbal et al. 2018). However, research on the length-weight relationship of P. schlosseri remains scarce, with most studies being based on field observations. The Sungsang coast, located in the estuary of the Musi River, is a wellknown site for mudskippers. Nevertheless, research data on mudskippers in this area is limited.

#### MATERIALS AND METHODS

#### Study area

71 72 73 74 75 76 77 78 78 79 The research was carried out at five stations in the study area, which extends from latitudes 2°21'482°21'482°21'482°31'482°21'482'2'482'2'4 longitudes 104°53'57104°53'57"-" E in the Sungsang coast of South Sumatra, Indonesia (Figure 1). The Musi River is a 80 major river with multiple uses for its resources. It flows through three provinces on Indonesia's Sumatra Island: South 81 Sumatra, Lampung, and Bengkulu. The coast of Sungang is situated within the Musi River estuary, where the river meets 82 the sea (Melki et al. 2018a, b). Local fishermen depend on the rich aquatic life in the river and its estuary for their livelihoods. 83 The Musi River estuary is home to a variety of fish species, including freshwater stingrays, catfish, and other fish, which are 84 not only a source of food but also contribute to the local economy and food security (Putri and Melki 2020). The mangrove 85 ecosystem within the Musi Estuary is in a state of optimal health, providing an ideal environment for the proliferation of 86 mudskippers (Iqbal et al. 2018; Ridho et al. 2019; Ridho et al. 2021).



89 90 91 92 93 94 95 96 97 98 Procedures A total of fifty-five specimens were collected and analyzed for P. schlosseri. A seine net (1x3 m, mesh 1 mm) was utilized to collect the fish. Environmental parameters were measured at the sampling sites where the fish samples were collected. Water temperature, pH, and dissolved oxygen were measured using a multiparameter (Hanna Instruments Inc., USA), and salinity was measured using a handrefraktometer hand refractometer (ATAGO Co. Ltd, Tokyo, Japan). Following collection, the specimens were preserved in a plastic bottle filled with 8 to 10% formalin solution until they were moved into the laboratory and placed in 75% ethanol.

99 A total of seventeen morphometric measurements were recorded, including total length (TL), standard length (SL), eye 100 diameter (ED), head diameter (HD), head length (HL), length of the dorsal fin 1 (LD1), the gap between D1 and D2 (GD1D2), 101 second dorsal fin length (LD2), and distance between anal and caudal fin (DAC), length of anal fin (LA), least height of the

**Commented [A3]:** Please review the modifications made to this paragraph for accuracy and relevance to the topic; if the author disagrees, it is better to ignore it.

pectoral fin (LPc), length of pectoral fin (PcF), the distance between pectoral and pelvic fin (DPI), length of pelvic fin (LPF),
 the width of pelvic fin (WPF), and length of caudal fin (LCF), and width of caudal fin (WCF) (Gangan et al. 2016; Rahman
 et al. 2022) was measured to the nearest 0.1 centimetercentimeters, and body weight was measured on a digital scale with
 0.1 gram accuracy.

#### 106 107 Data analysis

108 The following equation was used to approximate the length-weight relationships using the formula W= a x TLb (Tran et al. 2021; Vilchez et al. 2024), where W is the body weight (g), TL is the total length (cm), and a and b were estimated by the least-squares method based on logarithms using the formula Log (W)= log (a)+b log (TL) (Raeisi et al. 2011). Fish may exhibit isometric growth, characterized by equal growth in all three dimensions (b=3), or positive allometric growth, where width and height receive priority (b>3), or negative allometric growth, where length is prioritized (b<3) (Froese 2006). The effectiveness of linear regression can be quantified by the coefficient of determination (r2) (Tran et al. 2021).</p>

The K of the fish was estimated using the equation  $K = (W) / (a \times TLb)$ , where W is the body weight (g), SL is the total length (cm), and a and b are the regression coefficients. A non-parametric Kruskal-Wallis test with a 5% threshold of significance was employed to determine whether there were any significant variations in mean Wrm between species because the assumptions of parametric statistics could not be met. For each statistical test, the significance level was set at p<0.05. Principal Component Analysis (PCA) was employed to examine the correlation between morphometric characteristics and environmental parameters.

#### RESULTS DAN DISCUSSIONS

#### 123 Environmental parametersParameters

The environmental parameters of samples in all experiments conducted in the Sungsang coast area exhibited minimal fluctuation (Table 1). The environmental parameters that exert a substantial influence on the survival of mudskippers include temperature, salinity, acidity (pH), and dissolved oxygen content (DO) (Ansari et al. 2014; Ridho et al. 2021; Dewiyanti et al. 2022).

129 Table 1. The environmental parameters in the sampling sites130

| - | - | ~ |
|---|---|---|
| 1 | 3 | 1 |
| 1 | 3 | 2 |

121

122

| Sampling<br>site | Temperature<br>(°C) | pH<br>(water) | pH<br>(soil)  | DO (mg L <sup>-1</sup> ) | <u>133</u><br>Sal <b>ingt</b> y<br>(p <b>p</b> 95 |
|------------------|---------------------|---------------|---------------|--------------------------|---|
| 1                | 31.7±0.1            | 7.2±0.2       | $7.0\pm0.1$   | 6.9±0.5                  | 20.0 <b>1±306</b> 0                               |
| 2                | 31.7±0.2            | 7.1±0.1       | 6.8±0.3       | 6.3±0.3                  | 16.7 <b>1.37</b> 5                                |
| 3                | 31.3±0.1            | $7.1\pm0.1$   | $6.9{\pm}0.1$ | 6.3±0.6                  | 16.0±00   |
| 4                | 31.9±0.2            | 7.1±0.1       | $7.0\pm0.2$   | 7.8±0.5                  | 15.3±400  |
| 5                | 29.8±0.1            | 7.2±0.1       | 6.8±0.3       | 7.9±0.4                  | 15.0 <b>±401</b> 0                                |
|                  |                     |               |               |                          | 142   |

The temperature of the water varied from 29.8±0.1 to 31.9±0.2°C. According to previous studies, the optimal water temperature range

for mudskippers is between 23.5 and 35.5°C (Ridho et al. 2021; Dewiyanti et al. 2022; Arevalo et al. 2023). However,

mudskippers demonstrated a preference for milder water temperatures, with a mean of 26.7±2.1°C (Nay et al. 2018). The
pH levels of the water ranged from 7.1±0.1 to 7.2±0.2, and the pH levels of the soil ranged from 6.8±0.3 to 7.00.2. According
to several studies, the mudskipper exhibits optimal growth and reproductive capacity in aquatic environments with pH values
ranging from 6 to 8 (Ridho et al. 2021; Dewiyanti et al. 2022; Darojat et al. 2023).

The present study examined the dissolved oxygen (DO) levels in the aquatic environment, with a range of  $6.3\pm0.3$  to 148 149 7.9±0.4 mg L<sup>-1</sup>. This finding is notable when compared to the results reported by Ridho et al. (2021), that the mudskipper could survive at DO levels ranging from 4.2 to 6.2 mg L<sup>-1</sup>. In accordance with the findings of Dewiyanti et al. (2022), the range of DO levels in this study was from 4.9 to 7 mg L<sup>-1</sup>, indicating that mudskippers possess a considerable degree of 150 151 152 tolerance to variations in DO levels. The salinity levels in the study areas ranged from 15.0±0.0 to 20.0±0.0 ppt. In contrast, 153 Darojat et al. (2023) reported that mudskippers can survive in mangrove ecosystems with a salinity range of 1.7 to 2.58 ppt. 154 Ridho et al. (2021) also reported a salinity range of 0 to 0.1 ppt. However, Dewiyanti et al. (2022) identified a higher salinity 155 range, spanning from 18 to 25 ppt, and a more pronounced range of 24.4 to 34.4 ppt (Taniwel et al. 2020). The significance of these salinity levels is underscored by the observation that mudskippers are euryhaline, indicating their capacity to 156 157 withstand a broad spectrum of salinities (Looi et al. 2021). However, pronounced fluctuations in salinity can exert an 158 influence on their physiological processes and selection of habitat (Looi et al. 2021). Temperature, salinity, and dissolved oxygen (DO) levels represent critical physical parameters that exert a significan

Temperature, salinity, and dissolved oxygen (DO) levels represent critical physical parameters that exert a significant influence onsignificantly influence the viability and longevity of giant mudskippers. These fish exhibit a remarkable capacity for adaptability in response to fluctuating environmental conditions, as evidenced by their increased oxygen uptake rates in

#### response to elevated temperatures (Pattaratumrong and Pompha 2024). Furthermore, they employ behavioral strategies to mitigate exposure to extreme conditions.

#### 164

#### 165 Morphometric characteristic characteristic

166 The P. schlosseri found had an average total length (TL) of 20.08 cm, with a minimum length of 15 cm and a maximum 167 length of 22.60 cm. The average standard length (SL) of the fish was 17.34 cm, with a minimum length of 13 cm and a 168 maximum length of 20 cm (Table 2). The body length of P. schlosseri at the sampling sites was found to be equivalent to 169 the body length measured (Ridho et al. 2019, 2021) in the Musi River estuary, South Sumatra, Indonesia. However, the size 170 of this fish is larger than that found at the Cu Lao Dung Island, Soc Trang Province, Vietnam (Tran et al. 2022), with a size 171 of 12.10-18.65 cm, and that found at the Tanjung Piai, Pontian, Johor, Malaysia (Hui et al. 2019), sized approximately 20 172 cm. The length of these fish is likely influenced by the abundance of fish food sources in their habitat, as evidenced by the 173 findings of Dinh et al. (2020). Tran et al. (2021) also reported that the food composition of mudskippers was similar between Giant mudskippers display a distinctive body shape that is adapted for both swimming and terrestrial locomotion. Their 174

Giant mudskippers display a distinctive body shape that is adapted for both swimming and terrestrial locomotion. Their bodies are generally elongated and laterally compressed, a trait that facilitates movement in both water and on land (Pattaratumrong and Pompha 2024). The total length of these creatures can exhibit significant variation based on environmental factors and habitat conditions. For instance, studies have documented lengths of up to 25 cm in certain specimens, attributed to variations in habitat type and food availability (Zhou et al. 2023). In addition to morphometric measurements, giant mudskippers exhibit specific meristic traits that can be used to differentiate them from other mudskipper species. For instance, the dorsal fin composition, including the number of spines and soft rays, exhibits variation among populations, suggesting adaptations to local environmental conditions (Nor et al. 2023).

183 184

Table 2. Morphometric measurement results of *P. schlosseri* in <u>on</u> Sungsang coast

| No. | Morphometric | Ranged (cm) | Mean ± sd (cm) |
|-----|--------------|-------------|----------------|
|     | Measurements | -           |                |
| 1   | TL           | 15.00-22.60 | 20.08±2.0      |
| 2   | SL           | 13.00-20.00 | 17.34±1.7      |
| 3   | ED           | 0.40-1.70   | 0.83±0.4       |
| 4   | HD           | 2.40-4.80   | 3.44±0.6       |
| 5   | HL           | 3.40-6.40   | 4.81±0.8       |
| 6   | $LD_1$       | 1.50-3.00   | 2.67±0.4       |
| 7   | $GD_1D_2$    | 0.90-2.60   | 1.47±0.4       |
| 8   | $LD_2$       | 3.00-4.20   | 3.73±0.4       |
| 9   | DAC          | 2.00-3.90   | 3.06±0.5       |
| 10  | LA           | 2.60-4.30   | 3.49±0.4       |
| 11  | LPc right    | 1.30-2.80   | $1.89\pm0.4$   |
|     | LPc left     | 1.40-2.80   | 2.05±0.4       |
| 12  | PcF right    | 1.10-2.50   | 1.66±0.3       |
|     | PcF left     | 1.50-3.00   | 1.91±0.5       |
| 13  | DPI right    | 0.20-1.70   | 0.78±0.4       |
|     | DPI left     | 0.50-1.80   | 0.96±0.4       |
| 14  | LPF          | 0.80-2.80   | 1.63±0.7       |
| 15  | WPF          | 1.50-3.00   | 2.36±0.5       |
| 16  | LCF          | 2.00-4.70   | 3.40±0.8       |
| 17  | WCF          | 1.30-3.00   | 2.32±0.5       |

Table 3. Range of total length (TL) and body weight (W) of P. schlosseri in Sungsang coast

186 187

191 192

193

1

#### 7 Length-weight relationship

The length-weight relationship of the giant mudskipper (*P. schlosseri*) was determined through the analysis of <u>55fifty-</u>
 five specimens collected from five sampling sites along the Sungsang coast. The total length (TL) ranged from 15.00 to
 22.60 cm, and the body weight varied from 28.3 to 119.2 g (Table 3).

Formatted: Font color: Light Blue

**Commented [A4]:** Table 3 shows the average weight at 83.9 g, which should be 85.4 g. Please check

| Sampling | TL (cm)     | W (g)                           |
|----------|-------------|---------------------------------|
| Site     |             |                                 |
| 1        | 19.5 - 21.5 | 67.8 - 102.5                    |
| 2        | 15.0 - 21.0 | 28.3 - 103.7                    |
| 3        | 19.0 - 20.5 | 61.8 - 92.8                     |
| 4        | 20.0 - 22.5 | 87.7 - 108.3                    |
| 5        | 19.5 - 22.6 | 82.1 - 119.2                    |
| Average  | 20.1        | <mark>85.4<del>3.9</del></mark> |

Comment

195 The findings of the regression analysis and the length-weight relationship graph (Figure 2) yielded the following equation: 196 y = 0.0026x3.45. The b value of 3.45 indicates that the fish growth pattern is positive allometric (b > 3), signifying that 197 weight growth outpaces length increase. Positive allometric growth is indicated by a length-weight relationship (LWR) 198 where the exponent (b) is greater than 3. Studies have demonstrated that P. schlosseri exhibits such a relationship, with documented values of b indicating positive allometry (Ridho et al. 2019; Abiaobo et al. 2021; Looi et al. 2021; Mussa et al. 199 200 2024). For instance, a study conducted in the Musi River Estuary found that the correlation coefficient for the length-weight relationship (LWR) of *P. schlosseri* was 98.2%, with an exponent value of 3.189, confirming its positive allometric growth 201 202 (Ridho et al. 2019). This suggests that as the fish grows, it becomes relatively heavier compared to its length, which may be 203 advantageous for buoyancy and mobility in its habitat. This positive allometric growth pattern of P. schlosseri is consistent with findings from related species within the same family. For example, P. barbarus also exhibited positive allometric 204 205 growth in similar ecological contexts, reinforcing the notion that this growth strategy may be a common adaptive trait among 206 mudskippers (Indarjo et al. 2020; Abiaobo et al. 2021). The implications of such growth patterns are critical, as they can 207 influence the species' reproductive strategies, survival rates, and overall fitness in fluctuating environmental conditions 208 typical of mangrove ecosystems (Dinh 2016). 209



#### 210 211 212 213 214 215

194

Figure 2. Relationship between total length and body weight of *P. schlosseri* in Sungsang coast

In comparison with other species found in mangrove ecosystems, the allometric growth of *P. schlosseri* reflects typical trends in estuarine and intertidal species, where growth patterns are often influenced by environmental conditions such as temperature, food availability, and habitat structure (Chew et al. 2014; Looi et al. 2021). The positive allometry observed in the Sungsang population could be attributed to the productivity of the mangrove ecosystem, which provides abundant resources for these mudskippers. The Musi River estuary is home to a diverse array of mudskipper species, which exhibit various adaptations to their mangrove habitat. For instance, studies have documented the reproductive biology and feeding habits of mudskippers in this region, emphasizing their role in the local food web (Ridho et al. 2019; Ridho et al. 2021).

#### 222 Condition factor

The K value exhibited a maximum at sampling site 1 (K= 1.04) and a minimum at sampling site 5 (K= 0.94) (Figure 3). The variation in K values across the sampling sites was not statistically significant, suggesting that the fish samples were healthy and well-nourished at the time of the study. The K values in the Sungsang coastal area are comparable to those found in the Tran De District, Soc Trang Province, Mekong Delta, Vietnam mangrove habitat, which range from 1.01 to 1.03 (Dinh 2016), and the West Coast of Peninsular Malaysia, which range from 0.41 to 1.29 (Looi et al. 2021). **Commented [A5]:** Figure 2 shows the relationship between total length and body weight data. The text should follow standard US English, using commas for thousands and above and dots for decimals in all Tables, figures, and explanations.



234

235

236

237

238

239

240

241

242 243

244

245

246

247

#### Figure 3. Condition factor of P. schlosseri in Sungsang coast

Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the lengthweight relationship. The condition factor values indicated a range of nutritional status among the mudskippers, with most individuals displaying average to good health (Froese 2006). However, some specimens with lower condition factors were found to be lean, suggesting potential seasonal fluctuations in food availability that might influence the body mass-to-length ratio (Abdullah and Zain 2019; Tran et al. 2021; Nguyễn et al. 2022). Condition factors, which are used as an indicator of fish health, have been shown to vary with environmental conditions. This indicates that abiotic factors, such as temperature and salinity, as well as biotic factors, such as prey availability, significantly affect the growth patterns of these fishes (Dewiyanti et al., 2022; Dinh et al., 2022).

#### Correlation of morphometric characteristics with environmental factors

Principal component analysis was employed to ascertain the correlation between seventeen *P. schlosseri* morphometric characteristics and environmental factors, including water pH and soil pH, dissolved oxygen (DO), temperature, and salinity. The analysis yielded significant findings concentrated on two primary axes: F1 by 55.47% and F2 by 24.70%, with 80.17% representing the maximum amount of information (Figure 4).



#### Field Code Changed

267 268 The environmental parameter on the positive F1 axis is characterized by DO, which for sampling site 5 is high at 7.9 mg 269 L<sup>1</sup>. According to Kumar et al. (2021) and Mulyasari (2023), a very strong correlation relationship can mean that as the value 270 of the comparison character increases, the length of a morphometric character in fish will also increase. Consequently, 271 elevated levels of dissolved oxygen at the Sungsang coast could potentially influence the growth of morphometric 272 characteristics in P. schlosseri. A study by Khater et al. (2021) and Heriyati et al. (2022) indicated that low DO levels can 273 lead to a reduction in fish appetite and growth. The findings indicate that salinity exerts minimal influence on the 274 morphometric growth of P. schlosseri. The classification of mudskippers as euryhaline organisms is attributed to their 275 capacity to respond to variations in salt concentration (Taniwel et al. 2020; Kim et al. 2021; Hamidah et al. 2024).

Figure 4. PCA was examined to determine morphometric characteristics related to environmental factors of P. schlosseri in on Sungsang

288

289

coast

The positive F2 axis is characterized by sampling site 1, which is associated with the environmental parameter component of soil pH and the morphometric characteristics of WPF, defined as the width of the pelvic fins utilized during locomotion by mudskippers. This parameter is believed to be closely related to their biological functions (Hidayat et al. 2022; Quigley et al. 2022). The pH value of the soil at sampling site 1 is 7, indicating a high value within the threshold of *P. schlosseri* life. The measurement of soil pH is crucial as the mudskipper habitat is located in the sediment. A low pH value in the mudskipper habitat prompts the fish to allocate their energy towards environmental adjustments rather than growth and foraging (Smith and Nobriga 2023).

This study analyzed the giant mudskipper (*P. schlosseri*) in-on\_Sungsang coast, revealing positive allometric growth
 (b>3) and healthy condition factors. Dissolved oxygen and pH exhibited a strong influence on morphometric characteristics,
 while temperature and salinity supported optimal habitats. The findings emphasize the critical role of mangroves in
 sustaining P. schlosseri populations and offer insights for into mangrove ecosystem management.

#### REFERENCES

- Abdullah MIC, Zain KM. 2019. Length-weight relationships, condition factor and growth parameters of *Periophthalmus chrysospilos* (Bleeker, 1852) (Gobiiformes: Gobiidae), in Bayan Bay, Penang, Malaysia. Sains Malays 48 (2): 271–279. DOI: 10.17576/jsm-2019-4802-02.
- Abiaobo N, Asuquo IE, Ejiogu IN, James EJ. 2021. Aspects of the biology of *Periophthalmus barbarus* (mudskipper), from
   Jaja Creek, Niger Delta, Nigeria. Ecol Evol Biology 6 (1): 15. DOI: 10.11648/j.eeb.20210601.14.
- Ansari AA, Trivedi S, Saggu S, Rehman H. 2014. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. J Entomol Zool Stud 2 (6): 22–33.

Arevalo E, Cabral HN, Villeneuve B, Possémé C, Lepage M. 2023. Fish larvae dynamics in temperate estuaries: A review on processes, patterns and factors that determine recruitment. Fish Fish 24 (3): 466–487. DOI: 10.1111/faf.12740.
Arulnayagam A, Khim JS, Park J. 2021. Floral and faunal diversity in Sri Lankan mangrove forests: A systematic review. Sustainability 13 (17). DOI: 10.3390/su13179487.

- Chew SF, Hiong KC, Lam SP, Ong SW, Wee WL, Wong WP, Ip YK. 2014. Functional roles of Na+/K+-ATPase in active ammonia excretion and seawater acclimation in the giant mudskipper, *Periophthalmodon schlosseri*. Front Physiol 5. DOI: 10.3389/fphys.2014.00158.
- Corush JB, Zhang J. 2022. One size does not fit all: Variation in anatomical traits associated with emersion behavior in mudskippers (Gobiidae: Oxudercinae). Front Ecol Evol 10: 01–08. DOI: 10.3389/fevo.2022.967067.
- Darojat AZ, Marhendra APW, Kurniawan N. 2023. Identification of mudskipper species in mangrove area of Luwu Timur,
   Luwu Utara, and Wajo South Sulawesi Indonesia. Biotropika: J Tropical Biol 11 (2): 74–83. DOI: 10.21776/ub.biotropika.2023.011.02.02.
- Dewiyanti I, Melanie K, Almuniro S, Damora A, Nufadillah N, Batubara, AS. 2022. Growth patterns and condition factor
   of the mudskipper (*Periophthalmus gracilis*) in mangrove ecosystem rehabilitation areas in Banda Aceh and Aceh
   Besar, Indonesia. Fish Aquat Life 30 (2): 85–94. DOI: 10.2478/aopf-2022-0008.
- Dinh QM. 2016. Growth and body condition variation of the giant mudskipper *Periophthalmodon schlosseri* in dry and wet seasons. Tap Chi Sinh Hoc 38 (3). DOI: 10.15625/0866-7160/v38n3.7425.
- Dinh QM, Tran LT, Tran TTM, To DK, Nguyen TTK, Tran DD. 2020. Variation in diet composition of the mudskipper,
   *Periophthalmodon septemradiatus*, from Hau River, Vietnam. Bull Mar Sci 96 (3): 487–500. DOI: 10.5343/bms.2018.0067.
- Dinh QM, Nguyen THD, Truong NT, Doan DX, Nguyen TTK. 2022. Monthly variations in growth pattern and condition factor of *Periophthalmodon septemradiatus* (gobiiformes: periophthalminae) living along the Bassac River in Viet Nam. PeerJ 10: e13880. DOI: 10.7717/peerj.13880.

Formatted: Font color: Light Blue

Formatted: Font color: Light Blue

| 321        | estuaries of South Sumatra; IOP Conference Series: Earth and Environmental Science 278 (1): 012025. DOI:  |
|------------|---|
| 322        | 10.1088/1755-1315/278/1/012025.   |
| 323<br>324 | Froese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. J Appl Ichthyol 22 (4): 241–253. DOI: 10.1111/j.1439-0426.2006.00805.x.   |
| 325        | Gangan SS, Kumar R, Ramteke KK, Kumar AP, Jaiswar AK. 2016. Study of morphological variation discernible by   |
| 326        | multivariate analysis between the species of genus Setipinna (Teleostei: Clupeiformes). Ecol Enviro and Conserv   |
| 327        | 22 (September): S11–S16.  |
| 328        | Hamidah A, Murni P, Said M. 2024. The diversity of mudskipper fish family Gobiidae in mangrove area, Seberang District,   |
| 329        | Tanjung Jabung Regency, West Jambi. J Surv Fish Sci 11 (1). DOI: 10.53555/sfs.v11i01.2045.  |
| 330        | Heriyati E, Rustadi R, Isnansetyo A, Triyatmo B, Istiqomah I, Deendarlianto D, Budhijanto W. 2022. Microbubble aeration   |
| 331<br>332 | in a recirculating aquaculture system (RAS) increased dissolved oxygen, fish culture performance, and stress resistance of Red Tilapia ( <i>Oreochromis</i> sp.). Trends Sci 19 (20): 6251. DOI: 10.48048/tis.2022.6251.  |
| 333        | Hidayat S, Wicaksono A, Raharjeng ARP, Jin DSM, Alam P, Retnoaji B. 2022. The morphologies of mudskipper pelvic   |
| 334        | fins in relation to terrestrial and climbing behaviour: Proceedings of the Zoological Society 75 (1): 83–93. The  |
| 335        | University of Edinburgh, 8 February 2022. DOI: 10.1007/s12595-021-00422-1.  |
| 336        | Hui NY, Mohamed M, Othman MNA, Tokiman L. 2019. Diversity and behaviour of mudskippers of Tanjung Piai, Pontian,  |
| 337        | Johor. IOP Conference Series: Earth and Environmental Science 269 (1). DOI: 10.1088/1755-1315/269/1/012037.   |
| 338        | Indarjo A, Salim G, Zein M, Susiyanti S, Soejarwo PA, Nugraeni CD, Bija S, Pham YTH. 2020. Characteristics of Von   |
| 339        | Bertalanfy growth, allometric, condition index and mortality of Periophthalmus barbarus in mangrove and   |
| 340        | probiotics conservation area (KKMB), Tarakan, North Kalimantan. I J M S 25 (1): 31-38. DOI:   |
| 341        | 10.14710/ik.ijms.25.1.31-38.  |
| 342        | Iqbal M, Halim A, Adriani D, Pormansyah, Saputra RF. 2018. Range extension of Periophthalmodon septemradiatus   |
| 343        | (Gobiidae) in southern Sumatra, Indonesia. Cybium 42 (4): 376–378. DOI: 10.26028/cybium/2018-424-009.   |
| 344        | Jordan P, Fröhle P. 2022. Bridging the gap between coastal engineering and nature conservation?: A review of coastal  |
| 345        | ecosystems as nature-based solutions for coastal protection. J Coast Conserv 26 (2). DOI: 10.1007/s11852-021-   |
| 346        | 00848-x.  |
| 347        | Khater ES, Bahnasawy AH, Elghobashy H, Shaban Y, El-Sheikh FM, El-Reheem SA, Aboegela M. 2021. Mathematical   |
| 348        | model for predicting oxygen concentration in Tilapia fish farms. Sci Rep 11 (1). DOI: 10.1038/s41598-021-03604-   |
| 349        | 1.  |
| 350        | Kim J, Lee C, Yoo D, Kim H. 2021. Genetic adaptations in mudskipper and tetrapod give insights into their convergent  |
| 351        | water-to-land transition. Animals 11 (2): 584. DOI: 10.3390/ani11020584.  |
| 352        | Kumar GR, Bano F, Serajuddin M. 2021. Effect of formalin preservation on studies on morphology and condition factor of  |
| 353        | the treshwater Shark Wallago attu (Bloch and Schneider, 1801) using truss network system. Indian J Fish 68 (3).   |
| 354<br>255 | DOI: 10.210///ijt.2021.68.3.98695-16.   |
| 355        | Looi LJ, Aris AZ, Isa NM, Yusoff, FM, Haris H. 2021. Elemental composition and health risk assessment of giant  |
| 350        | mudskipper ( <i>Periophthalmodon schlosseri</i> ) from the intertidal zone of the west coast of Peninsular Malaysia. Front  |
| 55/<br>550 | Wat Sci /, DOI: 10.5389/IMARS.2020.018284.  |
| 250        | Mai ny, nan LA, Dini Qivi, Iran DD, Murata M, Sagara H, I anada A, Smirai K, Isminatsu A. 2019. Land invasion by<br>the much chipmer <i>Bestionkehandan sentemuscilaties</i> in frach and ealing waters of the Malenze Birger Sci Ban 0 (1)   |
| 320        | DOI: 10.1038/p1508.010.50700.5  |
| 360        | DOI. 10.1000/0541326-017-30/37-3.<br>Melki Isaansetuo A Widada I Murwantoko M 2018a Tha significance of water quality parameters on the diversity of  |
| 362        | moves, issues of $A_1$ , moves $A_2$ , which want to $A_2$ in the significance of water quarky parameters on the effects of the |
| 363        | Malki Isaansetyo A Widaya I Muwantoko M 2018b Distribution of amponium ovidizing bacteria in scientary with   |
| 367        | relation to water quality at the Musi Piter Indonesia Havati I Riosci 25 (d) 108 205 DOL 10 4208 db 25 4 108  |
| 265        | Relation to water quarty at the Music Kiver, inconesta, Hayau J Biosel 25 (4), 176–205. DOI: 10.4506/ilj0.25.4.196. Mulvasori N. Subarizono N. Ultomo RSR. Taufik I. Kuemini II. Vosmanic N. 2002. Morshoravira end constring   |
| 266        | Murjasari N, Subaryono N, Otonio BSB, Taurik I, Kushimi H, Tosmania N, 2025. Morphometric and genetic   |
| 367        | DOI: 10.1155/0237/107251  |
| 268        | JUL 10, 11, 11, 12, 12, 11, 11, 12, 12, 11, 12, 12  |
| 360        | mussa Ls, ALL DARA, Satell Sill, AUGAS ALI, AL-ASAGU MA, SUIMAILAAN, 2024, MUGASIPPETS & good Diolindicator for<br>polluted soils in the mudflat region of Southern Irag Macon I Mar Sci 38 (2), 111 110 DOI-   |
| 270        | 10 \$6620/mine v2812 354  |
| 370        | 10.3002/mjms.v5012.334.   |
| 371        | Admander Ain, Goodo Bint O, Kamin HO. 2024. Food and rectang of Admint industriper Pertoprintalmits barriers and only a straight of the start of the straight   |
| 372        | 10.32380/OWTVZ  |
| B74        | Nav TI Gervais CR Hoev AS Johansen II. Steffensen IF Rummer II. 2018 The emergence emergency: A mudskinner's  |

Fauziyah F, Nurhayati N, Bernas SM, Putera A, Suteja Y, Agustiani F. 2019. Biodiversity of fish resources in Sungsang

320

 Nay TJ, Gervais CR, Hoey AS, Johansen JL, Steffensen JF, Rummer JL. 2018. The emergence emergency: A mudskipper's mudskipper's response to temperatures. J Therm Biol 78 (September): 65–72. DOI: 10.1016/j.jtherbio.2018.09.005.
 Nguyễn NT, Ha LM, Nguyen ATN, Chu NH, Tran HD, Hưng NP, Ta TT. 2022. Variation in the allometry of morphometric characteristics, growth, and condition factors of wild *Bostrychus sinensis* (Butidae) in Northern Vietnam. Pak J Zool 55 (2). DOI: 10.17582/journal.pjz/20200917140936. 374 375 376 377 378

| 379        | Nor NM, Saifuzzaman S, Azmir IA, Hussin N. 2023. Morphological characteristics and reproductive organs assessment of   |
|------------|--|
| 380        | to 1150% the 2023 201 151  |
| 382        | Pace CM Gibb AC 2009 Mudskinper pectoral fin kinematics in aquatic and terrestrial environments. J Exp Biol 212(14)  |
| 383        | 2779-2286 DOI: 10.1242/jeb.029041  |
| 384        | Pattratumrong MS, Pompha T. 2024. Habitat of the amphibious mudskipper <i>Periophtalmodon schlosseri</i> in Songkhla Lake.   |
| 385        | Thailand. Biodiversitas 25 (5): 1875-1881. DOI: 10.13057/biodiv/d250503  |
| 386        | Putri WAE, Melki. 2020. Study of the water quality of the Musi River estuary, South Sumatra. J Mar Aquat Sci 6 (1): 36.  |
| 387        | DOI: 10.24843/jmas.2020.v06.i01.p05. [Indonesian].   |
| 388        | Quigley ZMG, Blob RW, Kawano S. 2022. Kinematic comparisons between mudskipper fins and Salamander limbs during  |
| 389        | terrestrial locomotion. J Exp Zool A Ecol Integr Physiol 357 (6): 612–625. DOI: 10.1002/jez.2594.  |
| 390        | Kaelsi H, Daini M, Pargianibari S T, Shabani MJ, Bibak M, Davodu K. 2011. Lengur-vergin relationships, conductor actions<br>and relative weight of five first species of Bushehr waters. Northern Persian Gulf. Afr I Biotechnol 10 (82): 19181. |
| 392        | 19186. DOI: 10.5897/AJB11.2650.  |
| 393        | Rahman MAF, Azmir IA, Hussin NJ. 2022. Morphological study of selected mudskipper species (Family: Oxudercidae) and  |
| 394        | development of key pictorial. Iran J Ichthyol 9 (4): 180–194. DOI: 10.22034/iji.v9i4.808.  |
| 395        | Ridho MR, Patriono E, Rahmawati D, Pratama R, Avesena M. 2021. Short communication: Investigating gonad length and   |
| 396        | tecundity in mudskippers (gobiidae) at the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 22 (10):  |
| 297<br>298 | 4415-4420. DOI: 10.1505//010011/0221054.<br>Ridho MR Patriono F. Solikha M. 2019. Food habits of three species of mudskinners in the Musi River Estuary. South   |
| 399        | Sumatra, Indonesia, Biodiversitas 20 (8): 2368–2374, DOI: 10.13057/biodiv/d200835.   |
| 400        | Santoso HB, Suhartono E, Yunita R, Biyatmoko D. 2020. Mudskipper fish as a bio-indicator for heavy metals pollution in   |
| 401        | a coastal wetland. Egypt J Aquat Biol Fish 24 (7): 1073-1095. DOI: 10.21608/ejabf.2020.144402.   |
| 402        | Santoso HB, Krisdianto K, Yunita R. 2024. Iron bioaccumulation and ecological implications in the coastal swamp wetlands   |
| 403        | ecosystem of South Kalimantan: insights from giant mudskipper fish as bioindicators. J Degrad Min Lands Manag,   |
| 404        | 11(3), 5539-5550. DOI: 10.15243/jdmlm.2024.113.5539.   |
| 405        | Septinar H, Putri YP, Midia KR, Bianto B. 2023. Mangrove forest conservation efforts through nurseries in Sungsang IV  |
| 406        | village, Banyuasin Regency. Enviro Sci J: Jurnal Ilmu Lingkungan, //-88. DOI: 10.31851/esjo.v112.11920.  |
| 407        | [Intronestan].   |
| 408        | Sinior KD, Bakai T, Maziai AO, Zalu CC, Santa A, Aishad A, Tenipte SE, Biowier teterson io. 2012. Aspects of the<br>enroductive biology of two arehar fiches Tayates (hetaraus (Hamilton 1827) and Tayates inculate (Pallas 1767)                |
| 410        | Environ Rio Fishes 93 (4): 491-503 DOI: 10.1007/s10641-011-9944-6  |
| 411        | Smith WE, Nobriga MK, 2023. A bioenergetics-based index of habitat suitability: spatial dynamics of foraging constraints   |
| 412        | and food limitation for a rare estuarine fish. Trans Am Fish Soc 152 (5): 650-671. DOI: 10.1002/tafs.10427.  |
| 413        | Steppan SJ, Meyer AA, Barrow LN, Alhajeri BH, Al-Zaidan ASY, Gignac PM, Erickson GM. 2022. Phylogenetics and the   |
| 414        | evolution of terrestriality in mudskippers (Gobiidae: Oxudercinae). Mol Phylogenetics Evol 169: 107416. DOI:   |
| 415        | 10.1016/j.ympev.2022.107416.   |
| 410<br>417 | Su J, FIESS DA, Gasparatos A. 2021. A meta-analysis of the ecological and economic outcomes of mangrove restoration.<br>Nat Commun 12 (1) DOI: 10.1038/s41467-021-25340-1  |
| 418        | Taniwel D, Leiwakabessy F, Rumahlatu D, 2020, Short communication: density and length-weight relationship of   |
| 419        | mudskipper ( <i>Periophthalmus</i> spp.) in the mangrove area of Kairatu Beach, Maluku, Indonesia. Biodiversitas 21  |
| 420        | (11). DOI: 10.13057/biodiv/d211155.  |
| 421        | Tran HD, Nguyen HH, Ha LM. 2021. Length-weight relationship and condition factor of the mudskipper ( <i>Periophthalmus</i>   |
| 422        | <i>modestus</i> ) in the Red River Delta. Reg Stud Mar Sci 46: 101903. DOI: 10.1016/j.rsma.2021.101903.  |
| 423<br>121 | Iran LA, Maekawa Y, Soyano K, Ishimatsu A. 2020. Morphology of the feeding apparatus in the herbivorous mudskipper,<br><i>Releash the linear strip (Linearus 1758)</i> , <i>Toomorphology 139 (2): 231 243 DOI: 10.1007/s00425.020</i>           |
| 424        | 00476-3  |
| 426        | Tran LX, Nguyen TTK, Vo TT. 2022. Morphological comparison of the cranial movement apparatus in mudskippers  |
| 427        | (Gobiidae: Oxudercinae). Zool 154 (August): 126042. DOI: 10.1016/j.zool.2022.126042.   |
| 428        | Vilchez M, Dattilo J, Brewer SK. 2024. Length-weight relationships of native and non-native fishes in the lower Red River  |
| 429        | Cathment, USA. J Appl Ichthyol 2024: 5. DOI: 10.1155/2024/5578825.   |
| 430        | Waleed TA, Abdel-Maksoud YK, Kanwar RS, Sewilam H. 2024. Mangroves in Egypt and the Middle East: current status,   |
| 431<br>422 | uneaus, and opportunities. Int J Environ Sci Technol. DOI: 10.1007/813/02-024-05/88-1.<br>You X Sun M Li L Bian C Chen L Yi Y Yu H Shi O 2018 Mudskinners and their genetic adoptations to an amphibious   |
| 433        | lifestyle. Animals 8 (2), DOI: 10.3390/ani8020024.   |
| 434        | Zhang Z, Fu Y, Zhao H, Zhang X. 2022. Social enrichment affects fish growth and aggression depending on fish species:  |
| 435        | applications for aquaculture. Front Mar Sci 9. DOI:10.3389/fmars.2022.1011780.   |
| 436        | Zhou H, Donatelli CM, Laneuville O, Standen EM. 2023. Skeletal anatomy of the pectoral fin in mudskipper species from  |
| 437        | terrestrial and aquatic habitats. J Morphol, 284(8). DOI: 10.1002/imor.21612.  |

| 438 | Ziadi-Künzli F, Maeda K, Puchenkov P, Bandi M. 2024. Anatomical insights into fish terrestrial locomotion: a study of |
|-----|---|
| 439 | barred mudskipper (Periophthalmus argentilineatus) fins based on µct 3d reconstructions. J Anat, 245(4), 593-624.     |
| 440 | DOI: 10.1111/ioa.14071.   |

- Zulkifli SZ, Mohamat-Yusuff F, Ismail A, Miyazaki N. 2012. Food preference of the giant mudskipper *Periophthalmodon* schlosseri (Teleostei: Gobiidae). Knowl Manag Aquat Ecosyst 405. DOI: 10.1051/kmae/2012013. 441 442 443



# [biodiv] Editor Decision

1 pesan

8 April 2025 pukul 05.57

Smujo Editors via SMUJO <support@smujo.com> Balas Ke: Smujo Editors <editors@smujo.id> Kepada: Melki Melki <melki@unsri.ac.id>, Fadhilah Dzakiyyah Ananta <FD ananta@gmail.com>, Isnaini <Isnaini@mipa.unsri.ac.id>, Fitri Agustriani <fitri agustriani@yahoo.com>, Rezi Apri <rezi apri@unsri.ac.id>, Hartoni <hartoni@mipa.unsri.ac.id>, Ellis Nurjualisti Ningsih <ellis.nurjualisti@gmail.com>, Jeni Meiverani <jenimeiyerani24@gmail.com>

Melki Melki, Fadhilah Dzakiyyah Ananta, Isnaini, Fitri Agustriani, Rezi Apri, Hartoni, Ellis Nurjualisti Ningsih, Jeni Meiyerani:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia". Complete your revision with a Table of Responses containing your answers to reviewer comments (for multiple comments) and/or enable Track Changes. We are waiting for your revision in the system (https://smujo.id/biodiv), do not send it via email.

Our decision is: Revisions Required

\_\_\_\_\_

Reviewer A:

This article needs major revision. All comments are available in the text. Send revised files with track changes and rebuttal letter.

**Recommendation: Revisions Required** 

\_\_\_\_\_

**Biodiversitas Journal of Biological Diversity** 

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.

A-21288-Article Text-1158096-1-4-20250407.doc 537K

### Analysis of morphology and population dynamics of giant

mudskipper <u>Periophthalmodon schlosseri (Pallas, 1770) (Gobiiformes:</u>
 <u>Oxudercidae) Periophtalmodon schlosseri (Pallas, 1770) (Gobiiformes:</u>
 Oxudercidae) at Sungsang estuaries, South Sumatra, Indonesia

Formatted: Font: Italic

Formatted: Font: Italic

Abstract. The Giant Mudskipper (Periophthalmodon schlosseri (Pallas, 1770) - Periophthalmodon schlosseri (Pallas, 1770) is one of 8 the most abundant mudskipper species, playing a vital role in the biomass of mangrove ecosystems. Mudskipper fish are also fo und in 10 the Sungsang coast, an estuary of the Musi River that is fed by river water from three provinces in Indonesia: South Sumatra, Lampung, and Bengkulu. The objective of this study wasis study aimed This study aimed to analyze the morphology and population dynamics of mudskippers along with their environmental parameters in Sungsang coastal South Sumatra. For this study, mudskipper specimens were 11 12 13 14 15 collected from five sampling sites along the Sungsang coast and analyzed for morphometric characteristics, length-weight relationships, and their correlations with key environmental parameters like temperature, pH, and dissolved oxygen. The analysis of fifty-five specimens revealed an average total length of 20.08 cm, a standard length of 17.34 cm, and an average weight of 85.4 g. The growth 16 pattern exhibited positive allometry (b>3), suggesting that as these fish grow, their body weight increases at a faster ratefaster faster than 17 their length. Condition factor analysis indicated that the fish sampled were healthy and in good nutritional condition. The principal 18 19 component analysis (PCA) further highlighted a strong association between dissolved oxygen and pH levels with the morphometric characteristics of the mudskippers, explaining 55.47% of the variation on the F1 axis and 24.70% on the F2 axis. This robust correlation 20 between environmental factors and morphometric characteristics underscores the reliability of our findings. These findings provide 21 crucial insights into the ecological health of the Giant Mudskipper and its dependence on specific environmental factors in the mangrove 22 habitat are of utmost importance.

23 Keywords: Environmental parameter, Length-weight relationship, Morphometric, Mudskipper, Sungsang coast

24 Running title: Morphology and Population Dynamics of Mudskipper

25

1

5

6 7

#### INTRODUCTION

The mangrove ecosystem is a significant area due to its role in providing a habitat for a wide variety of aquatic and terrestrial biota (Hasan et al. 2022; Valen et al. 2022). This ecosystem is important from a variety of angles, including its environmental functions, such as protecting estuaries and coastlines from storms, stabilizing the shore, and reducing coastal soil erosion and flooding (Setyawan and Winarno 2006; Wirabuana et al. 2025). Additionally, it serves as a nursery habitat and breeding ground for a wide range of biota, and it provides sources that include essential commodities for both subsistence and commerce (Arulnayagam et al. 2021; Su et al. 2021; Jordan and Fröhle 2022; Waleed et al. 2024).

32 During periods of low tide, mangrove swamps and tidal flats formed in creeks, estuaries, and coastal waterways 33 34 provide habitat for mudskippers (Mai et al. 2019; Ridho et al. 2019; Santoso et al. 2020; Darojat et al. 2023; Nathaniel et al. 2024). Mudskippers exhibit physiological, morphological, and behavioral adaptations that allow them to thrive in both 35 aquatic and terrestrial environments (You et al. 2018; Tran et al. 2020; Corush and Zhang 2022; Steppan et al. 2022). 36 Various factors, including food availability, habitat selection, human disturbance, and others influence the geographical 37 38 distribution of each species. A notable example is the giant mudskipper (Periopthalmodon, schlosseri) Periophthalmodo schlosseri, which contributes significantly to the biomass value of the mangrove ecosystem (Zulkifli et al. 2012; Dewiyant 39 et al. 2022). According to the IUCN Red List of Threatened Species, this species is currently listed as Least Concern (LC 40 indicating that it is not under any immediate threat of population decline (IUCN 2023). Periophthalmodon, schlosseri 41 widely distributed throughout the Indo-West Pacific region, including coastal and estuarine areas of Southeast Asi 42 northern Australia and parts of South Asia (Ansari et al. 2014; Parenti and Jaafar 2017).

Giant mudskippers are distinguished by their unique morphologies, which facilitate movement in both aquatic and terrestrial environments. Their pectoral fins are specialized for navigating on land, a crucial adaptation for survival in the intertidal zone (Pace and Gibb 2009; Zhou et al. 2023). The anatomical structure of these fins is not only important for movement but also reflects the evolutionary transition from aquatic to terrestrial life (Ziadi-Künzli et al. 2024). For example, the robust fin morphology allows mudskippers to generate thrust on land, which is crucial for escaping predators Commented [VH1]: Add references. Ex: https://sfi-cybium.fr/fr/first-record-small-eyed-loterprionobutis-microps-weber-1907-teleostei-eleotridaebutinae-java

https://iopscience.iop.org/article/10.1088/1755-1315/1036/1/012074

Commented [mm2R1]:

Commented [VH3]: add references. Ex: https://www.nature.com/articles/s41598-025-87307-x

https://smujo.id/biodiv/article/view/521

**Commented [VH4]:** add an explanation of the conservation status of this species based on the IUCN Red List, and also add the global distribution information

Formatted: Font: Italic

and foraging for food (Pace and Gibb 2009). Furthermore, studies have indicated that pelvic fin morphology varies among
 mudskipper species, affecting their climbing behavior and overall movement (Hidayat et al. 2022).

The giant mudskipper is a bioindicator species, which means that its presence or absence can indicate the ecological health of its habitat (Pattaratumrong and Pompha 2024). Its presence and abundance in the Sungsang estuary are an indication of environmental conditions, especially related to heavy metal pollution (Santoso et al. 2020; Santoso et al. 2024). Furthermore, the population structure of mudskippers in the region has been the subject of study, yielding insights into their reproductive biology and fecundity, which are influenced by seasonal changes and environmental factors (Ridho et al. 2021). The timing of spawning activities, for example, is correlated with the southwest monsoon, which affects resource availability and habitat conditions (Simon et al. 2012).

The biodiversity of fish species in the Sungsang estuary, including the giant mudskipper, is influenced by a variety of environmental factors. Numerous studies have documented the species diversity and community composition in this region, emphasizing the importance of mangrove ecosystems as critical habitats for mudskippers and other aquatic species (Fauziyah et al. 2019). However, the ongoing threat of human activities, such as deforestation and pollution, poses a significant threat to the ecosystem, thereby impacting mudskipper populations and their role. Consequently, conservation efforts are imperative to safeguard the habitat and ensure the long-term sustainability of mudskippers in South Sumatra (Septinar et al. 2023). A number of studies have been conducted on the foraging behavior of mudskippers in South Sumatra, encompassing

A number of studies have been conducted on the foraging behavior of mudskippers in South Sumatra, encompassing research on their dietary habits (Ridho et al. 2019), gonad length and fecundity (Ridho et al. 2021), and range extension of *P. septemradiatus* (Iqbal et al. 2018). However, research on the length-weight relationship of *P. schlosseri* remains scarce, with most studies being based on field observations. Sungsang coast, located in the estuary of the Musi River, is a well-known site for mudskippers. Despite numerous studies on the biology and ecology of mudskippers in Southeast Asia, data on length-weight relationships and morphometric-environment interactions of *P. schlosseri* in the Sungsang estuary remain scarce. This study aims to fill this gap by analyzing the length-weight relationships and morphometric-environment interactions of *P. schlosseri* in the Sungsang estuary.

#### MATERIALS AND METHODS

#### Study area

65

66

67

68

69

76

77

78

79 80

81

82

83

84

85

86

87 88 The research was carried out at five stations in the study area, which extends from latitudes 2°21'48" S and longitudes 104°53'57" E in the Sungsang estuaries of the Sungsang IV Village, South Sumatra, Indonesia (Figure 1). The description of these sampling locations is shown in Table 1. The Musi River is a major river with multiple uses for its resources. It flows through three provinces on Indonesia's Sumatra Island: South Sumatra, Lampung, and Bengkulu. The coast of Sungang is situated within the Musi River estuary, where the river meets the sea (Melki et al. 2018a, b). Local fishermen depend on the rich aquatic life in the river and its estuary for their livelihoods. The Musi River estuary is home to a variety of fish species, including freshwater stingrays, catfish, and other fish, which are not only a source of food but also contribute to the local economy and food security (Putri and Melki 2020). The mangrove ecosystem within the Musi Estuary is in a state of optimal health, providing an ideal environment for the proliferation of mudskippers (Iqbal et al. 2018; Ridho et al. 2019; Ridho et al. 2021)

Commented [VH6]: provide all detailed location and general description of each site in the Table Formatted: Font color: Blue, Strikethrough Formatted: Font color: Black Formatted: Font color: Blue Formatted: Font color: Blue

| Table 1. Description of sam | ipning locations in the S | ungsang estuaries    |   | - 1 | Formatted: Indent: First line: 0 cm          |
|-----------------------------|---------------------------|----------------------|---|-----|--|
| Sampling sites and          | Position                  |                      | Description                                       |     | Formatted Table                              |
| names                       | Longitudes (E)            | Latitudes (S)        |   |     |  |
| 1 – Sungsang IV             | 104° 53' 22.65"           | <u>2° 22' 00.07"</u> | Fisherman's village, but the population is not as | •   | Formatted: Left, Indent: First line: 0,05 cm |
|                             |                           |                      | large as in sites 2, 3 and 4. There is a healthy  |     |  |
|                             |                           |                      | mangrove ecosystem and this site is the mouth     |     |  |
|                             |                           |                      | of the estuary                                    |     |  |
| <u>2 – Sungsang III</u>     | <u>104° 53' 50.17"</u>    | <u>2° 21' 56.30"</u> | <u>Fisherman's village area</u>                   | 4   | Formatted: Left, Indent: First line: 0,05 cm |
| <u>3 – Sungsang II</u>      | <u>104° 54' 01.76"</u>    | <u>2° 21' 54.56"</u> | Fisherman's village area                          | •   | Formatted: Left, Indent: First line: 0,05 cm |
| <u>4 – Sungsang I</u>       | <u>104° 54' 14.22"</u>    | <u>2° 21' 47.61"</u> | Fisherman's village area                          | 4   | Formatted: Left_Indent: First line: 0.05 cm  |
| 5 – Marga Sungsang          | 104° 54' 21 17"           | 2° 21' 33 41"        | Fisherman's village, but the population is not as | -   |  |
| <u>o maga bangbang</u>      | 101 01 21117              | <u>2 21 00111</u>    | large as in sites 2, 3 and 4. There is a good     |     | Formatted: Left, Indent: First line: 0,05 cm |
|                             |                           |                      | mangrove ecosystem and this site is closer to     |     |  |
|                             |                           |                      | the river   | _   |  |

89

**Commented [VH5]:** add reference. Ex: https://smujo.id/biodiv/article/view/17613



Figure 1. The study area of *P. schlosseri* in Sungsang coast

#### 3 Sampling and preservation

A total of eleven individuals of *P. schlosseri* were collected at each site (n = 55 total) during a single sampling event in 94 95 July 2024 to account for variation. Upon completion of ongoing genetic analyses, voucher specimens will be deposited a 96 <u>Universitas Sriwijaya</u>. Fish sampling was conducted using a  $1 \times 3$  m seine net with a 1 mm mesh size suitable for 97 capturing small estuarine species. After collection, samples were immediately placed in labeled plastic bottles containing 98 8-10% formalin solution for initial preservation. In the laboratory, samples were transferred to 75% ethanol for long-term 99 storage and further morphometric and meristic analyses. The use of 8-10% formalin for initial fixation followed by 75 100 ethanol for long-term storage remains a widely accepted and effective method of preserving fish specimens for 101 morphometric and meristic analysis. This combination not only ensures adequate tissue fixation and structural integrit 102 over time, but also facilitates detailed laboratory evaluation without significant degradation of key anatomical feature 103 Previous studies have confirmed the reliability of this method in maintaining specimen quality for systematic an 104 taxonomic research purposes (Sotola et al., 2019; Jawad et al., 2020). 105

#### 106 Morphometric measurements

107 A total of seventeen morphometric measurements were recorded, including total length (TL), standard length (SL), eye 108 diameter (ED), head diameter (HD), head length (HL), length of the dorsal fin 1 (LD1), the gap between D1 and D2 109 (GD1D2), second dorsal fin length (LD2), and distance between anal and caudal fin (DAC), length of anal fin (LA), least 110 height of the pectoral fin (LPc), length of pectoral fin (PcF), the distance between pectoral and pelvic fin (DPI), length of 111 pelvic fin (LPF), the width of pelvic fin (WPF), and length of caudal fin (LCF), and width of caudal fin (WCF) (Figure 2) 112 (Gangan et al. 2016; Rahman et al. 2022). All morphometric data were standardized by dividing each measurement by th 113 standard length (SL) and then multiplying by 100% to eliminate the effect of size variation between individuals. Eac 114 measurement -was measured to the nearest 0.1 centimeters, and body weight was measured on a digital scale with 0.1 gram 115 accuracy.

Commented [VH7]: is there voucher specimen code?

Commented [VH8]: Add references.

Commented [VH9]: Add references.

**Commented [VH10]:** Measurement data cannot be presented directly before being equalized by dividing by SL and then multiplying by 100%

Commented [VH11]: Provide a figure of measurements



#### Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Sokefun et al. 2022; Rahman et al. 2022)

#### 118 119 120 121 122

123

124

125

117

#### Environmental parameter measurements

Environmental parameters were measured in situ at each sampling site where fish samples were collected to assess the physicochemical characteristics of the habitat. Water temperature, pH and dissolved oxygen were measured using a portable multiparameter instrument (Hanna Instruments Inc., USA) to ensure accurate and simultaneous measurements. Salinity was measured using a hand refractometer (ATAGO Co. Ltd, Tokyo, Japan). All measurements were performed in triplicate to ensure the accuracy and reliability of the data.

#### 126 127 Data analysis

The following equation was used to approximate the length-weight relationships using the formula  $W=a \times TLb$  (Tran et al. 2021; Vilchez et al. 2024), where W is the body weight (g), TL is the total length (cm), and a and b were estimated by the least-squares method based on logarithms using the formula Log (W)= log (a)+b log (TL) (Raeisi et al. 2011). Fish may exhibit isometric growth, characterized by equal growth in all three dimensions (b=3), or positive allometric growth, where width and height receive priority (b>3), or negative allometric growth, where length is prioritized (b<3) (Froese 2006). The effectiveness of linear regression can be quantified by the coefficient of determination (r2) (Tran et al. 2021).

The K of the fish was estimated using the equation  $K = (W) / (a \times TLb)$ , where W is the body weight (g), TL is the total length (cm), and a and b are the regression coefficients. A non-parametric Kruskal-Wallis test with a 5% threshold of significance was employed to determine whether there were any significant variations in mean Wrm between species because the assumptions of parametric statistics could not be met. For each statistical test, the significance level was set at p<0.05.

139 Principal Component Analysis (PCA) was performed using XLSTAT version 2021.4.1 (Addinsoft, New York, USA) 140 integrated with Microsoft Excel. Prior to analysis, all morphometric and environmental data were standardized to eliminate unit bias and ensure comparability between variables. PCA was used to identify patterns and correlations between 141 142 environmental parameters and morphometric traits of P. schlosseri across sampling sites. PCA reduces multidimensional 143 data into principal components that explain the maximum variance in the data set. A biplot of the first two principal 144 components was generated to visualize the distribution of active variables (environmental and morphometric parameters) and active observations (sampling sites). Variables with similar directions and vector lengths were interpreted as having a 145 146 stronger influence or association within the same dimension. 147

#### RESULTS DAN DISCUSSIONS

#### 150 Environmental parameters

The environmental parameters of samples in all experiments conducted in the Sungsang coast area exhibited minimal fluctuation (Table 1). The environmental parameters that exert a substantial influence on the survival of mudskippers include temperature, salinity, acidity (pH), and dissolved oxygen content (DO) (Ansari et al. 2014; Ridho et al. 2021; Dewiyanti et al. 2022).

**Table 1.** The environmental parameters in the sampling sites

| <i>,</i> | Tuble 1. The environ | mental parameters in the samp | Jung Sites |           |                          |                |   |
|----------|----------------------|-------------------------------|------------|-----------|--------------------------|----------------|---|
|          | Sampling site        | Temperature (°C)              | pH (water) | pH (soil) | DO (mg L <sup>-1</sup> ) | Salinity (ppt) |   |
|          | 1                    | 31.7±0.1                      | 7.2±0.2    | 7.0±0.1   | 6.9±0.5                  | 20.0±0.0       | Ī |
|          | 2                    | 31.7±0.2                      | 7.1±0.1    | 6.8±0.3   | 6.3±0.3                  | 16.7±1.5       |   |
|          | 3                    | 31.3±0.1                      | 7.1±0.1    | 6.9±0.1   | 6.3±0.6                  | 16.0±0.0       |   |
|          | 4                    | 31.9±0.2                      | 7.1±0.1    | 7.0±0.2   | 7.8±0.5                  | 15.3±0.6       |   |
|          | 5                    | 29.8±0.1                      | 7.2±0.1    | 6.8±0.3   | 7.9±0.4                  | 15.0±0.0       |   |

#### 157 158

148

149

The temperature of the water varied from 29.8±0.1 to 31.9±0.2°C. According to previous studies, the optimal water

#### Formatted: Font: Bold

#### Formatted: Indent: First line: 0 cm

temperature range for mudskippers is between 23.5 and 35.5 °C (Ridho et al. 2021; Dewiyanti et al. 2022; Arevalo et al. 2023). However, mudskippers demonstrated a preference for milder water temperatures, with a mean of  $26.7\pm2.1$  °C (Nay et al. 2018). The pH levels of the water ranged from  $7.1\pm0.1$  to  $7.2\pm0.2$ , and the pH levels of the soil ranged from  $6.8\pm0.3$ to 7.00.2. According to several studies, the mudskipper exhibits optimal growth and reproductive capacity in aquatic environments with pH values ranging from 6 to 8 (Ridho et al. 2021; Dewiyanti et al. 2022; Darojat et al. 2023).

The present study examined the dissolved oxygen (DO) levels in the aquatic environment, with a range of  $6.3\pm0.3$  to 164 7.9±0.4 mg L<sup>-1</sup>. This finding is notable when compared to the results reported by Ridho et al. (2021), that the mudskipper 165 could survive at DO levels ranging from 4.2 to 6.2 mg L<sup>-1</sup>. In accordance with the findings of Dewiyanti et al. (2022), the range of DO levels in this study was from 4.9 to 7 mg L<sup>-1</sup>, indicating that mudskippers possess a considerable degree of 166 167 tolerance to variations in DO levels. The salinity levels in the study areas ranged from 15.0±0.0 to 20.0±0.0 ppt. In contrast, 168 169 Darojat et al. (2023) reported that mudskippers can survive in mangrove ecosystems with a salinity range of 1.7 to 2.58 ppt. 170 Ridho et al. (2021) also reported a salinity range of 0 to 0.1 ppt. However, Dewiyanti et al. (2022) identified a higher 171 salinity range, spanning from 18 to 25 ppt, and a more pronounced range of 24.4 to 34.4 ppt (Taniwel et al. 2020). The 172 significance of these salinity levels is underscored by the observation that mudskippers are euryhaline, indicating their 173 capacity to withstand a broad spectrum of salinities (Looi et al. 2021). However, pronounced fluctuations in salinity can 174 exert an influence on their physiological processes and selection of habitat (Looi et al. 2021).

Temperature, salinity, and dissolved oxygen (DO) levels represent critical physical parameters that significantly influence the viability and growth potential of giant mudskippers. These fish exhibit a remarkable capacity for adaptability in response to fluctuating environmental conditions, as evidenced by their increased oxygen uptake rates in response to elevated temperatures (Pattaratumrong and Pompha 2024). Furthermore, they employ behavioral strategies to mitigate exposure to extreme conditions.

#### 181 Morphometric characteristic

P. schlosseri Periophthalmodon schlosseri observed in this study had a mean total length (TL) of 20.08 cm, ranging 182 183 from 15.00 cm to 22.60 cm, while the mean standard length (SL) was 17.34 cm, with a range of 13.00 cm to 20.00 cm 184 (Table 2). The body size recorded at the sampling sites in the Sungsang estuary is comparable to previous findings in the 185 Musi River estuary, South Sumatra, Indonesia (Ridho et al. 2019, 2021). However, it is significantly larger than 186 individuals reported from Cu Lao Dung Island, Soc Trang Province, Vietnam, which ranged from 12.10-18.65 cm (Tran et 187 al. 2022), and slightly larger than those from Tanjung Piai, Pontian, Johor, Malaysia, which ranged from approximately 20 188 cm (Hui et al. 2019). This difference may be due to several ecological factors, including higher habitat productivity, 189 greater availability of prey organisms, or potentially lower levels of anthropogenic disturbance in the Sungsang estuary. In 190 support of this, Dinh et al. (2020) suggested that food abundance plays an important role in shaping the growth of 191 mudskippers. Furthermore, Tran et al. (2021) reported that the diet composition of mudskippers varied with fish size, 192 season, and habitat, suggesting that local environmental conditions may significantly influence growth performance in 193 different populations 194

Commented [VH12]: Provide the figure of specimen Commented [VH13]: Complete the name in the start of

paragraph



Figure 3. Sample of mudskipper (A. Periophthalmodon schlosseri, B. Morphometric measurement)
 197

Giant mudskippers display a distinctive body shape that is adapted for both swimming and terrestrial locomotion. Their bodies are generally elongated and laterally compressed, a trait that facilitates movement in both water and on land (Pattaratumrong and Pompha 2024). The total length of these creatures can exhibit significant variation based on environmental factors and habitat conditions. For instance, studies have documented lengths of up to 25 cm in certain specimens attributed to variations in habitat type and food availability (Zhou et al. 2023). In addition to morphometric measurements, giant mudskippers exhibit specific meristic traits that can be used to differentiate them from other Formatted: Indent: First line: 0 cm

204 205 206

# Table 2. Morphometric measurement results of *P. schlosseri* on Sungsang coast 208

Commented [mm15R14]: revision has been corrected Morphometric Measurements Ranged (cm) Mean ± sd (cm) 15.00-22.60 20.08±2.0 TL SL 13.00-20.00 17.34±1.7 ED 0.40-1.70  $0.83 \pm 0.4$ 2.40-4.80 3.44±0.6 HD HL 3.40-6.40 4.81±0.8  $LD_1$ 1 50-3 00 2.67±0.4  $GD_1D_2$ 0.90-2.60 1.47±0.4 3.00-4.20 3.73±0.4  $LD_2$ DAC 2.00-3.90 3.06±0.5 LA 2.60-4.30  $3.49 \pm 0.4$ LPc right 1.30-2.80 1.89±0.4 LPc left 1.40-2.80 2.05±0.4 PcF right 1.10-2.50  $1.66 \pm 0.3$ PcF left 1.50-3.00 1.91±0.5 DPI right 0.20-1.70 0.78±0.4 DPI left 0.50-1.80 0.96±0.4 0.80-2.80  $1.63 \pm 0.7$ LPF WPF 1.50-3.00 2.36±0.5 LCF 2.00-4.70 3.40±0.8 WCF 1.30-3.00 2.32±0.5

#### 209 Length-weight relationship

210 The length-weight relationship of the giant mudskipper (P. schlosseri) was determined through the analysis of 55

mudskipper species. For instance, the dorsal fin composition, including the number of spines and soft rays, exhibits

variation among populations, suggesting adaptations to local environmental conditions (Nor et al. 2023).

specimens collected from five sampling sites along the Sungsang coast. The total length (TL) ranged from 15.00 to 22.60

cm, and the body weight varied from 28.3 to 119.2 g (Table 3).

213 214

 Table 3. Range of total length (TL) and body weight (W) of P. schlosseri in Sungsang coast

| Sampling Site | TL (cm)     | W (g)        |  |  |
|---------------|-------------|--------------|--|--|
| 1             | 19.5 - 21.5 | 67.8 - 102.5 |  |  |
| 2             | 15.0 - 21.0 | 28.3 - 103.7 |  |  |
| 3             | 19.0 - 20.5 | 61.8 - 92.8  |  |  |
| 4             | 20.0 - 22.5 | 87.7 - 108.3 |  |  |
| 5             | 19.5 - 22.6 | 82.1 - 119.2 |  |  |
| Average       | 20.1        | 85.4         |  |  |

215

216 The findings of the regression analysis and the length-weight relationship graph (Figure 2) yielded the following 217 equation: y = 0.0026x3.45. The b value of 3.45 indicates that the fish growth pattern is positive allometric (b > 3), 218 signifying that weight growth outpaces length increase. Positive allometric growth is indicated by a length-weight 219 relationship (LWR) where the exponent (b) is greater than 3. Studies have demonstrated that P. schlosseri exhibits such a 220 relationship, with documented values of b indicating positive allometry (Ridho et al. 2019; Abiaobo et al. 2021; Looi et al. 221 2021; Mussa et al. 2024). For instance, a study conducted in the Musi River Estuary found that the correlation coefficient 222 for the length-weight relationship (LWR) of P. schlosseri was 98.2%, with an exponent value of 3.189, confirming its 223 positive allometric growth (Ridho et al. 2019). This suggests that as the fish grows, it becomes relatively heavier compared 224 to its length, which may be advantageous for buoyancy and mobility in its habitat. This positive allometric growth pattern 225 of P. schlosseri is consistent with findings from related species within the same family. For example, P. barbarus also 226 exhibited positive allometric growth in similar ecological contexts, reinforcing the notion that this growth strategy may be 227 a common adaptive trait among mudskippers (Indarjo et al. 2020; Abiaobo et al. 2021). The implications of such growth 228 patterns are critical, as they can influence the species' reproductive strategies, survival rates, and overall fitness in 229 fluctuating environmental conditions typical of mangrove ecosystems (Dinh 2016).

230

Commented [VH14]: See in the method comment



Figure 2. Relationship between total length and body weight of *P. schlosseri* in Sungsang coast
 Galaxies and Salaxies and

In comparison with other species found in mangrove ecosystems, the allometric growth of *P. schlosseri* reflects typical trends in estuarine and intertidal species, where growth patterns are often influenced by environmental conditions such as temperature, food availability, and habitat structure (Chew et al. 2014; Looi et al. 2021). The positive allometry observed in the Sungsang population could be attributed to the productivity of the mangrove ecosystem, which provides abundant resources for these mudskippers. The Musi River estuary is home to a diverse array of mudskipper species, which exhibit various adaptations to their mangrove habitat. For instance, studies have documented the reproductive biology and feeding habits of mudskippers in this region, emphasizing their role in the local food web (Ridho et al. 2019; Ridho et al. 2021).

#### 241 Condition factor

The K value exhibited a maximum at sampling site 1 (K= 1.04) and a minimum at sampling site 5 (K= 0.94) (Figure 3). The variation in K values across the sampling sites was not statistically significant, suggesting that the fish samples were healthy and well-nourished at the time of the study. The K values in the Sungsang coastal area are comparable to those found in the Tran De District, Soc Trang Province, Mekong Delta, Vietnam mangrove habitat, which range from 1.01 to 1.03 (Dinh 2016), and the West Coast of Peninsular Malaysia, which range from 0.41 to 1.29 (Looi et al. 2021).



Figure 3. Condition factor of *P. schlosseri* in Sungsang coast

Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the lengthweight relationship. The condition factor values indicated a range of nutritional status among the mudskippers, with most individuals displaying average to good health (Froese 2006). However, some specimens with lower condition factors were found to be lean, suggesting potential seasonal fluctuations in food availability that might influence the body mass-tolength ratio (Abdullah and Zain 2019; Tran et al. 2021; Nguyễn et al. 2022). Condition factors, which are used as an indicator of fish health, have been shown to vary with environmental conditions. This indicates that abiotic factors, such as temperature and salinity, as well as biotic factors, such as prey availability, significantly affect the growth patterns of these fishes (Dewiyanti et al., 2022; Dinh et al., 2022).

#### 258 Principal component analysis (PCA)

259 Principal component analysis was employed to ascertain the correlation between seventeen P. schlosseri morphometric 260 characteristics and environmental factors, including water pH and soil pH, dissolved oxygen (DO), temperature, and 261 salinity. The analysis yielded significant findings concentrated on two primary axes: F1 by 55.47% and F2 by 24.70%, 262 with 80.17% representing the maximum amount of information (Figure 4).





264 265 266 Figure 4. PCA was examined to determine morphometric characteristics related to environmental factors of P. schlosseri on Sungsang

#### 267

268 The environmental parameter on the positive F1 axis is characterized by DO, which for sampling site 5 is high at 7.9 269 mg L<sup>-1</sup>. According to Kumar et al. (2021) and Mulyasari (2023), a very strong correlation relationship can mean that as the value of the comparison character increases, the length of a morphometric character in fish will also increase. 270 271 Consequently, elevated levels of dissolved oxygen at the Sungsang coast could potentially influence the growth of morphometric characteristics in P. schlosseri. A study by Khater et al. (2021) and Heriyati et al. (2022) indicated that low 272 273 DO levels can lead to a reduction in fish appetite and growth. The findings indicate that salinity exerts minimal influence 274 on the morphometric growth of P. schlosseri. The classification of mudskippers as euryhaline organisms is attributed to 275 their capacity to respond to variations in salt concentration (Taniwel et al. 2020; Kim et al. 2021; Hamidah et al. 2024).

276 The positive F2 axis is characterized by sampling site 1, which is associated with the environmental parameter 277 component of soil pH and the morphometric characteristics of WPF, defined as the width of the pelvic fins utilized during 278 locomotion by mudskippers. This parameter is believed to be closely related to their biological functions (Hidayat et al. 279 2022; Quigley et al. 2022). The pH value of the soil at sampling site 1 is 7, indicating a high value within the threshold of 280 P. schlosseri life. The measurement of soil pH is crucial as the mudskipper habitat is located in the sediment. A low pH 281 value in the mudskipper habitat prompts the fish to allocate their energy toward environmental adjustments rather than 282 growth and foraging (Smith and Nobriga 2023).

This study analyzed the giant muckipper (*P. schlosseri*) *P. schlosseri* on Sungsang coast, revealing positive allometric growth (b>3) and healthy condition factors. Dissolved oxygen and pH exhibited a strong influence on 283 284 285 morphometric characteristics, while temperature and salinity supported optimal habitats. The findings emphasize the 286 critical role of mangroves in sustaining P. schlosseri P. schlosseri populations and offer insights into mangrove ecosystem management. This study highlights that dissolved oxygen and pH are the most influential environmental variables 287 288 affecting the morphometric variation of P. schlosseri, suggesting their potential as key indicators in mangrove ecosystem 289 monitoring.

#### Where is the acknowledgment?

#### Acknowledgements

We would like to express our sincere gratitude to Abah Badrun for his assistance in collecting mudskippers, which was very important for this research. We would also like to thank Gusti Ayu for her patience and help in setting up the research site.

#### REFERENCES

 Abdullah MIC, Zain KM. 2019. Length-weight relationships, condition factor and growth parameters of *Periophthalmus chrysospilos* (Bleeker, 1852) (Gobiiformes: Gobiidae), in Bayan Bay, Penang, Malaysia. Sains Malays 48 (2): 271–279. DOI: 10.17576/jsm-2019-4802-02.
 Abiaobo N, Asuquo IE, Ejiogu IN, James EJ. 2021. Aspects of the biology of *Periophthalmus barbarus* (mudskipper), from Jaja Creek, Niger Delta, Niger Delta 297 298 299 300 301 302

Nigeria. Ecol Evol Biology 6 (1): 15. DOI: 10.11648/j.eeb.20210601.14. Ansari AA, Trivedi S, Saggu S, Rehman H. 2014. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. J Entomol Zool Stud 2 (6): 22-33.

Commented [VH16]: Be consistent! Without (......)

Commented [VH17]: italic

Formatted: Font: Bold

Formatted: Indent: First line: 0 cm Formatted: Font: Not Bold

296

290

291

292

293

294

- Arevalo E, Cabral HN, Villeneuve B, Possémé C, Lepage M. 2023. Fish larvae dynamics in temperate estuaries: A review on processes, patterns and factors that determine recruitment. Fish Fish 24 (3): 466-487. DOI: 10.1111/faf.12740.
- Arulnayagam A, Khim JS, Park J. 2021. Floral and faunal diversity in 57 Lankan mangrove forests: A systematic review. Sustainability 13 (17). DOI: 10.3390/su13179487.
- 10.3390/su151/9487.
   Chew SF, Hiong KC, Lam SP, Ong SW, Wee WL, Wong WP, Ip YK. 2014. Functional roles of Na+/K+-ATPase in active ammonia excretion and seawater acclimation in the giant mudskipper, *Periophthalmodon schlosseri*. Front Physiol 5. DOI: 10.3389/fphys.2014.00158.
   Corush JB, Zhang J. 2022. One size does not fit all: Variation in anatomical traits associated with emersion behavior in mudskippers (Gobiidae: Oxudercinae). Front Ecol Evol 10: 01-08. DOI: 10.3389/fevo.2022.967067.
- Darojat AZ, Marhendra APW, Kurniawan N. 2023. Identification of mudskipper species in mangrove area of Luwu Timur, Luwu Utara, and Wajo South Sulawesi Indonesia. Biotropika: J Tropical Biol 11 (2): 74–83. DOI: 10.21776/ub.biotropika.2023.011.02.02.
  Dewiyanti I, Melanie K, Almuniro S, Damora A, Nufadillah N, Batubara, AS. 2022. Growth patterns and condition factor of the mudskipper
- (Periophthalmus gracilis) in mangrove ecosystem rehabilitation areas in Banda Aceh and Aceh Besar, Indonesia. Fish Aquat Life 30 (2): 85–94 DOI: 10.2478/aopf-2022-0008.
- Dinh QM. 2016. Growth and body condition variation of the giant mudskipper *Periophthalmodon schlosseri* in dry and wet seasons. Tap Chi Sinh Hoc 38 (3). DOI: 10.15625/0866-7160/v38n3.7425.
- 56 (5). DOI: 10.12622/0806-100/VS0B3.1423.
  Dinh QM, Tran LT, Tran TTM, To DK, Nguyen TTK, Tran DD. 2020. Variation in diet composition of the mudskipper, *Periophthalmodon septemradiatus*, from Hau River, Vietnam. Bull Mar Sci 96 (3): 487–500. DOI: 10.5343/bms.2018.0067.
  Dinh QM, Nguyen THD, Truong NT, Doan DX, Nguyen TTK. 2022. Monthly variations in growth pattern and condition factor of *Periophthalmodon*
- septemradiatus (gobiiformes: periophthalminae) living along the Bassac River in Viet Nam. PeerJ 10: e13880. DOI: 10.7717/peerJ.13880. Fauziyah F, Nurhayati N, Bernas SM, Putera A, Suteja Y, Agustiani F. 2019. Biodiversity of fish resources in Sungsang estuaries of South Sumatra; IOP
- Conference Series: Earth and Environmental Science 278 (1): 012025, DOI: 10.1088/1755-1315/278/1/012025. Froese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. J Appl Ichthyol 22 (4): 241– 253. DOI: 10.1111/j.1439-0426.2006.00805.x.
- Gangan SS, Kumar R, Ramteke KK, Kumar AP, Jaiswar AK. 2016. Study of morphological variation discernible by multivariate analysis between the species of genus Setipinna (Teleostei: Clupeiformes). Ecol Enviro and Conserv 22 (September): S11–S16. Hamidah A, Murni P, Said M. 2024. The diversity of mudskipper fish family Gobiidae in mangrove area, Seberang District, Tanjung Jabung Regency
- West Jambi. J Surv Fish Sci 11 (1). DOI: 10.53555/sfs.v11i01.2045.
- Heaven V, Basen V, Solver F, Basen V, Basen M, Basen M, Basen M, Basen V, Basen V, Solver J, Kasen V, Kase system (RAS) increased dissolved oxygen, fish culture performance, and stress resistance of Red Tilapia (Oreochromis sp.). Trends Sci 19 (20): 6251. DOI: 10.48048/tis.2022.6251
- Hidayat S, Wicaksono A, Raharjeng ARP, Jin DSM, Alam P, Retnoaji B. 2022. The morphologies of mudskipper pelvic fins in relation to terrestrial and climbing behaviour; Proceedings of the Zoological Society 75 (1): 83-93. The University of Edinburgh, 8 February 2022. DOI: 10.1007/s12595-021-
- Hui NY, Mohamed M, Othman MNA, Tokiman L. 2019. Diversity and behaviour of mudskippers of Tanjung Piai, Pontian, Johor. IOP Conference Series: Earth and Environmental Science 269 (1). DOI: 10.1088/1755-1315/269/1/012037. Indarjo A, Salim G, Zein M, Susiyanti S, Soejarwo PA, Nugraeni CD, Bija S, Pham YTH. 2020. Characteristics of Von Bertalanfy growth, allometric
- Induity of John M, John M, John M, John M, John M, John MD, John M, John MM, John M, John MM, John M, John MM, John M, John MM, John
- Indonesia. Cybium 42 (4): 376–378. DOI: 10.26028/cybium/2018-424-009.
- IUCN. 2023. Periophthalmodon List of Threatened Species 2023: e.T196314A15320642 schlosseri. The IUCN Red IUCN. 2023. Performationation sectionseri. The TOCK Red List of Theorem Species 2025. CHARGENERIES 2007. www.iucnredlist.org/species/196314/153206425. Jawad LA, Koya A, Gnohossou P. 2020. Fixation, preservation and freezing effects on morphometrics of two fish species collected from Lake Ganv Benin, West Africa. Thalassia Sal 42, 75-82. DOI: 10.1285/115910725v42p75.
- Jordan P, Fröhle P. 2022. Bridging the gap between coastal engineering and nature conservation?: A review of coastal ecosystems as nature-b solutions for coastal protection. J Coast Conserv 26 (2). DOI: 10.1007/s11852-021-00848-x.
- Khater ES, Bahnasawy AH, Elghobashy H, Shaban Y, El-Sheikh FM, El-Reheem SA, Aboegela M. 2021. Mathematical model for predicting oxygen concentration in Tilapia fish farms. Sci Rep 11 (1). DOI: 10.1038/s41598-021-03604-1.
- Kim J, Lee C, Yoo D, Kim H. 2021. Genetic adaptations in mudskipper and tetrapod give insights into their convergent water-to-land transition. Animals 11 (2): 584. DOI: 10.3390/ani11020584
- Kumar GR, Bano F, Serajuddin M. 2021. Effect of formalin preservation on studies on morphology and condition factor of the freshwater Shark Wallage attu (Bloch and Schneider, 1801) using truss network system. Indian J Fish 68 (3). DOI: 10.21077/ijf.2021.68.3.98695-16. Looi LJ, Aris AZ, Isa NM, Yusoff, FM, Haris H. 2021. Elemental composition and health risk assessment of giant mudskipper (*Periophthalmodon*)
- Looi LJ, Aris AZ, Isa NM, Yusoff, FM, Haris H. 2021. Elemental composition and health risk assessment of giant mudskipper (*Periophthalmodon schlosseri*) from the intertidal zone of the west coast of Peninsular Malaysia. Front Mar Sci 7. DOI: 10.338/fmars.2020.618284.
   Mai HV, Tran LX, Dinh QM, Tran DD, Murata M, Sagara H, Yamada A, Shirai K, Ishimatsu A. 2019. Land invasion by the mudskipper, *Periophthalmodon septemradiatus*, in fresh and saline waters of the Mekong River. Sci Rep 9(1). DOI: 10.1038/s41598-019-50799-5.
   Melki, Isnansetyo A, Widada J, Murwantoko M. 2018a. The significance of water quality parameters on the diversity of ammonia-oxidizing bacteria in the water surface of Musi River, Indonesia. AACL Bioflux 11 (6), 1908–1918.
   Melki, Isnansetyo A, Widada J, Murwantoko M. 2018b. Distribution of ammonium-oxidizing bacteria in sediment with relation to water quality at the Musi River, Indonesia. Hayati J Biosci 25 (4), 198–205. DOI: 10.4308/hjb.25.4.198.
   Mulyasari N, Subaryono N, Utomo BSB, Taufik I, Kusmini II, Yosmaniar N. 2023. Morphometric and genetic characterization of dominant fish species in prong Fiver. Yonyakarta. Indonesia, Sci Watel 138 (2): 111–120 DOI: 10.1015/20037(19725).

- in Progo River, Yogyakarta, Indonesia. Sci World J 38 (2): 111–120. DOI: 10.1155/2023/7197251. Mussa ZJ, Aziz BAAA, Saleh SM, Abbas AH, Al-Asadi MK, Jumah AAK. 2024. Mudskippers a good bioindicator for polluted soils in the mudflat
- Mussa DJ, AZZ DAAA, Satell SM, AOGS AH, AFASadi WK, Juliah AAK. 2024. Musskipper's a good binducator for pointed sorts in the muthat region of Southern Iraq. Mesop J Mar Sci 38 (2): 111–119. DOI: 10.58629/mjms.v38i2.354.
  Nathaniel AM, Gbobo BMFO, Raimi MO. 2024. Food and feeding of Atlantic mudskipper *Periophthalmus barbarus* in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria. Qeios. DOI: 10.32388/QNWTVZ.
  Nay TJ, Gervais CR, Hoey AS, Johansen JL, Steffensen JF, Rummer JL. 2018. The emergence emergency: A mudskipper's response to temperatures. J Therm Biol 78 (September): 65–72. DOI: 10.1016/j.jtherbio.2018.09.005.

- Nguyễn NT, Ha LM, Nguyen ATN, Chu NH, Tran HD, Hung NP, Ta TT. 2022. Variation in the allometry of morphometric characteristics, growth, and condition factors of wild *Bostrychus sinensis* (Butidae) in Northern Vietnam. Pak J Zool 55 (2). DOI: 10.17582/journal.pjz/20200917140936. Nor NM, Saifuzzaman S, Azmir IA, Hussin N. 2023. Morphological characteristics and reproductive organs assessment of blue-spotted mudskipper Boleophthalmus boddarti in Peninsular Malaysia. Biotropia 30 (1): 21-36. DOI: 10.11598/btb.2023.30.1.1561
- Pace CM, Gibb AC. 2009. Mudskipper pectoral fin kinematics in aquatic and terrestrial environments. J Exp Biol, 212(14), 2279-2286. DOI: 10.1242/jeb.029041.

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: Font: Not Italic

| 379        | Parenti LR, Jaafar Z. 2017. The natural distribution of mudskippers. In Fishes Out of Water (pp. 37-68). CRC Press.  |                   | Formatted: Font: Not Italic |
|------------|--|-------------------|-----------------------------|
| 380        | Pattaratumrong MS, Pompha T. 2024. Habitat of the amphibious mudskipper <i>Pertophtalmodon schlosseri</i> in Songkhla Lake, Thailand. Biodiversitas 25 (5): 1975-1981. DOI: 10.1305/Thiodiwi/2050503   |                   |                             |
| 382        | (5). 1675-1661. DOI: 10.1503/10004/02.0005 Putri WAE. Melki, 2020. Study of the water guality of the Musi River estuary. South Sumatra, J Mar Aguat Sci 6 (1): 36. DOI:  |                   |                             |
| 383        | 10.24843/jmas.2020.v06.i01.p05. [Indonesian].  |                   |                             |
| 384        | Quigley ZMG, Blob RW, Kawano S. 2022. Kinematic comparisons between mudskipper fins and Salamander limbs during terrestrial locomotion. J Exp  |                   |                             |
| 385        | Zool A Ecol Integr Physiol 337 (6): 612–625. DOI: 10.1002/jez.2594.  |                   |                             |
| 287        | Raeisi H, Dalin M, Paghamban SY, Shabani MJ, Bibak M, Davoodi K. 2011. Length-weight relationships, condition factors and relative weight of five<br>Factor provide a Durback survey of the provide the Distributed in (2021) 10196 DOI:10.1036/07.41011.20560   |                   |                             |
| 388        | This species of Busnehr Waters, Northern Persian Guilt, Art J Biotechnol 10 (82): 19181–19180, DOI: 10.589//AJB11.2000.<br>Rahman MAF Azmir IA Hussin NL 2022 Morphological study of selected mudskinger species (Family: Oxudergidae) and development of key  |                   |                             |
| 389        | neural with the second second many second many second many provide second many second many of a second many sec |                   |                             |
| 390        | Ridho MR, Patriono E, Rahmawati D, Pratama R, Avesena M. 2021. Short communication: Investigating gonad length and fecundity in mudskippers  |                   |                             |
| 391        | (gobiidae) at the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 22 (10): 4413–4420. DOI: 10.13057/biodiv/d221034.  |                   |                             |
| 392        | Ridho MR, Patriono E, Solikha M. 2019. Food habits of three species of mudskippers in the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas  |                   |                             |
| 393        | 20 (8): 2368–2374. DOI: 10.1305/biodiv/d200835.<br>Santose JLP, Subatora E, Zvinia P, Biustracko D, 2020. Mudekinaar fich as a bio indicator for bouw motels pollution in a general worldand. Event L  |                   |                             |
| 395        | Sanoso ID, Sunatono E, Tunta K, Biyannoko D. 2020. Muuskipper isin as a dio-indicator for neavy metals pondition in a coastar weband. Egypt J<br>Agnat Biol Eish 24 (7): 1072-1095 DOI: 10.21608/aishf 2020 144402   |                   |                             |
| 396        | Santoso HB, Krisdianto K, Yunita R. 2024. Iron bioaccumulation and ecological implications in the coastal swamp wetlands ecosystem of South  |                   |                             |
| 397        | Kalimantan: insights from giant mudskipper fish as bioindicators. J Degrad Min Lands Manag, 11(3), 5539-5550. DOI:   |                   |                             |
| 398        | 10.15243/jdmlm.2024.113.5539.  |                   |                             |
| 399        | Septinar H, Putri YP, Midia KR, Bianto B. 2023. Mangrove forest conservation efforts through nurseries in Sungsang IV village, Banyuasin Regency.  |                   |                             |
| 400        | Enviro Sci J: Jurnal Ilmu Lingkungan, 77-88. DOI: 10.31851/esjo.v1i2.11920. [Indonesian].  |                   |                             |
| 401        | servavian AD, winanto K. 2000. The direct exploration in the mangrove ecosystem in Central Java and the land use in its surrounding, degradation and its surrounding. The direct exploration of the dire |                   |                             |
| 403        | Simon KD, Bakar Y, Mazlan AG, Zaidi CC, Samat A, Arshad A, Temple SE, Brown-Peterson NJ, 2012, Aspects of the reproductive biology of two  |                   |                             |
| 404        | archer fishes Toxotes chatareus, (Hamilton 1822) and Toxotes jaculatrix (Pallas 1767). Environ Biol Fishes 93 (4): 491-503. DOI: 10.1007/s10641-   |                   |                             |
| 405        | 011-9944-6.  |                   |                             |
| 406        | Smith WE, Nobriga MK. 2023. A bioenergetics-based index of habitat suitability: spatial dynamics of foraging constraints and food limitation for a rare  |                   |                             |
| 407        | estuarmentsh. Trans Am Fish Soc 152 (5): 650–671. DOI: 10.1002/tats.10427.   |                   |                             |
| 409        | Sokerul O, Gan HW, Tall WF, 2022, Mol prometical characterization to use Atlantic muckspiper species of <i>endphandamus barbarus</i> (Lemadus, 1700)<br>(Perriformes: Gobiae) from Abonema in Port Harcourt Rivers State Nigeria Int. J. Fish Anuae 10 (3): 72-76 DOI:   |                   | Formatted: Font: Italic     |
| 410        | 10.22271/fish.2022.v10.i3a.2719.   |                   |                             |
| 411        | Sotola VA, Craig CA, Pfaff PJ, Maikoetter JD, Martin NH, Bonner TH. 2019. Effect of preservation on fish morphology over time: Implications for  |                   |                             |
| 412        | morphological studies. PLoS ONE 14(3): e0213915. DOI: 10.1371/journal. pone.0213915.   |                   |                             |
| 415        | Steppan SJ, Meyer AA, Barrow LN, Alhajeri BH, Al-Zaidan ASY, Gignac PM, Erickson GM. 2022. Phylogenetics and the evolution of terrestriality in<br>modelinergy (Collider Quidenziero). Mel Dieteorgerine Eric 160, 107416. DOI:10.1016/j.urgar.2022.107416.  |                   |                             |
| 415        | Bu L Fries DA Gasparatos A 2021 A meta-analysis of the ecological and economic outcomes of mangrove restoration Nat Commun 12 (1) DOI:   |                   |                             |
| 416        | 10.1038/41467-021-25349-1.   |                   |                             |
| 417        | Taniwel D, Leiwakabessy F, Rumahlatu D. 2020. Short communication: density and length-weight relationship of mudskipper (Periophthalmus spp.) in   |                   |                             |
| 418        | the mangrove area of Kairatu Beach, Maluku, Indonesia. Biodiversitas 21 (11). DOI: 10.13057/biodiv/d211155.  |                   |                             |
| 419        | Tran HD, Nguyen HH, Ha LM. 2021. Length-weight relationship and condition factor of the mudskipper ( <i>Periophthalmus modestus</i> ) in the Red River<br>Dealth Dealth Mar Sci 40, 101002, DOL 10, 10166, arms 2021, 101002.  |                   |                             |
| 420        | Tran I X Maekawa V Soyano K Ishinatsu A 2020 Morphology of the feeding apparatus in the herbiyozous mudskipper. <i>Boleonbthalmus pectinizastris</i>   |                   |                             |
| 422        | (Linnex, 1758). Zoomorphology 139 (2): 231–243, DQI: 10.1007/s00435-020-00476-3.   |                   |                             |
| 423        | Tran LX, Nguyen TTK, Vo TT. 2022. Morphological comparison of the cranial movement apparatus in mudskippers (Gobiidae: Oxudercinae). Zool 154  |                   |                             |
| 424        | (August): 126042. DOI: 10.1016/j.zool.2022.126042.   |                   |                             |
| 425        | Valen FS, Hasan V, Ottoni FP, Nafisyah AL, Erwinda M, Annisa AN, Adis MA. 2022. First country record of the bearded gudgeon <i>Pogoneleotris</i>   |                   |                             |
| 420        | neterolepis (Gunther, 1869) (Teleostel: Eleotridae) from indonesia, JOP Conf. Ser.: Earth Environ, Sci. 1036 (012074), DOI: 10.1088/1755-<br>1315/1036/1/012074  | K                 | Formatted: Font: Not Italic |
| 428        | Vilchez M, Dattilo J, Brewer SK. 2024. Length-weight relationships of native and non-native fishes in the lower Red River Cathment, USA. J Appl  | $\langle \rangle$ | Formatted: Font: Not Bold   |
| 429        | Ichthyol 2024: 5. DOI: 10.1155/2024/5578825.   |                   | Formatted. Form. Not Bold   |
| 430        | Waleed TA, Abdel-Maksoud YK, Kanwar RS, Sewilam H. 2024. Mangroves in Egypt and the Middle East: current status, threats, and opportunities. Int J   |                   | Formatted: Font: Not Bold   |
| 431        | Environ Sci recinoli. DOI: 10.1007/815702-024-05788-1.<br>Wirahuana PVAP Raskorowati L Pamundas R Mulvana R South L Purnohasuki H Andrivono S Hasan V 2025 Mandroves fauna compositions  |                   |                             |
| 433        | and carbon sequestration after ten years restoration on Flores Island, Indonesia. Sci Rep 15 (4866), DOI:10.1038/s41598.025-87307-x  |                   | Formatted: Font: Not Bold   |
| 434        | You X, Sun M, Li J, Bian C, Chen J, Yi Y, Yu H, Shi Q. 2018. Mudskippers and their genetic adaptations to an amphibious lifestyle. Animals 8 (2). DOI:   |                   | Formatted: Font: Not Bold   |
| 435        | 10.3390/ani8020024.  |                   |                             |
| 430<br>437 | LABR Z, FU T, ZHAO H, ZHABR X. 2022. Social enrichment affects fish growth and aggression depending on fish species: applications for aquaculture.<br>Feront Mar Sci θ. DOLID 13380/fmare 2022 1011780.  |                   |                             |
| 438        | Tour Mar Set 2, DOI:10.5507/III.01.52022.1011700.<br>Zhou H. Donatelli CM. Laneuville O. Standen EM. 2023. Skeletal anatomy of the nectoral fin in mudskipner species from terrestrial and aquatic habitats.   |                   |                             |
| 439        | J Morphol, 284(8). DOI: 10.1002/jmor.21612.  |                   |                             |
| 440        | Ziadi-Künzli F, Maeda K, Puchenkov P, Bandi M. 2024. Anatomical insights into fish terrestrial locomotion: a study of barred mudskipper  |                   |                             |
| 441        | (Periophthalmus argentilineatus) fins based on µct 3d reconstructions. J Anat, 245(4), 593-624. DOI: 10.1111/joa.14071.  |                   |                             |
| 442<br>443 | Zulkilli SZ, Mohamat-Yusufi F, Ismail A, Miyazaki N. 2012. Food preference of the giant mudskipper <i>Periophthalmodon schlosseri</i> (Teleostei:<br>Gobildea) Knowit Facourt 405, DOL 10.1014 (more 2012012)  |                   |                             |
| 444        | Goolade), Kilowi Manag Aquai Ecosyst 405, DOI: 10.1051/Kila@2012015.   |                   |                             |
|            |  |                   |                             |

# Table of Responses

| Lines | Reviewer Comments/Suggest   | Answer  |
|-------|---|---|
| 2-3   | Font: italic<br>Periophthalmodon schlosseri (Pallas,<br>1770) (Gobiiformes: Oxudercidae)  | Repaired as recommended<br><i>Periophthalmodon schlosseri</i> (Pallas, 1770)<br>(Gobiiformes: Oxudercidae)  |
| 8-16  | Abstract. The Giant Mudskipper<br>( <i>Periophthalmodon schlosseri</i> (Pallas,<br>1770)) is one of the most abundant<br>mudskipper species, playing a vital<br>role in the biomass of mangrove<br>ecosystems. Mudskipper fish are also<br>found in the Sungsang coast, an<br>estuary of the Musi River that is fed by<br>river water from three provinces in<br>Indonesia: South Sumatra, Lampung,<br>and Bengkulu. The objective of this<br>study was to analyze the morphology<br>and population dynamics of<br>mudskippers along with their<br>environmental parameters in Sungsang<br>coastal South Sumatra. For this study,<br>mudskipper specimens were collected<br>from five sampling sites along the<br>Sungsang coast and analyzed for<br>morphometric characteristics, length-<br>weight relationships, and their<br>correlations with key environmental<br>parameters like temperature, pH, and<br>dissolved oxygen. The analysis of<br>fifty-five specimens revealed an<br>average total length of 20.08 cm, a<br>standard length of 17.34 cm, and an<br>average weight of 85.4 g. The growth<br>pattern exhibited positive allometry<br>(b>3), suggesting that as these fish<br>grow, their body weight increases at a<br>faster rate than their length. | Abstract. The Giant Mudskipper<br>Periophthalmodon schlosseri (Pallas, 1770) is one<br>of the most abundant mudskipper species, playing a<br>vital role in the biomass of mangrove ecosystems.<br>Mudskipper fish are also found in the Sungsang<br>coast, an estuary of the Musi River that is fed by<br>river water from three provinces in Indonesia: South<br>Sumatra, Lampung, and Bengkulu. This study<br>aimed to analyze the morphology and population<br>dynamics of mudskippers along with their<br>environmental parameters in Sungsang coastal<br>South Sumatra. For this study, mudskipper<br>specimens were collected from five sampling sites<br>along the Sungsang coast and analyzed for<br>morphometric characteristics, length-weight<br>relationships, and their correlations with key<br>environmental parameters like temperature, pH, and<br>dissolved oxygen. The analysis of fifty-five<br>specimens revealed an average total length of 20.08<br>cm, a standard length of 17.34 cm, and an average<br>weight of 85.4 g. The growth pattern exhibited<br>positive allometry (b>3), suggesting that as these<br>fish grow, their body weight increases faster than<br>their length. |
| 26-27 | Add references:<br>"The mangrove ecosystem is a<br>significant area due to its role in<br>providing a habitat for a wide variety<br>of aquatic and terrestrial biota."  | <ul> <li>added as recommended:</li> <li>"The mangrove ecosystem is a significant area due to its role in providing a habitat for a wide variety of aquatic and terrestrial biota (Hasan et al. 2022; Valen et al. 2022)." (in line 27)</li> <li>added to reference:</li> <li>Hasan V, South J, Katz A, Ottoni FP. 2022. First record of the Small-eyed loter <i>Prionobutis microps</i> (Weber, 1907) (Teleostei: Eleotridae: Butinae) in Java Indonesia Cybium 46(1): 49-</li> </ul>   |

|       |  | <ul> <li>51. DOI: 10.26028/CYBIUM/2022-461-008.</li> <li>(in lines 330-331)</li> <li>Valen FS, Hasan V, Ottoni FP, Nafisyah AL, Erwinda M, Annisa AN, Adis MA. 2022. First country record of the bearded gudgeon <i>Pogoneleotris heterolepis</i> (Günther, 1869) (Teleostei: Eleotridae) from Indonesia. IOP Conf. Ser.: Earth Environ. Sci. 1036 (012074). DOI: 10.1088/1755-1315/1036/1/012074.</li> <li>(in lines 425-427)</li> </ul>  |
|-------|--|--|
| 27-28 | "This ecosystem is important from a<br>variety of angles, including its<br>environmental functions, such as<br>protecting estuaries and coastlines<br>from storms, stabilizing the shore, and<br>reducing coastal soil erosion and<br>flooding." | <ul> <li>added as recommended:</li> <li>"This ecosystem is important from a variety of angles, including its environmental functions, such as protecting estuaries and coastlines from storms, stabilizing the shore, and reducing coastal soil erosion and flooding (Setyawan and Winarno 2006; Wirabuana et al. 2025)." (in line 29)</li> <li>added to reference:</li> <li>Setyawan AD, Winarno K. 2006. The direct exploitation in the mangrove ecosystem in Central Java and the land use in its surrounding; degradation and its restoration effort. Biodiversitas 7 (3): 282-291. DOI: 10.13057/biodiv/d070318.</li> <li>(in lines 401-402)</li> <li>Wirabuana PYAP, Baskorowati L, Pamungkas B, Mulyana B, South J, Purnobasuki H, Andriyono S, Hasan V. 2025. Mangroves, fauna compositions and carbon sequestration after ten years restoration on Flores Island, Indonesia. Sci Rep 15 (4866). DOI:10.1038/s41598-025-87307- x.</li> </ul> |
| 37-38 | "A notable example is the giant<br>mudskipper ( <i>P. schlosseri</i> ), which<br>contributes significantly to the biomass<br>value of the mangrove ecosystem."   | A notable example is the giant mudskipper<br><i>Periophthalmodon schlosseri</i> , which contributes<br>significantly to the biomass value of the mangrove<br>ecosystem. According to the IUCN Red List of  |
|       | add an explanation of the conservation<br>status of this species based on the<br>IUCN Red List, and also add the<br>global distribution information  | Threatened Species, this species is currently listed<br>as Least Concern (LC), indicating that it is not<br>under any immediate threat of population decline<br>(IUCN 2023). <i>Periophthalmodon schlosseri</i> is<br>widely distributed throughout the Indo-West Pacific<br>region, including coastal and estuarine areas of<br>Southeast Asia, northern Australia and parts of<br>South Asia (Ansari et al. 2014; Parenti and Jaafar<br>2017). (in lines 37-42)  |
|       |   | added to reference:                                    |
|-------|---|--|
|       |   | IUCN. 2023. Periophthalmodon schlosseri. The           |
|       |   | IUCN Red List of Threatened Species 2023:              |
|       |   | e.T196314A153206425.                                   |
|       |   | www.iucnredlist.org/species/196314/153206425.          |
|       |   | (in lines 345-346)                                     |
|       |   | Parenti LR, Jaafar Z. 2017. The natural distribution   |
|       |   | of mudskippers. In Fishes Out of Water (pp. 37-        |
|       |   | 68). CRC Press.  |
|       |   | (in line 379)  |
| 50-51 | The giant mudskipper is a bioindicator  | The giant mudskipper is a bioindicator species,        |
|       | species, which means that its presence  | which means that its presence or absence can           |
|       | or absence can indicate the ecological  | indicate the ecological health of its habitat          |
|       | health of its habitat                   | (Pattaratumrong and Pompha 2024).                      |
| 77-78 | provide all detailed location and       | The research was carried out at five stations in the   |
|       | general description of each site in the | study area in the Sungsang estuaries of South          |
|       | Table                                   | Sumatra, Indonesia (Figure 1). The description of      |
|       |   | these sampling locations is shown in Table 1.          |
|       | "The research was carried out at five   |  |
|       | stations in the study area, which       | Table 1. Description of sampling locations in the      |
|       | extends from latitudes 2°21'48" S and   | Sungsang estuaries                                     |
|       | longitudes 104°53'57" E in the          | (in line 88)   |
|       | Sungsang estuaries of the Sungsang IV   |  |
|       | Village, South Sumatra, Indonesia       |  |
|       | (Figure 1)."                            |  |
| 94    | is there voucher specimen code?         | Upon completion of ongoing genetic analyses,           |
|       |   | voucher specimens will be deposited at Universitas     |
|       |   | Sriwijaya. (in lines 95-96)                            |
| 98    | Add references.                         | The use of 8-10% formalin for initial fixation         |
|       | "8-10% formalin"                        | followed by 75% ethanol for long-term storage          |
|       | "75% ethanol"                           | remains a widely accepted and effective method of      |
|       |   | preserving fish specimens for morphometric and         |
|       |   | meristic analysis. This combination not only ensures   |
|       |   | adequate tissue fixation and structural integrity over |
|       |   | time, but also facilitates detailed laboratory         |
|       |   | evaluation without significant degradation of key      |
|       |   | anatomical features. Previous studies have             |
|       |   | confirmed the reliability of this method in            |
|       |   | maintaining specimen quality for systematic and        |
|       |   | taxonomic research purposes (Sotola et al., 2019;      |
|       |   | Jawad et al., 2020). (in lines 99-104)                 |
|       |   | added to reference:                                    |
|       |   | Sotola VA, Craig CA, Pfaff PJ, Maikoetter JD,          |
|       |   | Martin NH, Bonner TH. 2019. Effect of                  |
|       |   | preservation on fish morphology over time:             |
|       |   | Implications for morphological studies. PLoS           |
|       |   | ONE 14(3): e0213915. DOI: 10.1371/journal.             |
|       |   | pone.0213915.  |
|       |   | (in lines 411-412)                                     |

| 106 | Measurement data cannot be presented<br>directly before being equalized by<br>dividing by SL and then multiplying<br>by 100% | Jawad LA, Koya A, Gnohossou P. 2020. Fixation,<br>preservation and freezing effects on<br>morphometrics of two fish species collected from<br>Lake Ganvie, Benin, West Africa. Thalassia<br>Sal 42, 75-82. DOI: 10.1285/i15910725v42p75.<br>(in lines 347-348)<br>All morphometric data were standardized by<br>dividing each measurement by the standard length<br>(SL) and then multiplying by 100% to eliminate the<br>effect of size variation between individuals. Each<br>measurement was measured to the nearest 0.1<br>centimeters, and body weight was measured on a<br>digital scale with 0.1 gram accuracy. |
|-----|--|--|
|     |  | (in lines 112-113)   |
| 107 | Provide a figure of measurements<br>"morphometric measurement"   | TLTLImage: SLLD2WCFHDLPCUPFPCFFigure 2. Morphometric measurements of<br>mudskippers (Gangan et al. 2016; Sokefun et al.<br>2022; Rahman et al. 2022)(in lines 117-118)<br>added to reference:<br>Sokefun O, Gan HM, Tan MP. 2022.<br>Morphometrical characterization of the Atlantic<br>mudskipper species ( <i>Periophthalmus barbarus</i> )<br>(Linnaeus, 1766) (Perciformes; Gobiiae) from<br>Abonema in Port Harcourt, Rivers State, Nigeria.<br>Int J Fish Aquac 10 (3): 72-76. DOI:<br>10.22271/fish.2022.v10.i3a.2719.<br>(in lines 408-410)  |

| 181 | Provide the figure of specimen              | AFigure 3. Sample of mudskipper (A. Periophthalmodon<br>colosseri, B. Morphometric measurement)(in lines 195-196)  |
|-----|---|--|
| 182 | Complete the name in the start of paragraph | Periophthalmodon schlosseri  |
| 207 | See in the method comment                   | revision has been corrected  |
| 283 | Be consistent! Without ()                   | P. schlosseri  |
| 286 | italic                                      | P. schlosseri  |
| 291 | Where is the acknowledgment?                | Acknowledgements<br>We would like to express our sincere gratitude to<br>Abah Badrun for his assistance in collecting<br>mudskippers, which was very important for this<br>research. We would also like to thank Gusti Ayu for<br>her patience and help in setting up the research site.<br>(in lines 292-295) |



# [biodiv] Editor Decision

1 pesan

15 April 2025 pukul 21.52

Smujo Editors via SMUJO <support@smujo.com> Balas Ke: Smujo Editors <editors@smujo.id> Kepada: Melki Melki <melki@unsri.ac.id>, Fadhilah Dzakiyyah Ananta <FD ananta@gmail.com>, Isnaini Isnaini@mipa.unsri.ac.id>, Fitri Agustriani <fitri agustriani@yahoo.com>, Rezi Apri <rezi apri@unsri.ac.id>, Hartoni <hartoni@mipa.unsri.ac.id>, Ellis Nurjualisti Ningsih <ellis.nurjualisti@gmail.com>, Jeni Meiverani <jenimeiyerani24@gmail.com>

Melki Melki, Fadhilah Dzakiyyah Ananta, Isnaini, Fitri Agustriani, Rezi Apri, Hartoni, Ellis Nurjualisti Ningsih, Jeni Meiyerani:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia". Complete your revision with a Table of Responses containing your answers to reviewer comments (for multiple comments) and/or enable Track Changes. We are waiting for your revision in the system (https://smujo.id/biodiv), do not send it via email.

Our decision is: Revisions Required

\_\_\_\_\_

Reviewer A:

The author has revised most of the suggestions, but there are some details such as the specimen voucher code number and reference format that need improvement.

**Recommendation: Revisions Required** 

\_\_\_\_\_

**Biodiversitas Journal of Biological Diversity** 

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.

A-21288-Article Text-1158892-1-4-20250413.doc 551K

# Analysis of morphology and population dynamics of giant mudskipper *Periophthalmodon schlosseri* (Pallas, 1770) (Gobiiformes: Oxudercidae) at Sungsang estuaries, South Sumatra, Indonesia

7 Abstract. The Giant Mudskipper Periophthalmodon schlosseri (Pallas, 1770) Periophthalmodon schlosseri (Pallas, 1770) is one of the 8 most abundant mudskipper species, playing a vital role in the biomass of mangrove ecosystems. Mudskipper fish are also found in the 9 Sungsang coast, an estuary of the Musi River that is fed by river water from three provinces in Indonesia: South Sumatra, Lampung, and 10 Bengkulu. This study aimed This study aimed to analyze the morphology and population dynamics of mudskippers along with their 11 environmental parameters in Sungsang coastal South Sumatra. For this study, mudskipper specimens were collected from five sampling 12 sites along the Sungsang coast and analyzed for morphometric characteristics, length-weight relationships, and their correlations with 13 key environmental parameters like temperature, pH, and dissolved oxygen. The analysis of fifty-five specimens revealed an average 14 total length of 20.08 cm, a standard length of 17.34 cm, and an average weight of 85.4 g. The growth pattern exhibited positive 15 allometry (b>3), suggesting that as these fish grow, their body weight increases faster than their length. Condition factor analysis 16 indicated that the fish sampled were healthy and in good nutritional condition. The principal component analysis (PCA) further 17 highlighted a strong association between dissolved oxygen and pH levels with the morphometric characteristics of the mudskippers, 18 explaining 55.47% of the variation on the F1 axis and 24.70% on the F2 axis. This robust correlation between environmental factors and 19 morphometric characteristics underscores the reliability of our findings. These findings provide crucial insights into the ecological 20 health of the Giant Mudskipper and its dependence on specific environmental factors in the mangrove habitat are of utmost importance.

21 Keywords: Environmental parameter, Length-weight relationship, Morphometric, Mudskipper, Sungsang coast

22 Running title: Morphology and Population Dynamics of Mudskipper

4

5

6

23

# **INTRODUCTION**

24 The mangrove ecosystem is an important area due to its role in providing a habitat for a wide variety of aquatic and 25 terrestrial biota, as evidenced by the discovery of rare and previously unrecorded fish species such as the bearded 26 gudgeon *Pogoneleotris heterolepis* in the Kapuas River estuary (Valen et al. 2022) and the small-eyed 27 gudgeon *Prionobutis microps* in the Solo River estuary (Hasan et al. 2022), highlighting the ecological importance of these 28 transitional zones as critical habitats for endemic and specialized aquatic species. This ecosystem is important from a 29 variety of angles, including its environmental functions, such as protecting estuaries and coastlines from storms, stabilizing 30 the shore, and reducing coastal soil erosion and flooding, as shown by successful restoration in Central Java (Setyawan and Winarno 2006) and Flores Island (Wirabuana et al. 2025). Restored mangroves in Pasar Banggi prevented erosion. In 31 32 Flores, 10-year-old mangroves improved sediment retention and wave absorption. Additionally, it serves as a nursery habitat and breeding ground for a wide range of biota, and it provides sources that include essential commodities for both 33 subsistence and commerce (Arulnayagam et al. 2021; Su et al. 2021; Jordan and Fröhle 2022; Waleed et al. 2024). 34

35 During periods of low tide, mangrove swamps and tidal flats formed in creeks, estuaries, and coastal waterways provide habitat for mudskippers (Mai et al. 2019; Ridho et al. 2019; Santoso et al. 2020; Darojat et al. 2023; Nathaniel et al. 36 2024). Mudskippers exhibit physiological, morphological, and behavioral adaptations that allow them to thrive in both 37 aquatic and terrestrial environments (You et al. 2018; Tran et al. 2020; Corush and Zhang 2022; Steppan et al. 2022). 38 39 Various factors, including food availability, habitat selection, human disturbance, and others influence the geographical 40 distribution of each species. A notable example is the giant mudskipper Periophthalmodon schlosseri, which contributes significantly to the biomass value of the mangrove ecosystem (Zulkifli et al. 2012; Dewiyanti et al. 2022). According to 41 the IUCN Red List of Threatened Species, this species is currently listed as Least Concern (LC), indicating that it is not 42 under any immediate threat of population decline (IUCN 2023). Periophthalmodon schlosseri is widely distributed 43 44 throughout the Indo-West Pacific region, including coastal and estuarine areas of Southeast Asia, northern Australia and 45 parts of South Asia (Ansari et al. 2014; Parenti and Jaafar 2017).

Giant mudskippers are distinguished by their unique morphologies, which facilitate movement in both aquatic and terrestrial environments. Their pectoral fins are specialized for navigating on land, a crucial adaptation for survival in the intertidal zone (Pace and Gibb 2009; Zhou et al. 2023). The anatomical structure of these fins is not only important for movement but also reflects the evolutionary transition from aquatic to terrestrial life (Ziadi-Künzli et al. 2024). For example, the robust fin morphology allows mudskippers to generate thrust on land, which is crucial for escaping predators
 and foraging for food (Pace and Gibb 2009). Furthermore, studies have indicated that pelvic fin morphology varies among
 mudskipper species, affecting their climbing behavior and overall movement (Hidayat et al. 2022).

The giant mudskipper Periophthalmodon schlosseri serves as a valuable bioindicator species, with its population 53 dynamics reflecting both habitat quality and environmental stressors. Studies in Songkhla Lake, Thailand, demonstrate its 54 sensitivity to ecosystem degradation, showing highest densities in undisturbed mangrove-associated mudflats and 55 56 complete absence in seawall-modified habitats without mangroves (Pattaratumrong and Pompha 2024). This pattern 57 mirrors findings from the Sungsang estuary, where mudskipper presence correlates with heavy metal pollution levels, making them effective biomarkers for coastal contamination (Santoso et al. 2020, 2024). Their ecological significance 58 extends to reproductive biology, as population structure and fecundity studies reveal seasonal spawning synchronized with 59 60 the southwest monsoon (Simon et al. 2012; Ridho et al. 2021), linking life-history traits directly to environmental cycles. 61 Together, these studies establish the giant mudskipper as an integrative indicator of ecosystem health, responding to habitat integrity, pollution pressures, and climatic influences across its range. 62

The biodiversity of fish species in the Sungsang estuary, including the giant mudskipper, is influenced by a variety of environmental factors. Numerous studies have documented the species diversity and community composition in this region, emphasizing the importance of mangrove ecosystems as critical habitats for mudskippers and other aquatic species (Fauziyah et al. 2019). However, the ongoing threat of human activities, such as deforestation and pollution, poses a significant threat to the ecosystem, thereby impacting mudskipper populations and their role. Consequently, conservation efforts are imperative to safeguard the habitat and ensure the long-term sustainability of mudskippers in South Sumatra (Septinar et al. 2023).

70 A number of studies have been conducted on the foraging behavior of mudskippers in South Sumatra, encompassing 71 research on their dietary habits (Ridho et al. 2019), gonad length and fecundity (Ridho et al. 2021), and range extension of P. septemradiatus (Iqbal et al. 2018). However, research on the length-weight relationship of P. schlosseri remains scarce, 72 with most studies being based on field observations. Sungsang coast, located in the estuary of the Musi River, is a well-73 74 known site for mudskippers. Despite numerous studies on the biology and ecology of mudskippers in Southeast Asia, data 75 on length-weight relationships and morphometric-environment interactions of P. schlosseri in the Sungsang estuary remain 76 scarce. This study aims to fill this gap by analyzing the length-weight relationships and morphometric-environment 77 interactions of *P. schlosseri* in the Sungsang estuary. 78

# MATERIALS AND METHODS

# 82 Study area

83 The research was carried out at five stations in the study area in the Sungsang estuaries of South Sumatra, Indonesia (Figure 1). The description of these sampling locations is shown in Table 1. The Musi River is a major river with multiple 84 uses for its resources. It flows through three provinces on Indonesia's Sumatra Island: South Sumatra, Lampung, and 85 Bengkulu. The coast of Sungang is situated within the Musi River estuary, where the river meets the sea (Melki et al. 86 87 2018a, b). Local fishermen depend on the rich aquatic life in the river and its estuary for their livelihoods. The Musi River 88 estuary is home to a variety of fish species, including freshwater stingrays, catfish, and other fish, which are not only a 89 source of food but also contribute to the local economy and food security (Putri and Melki 2020). The mangrove 90 ecosystem within the Musi Estuary is in a state of optimal health, providing an ideal environment for the proliferation of 91 mudskippers (Iqbal et al. 2018; Ridho et al. 2019; Ridho et al. 2021).

92

79 80

81



93 94 95 96

# Table 1. Description of sampling locations in the Sungsang estuaries

| Sampling sites and              | Position                     |                            | - Description  |  |
|---------------------------------|------------------------------|----------------------------|--|--|
| names                           | Longitudes (E)               | <mark>Latitudes (S)</mark> | Description  |  |
| <u>1 – Sungsang IV</u>          | 104° 53' 22.65"              | 2° 22' 00.07"              | Fisherman's village, but the population is not as<br>large as in sites 2, 3 and 4. There is a healthy<br>mangrove ecosystem and this site is the mouth<br>of the estuary |  |
| <mark>2 – Sungsang III</mark>   | <mark>104° 53' 50.17"</mark> | <mark>2° 21' 56.30"</mark> | A fisherman village area with a moderate<br>population, known for its active fishing<br>community  |  |
| <mark>3 – Sungsang II</mark>    | <mark>104° 54' 01.76"</mark> | <mark>2° 21' 54.56"</mark> | Similar to Sungsang III, it's a fisherman village<br>with a high population density and active<br>fishing activitie  |  |
| <mark>4 – Sungsang I</mark>     | 104° 54' 14.22"              | <mark>2° 21' 47.61"</mark> | A fisherman village with a relatively larger<br>population, also known for its significant fishing<br>activities   |  |
| <mark>5 – Marga Sungsang</mark> | 104° 54' 21.17"              | <mark>2° 21' 33.41"</mark> | Fisherman's village, but the population is not as<br>large as in sites 2, 3 and 4. There is a good<br>mangrove ecosystem and this site is closer to<br>the river         |  |

97 98

# Sampling and preservation

A total of eleven individuals of *P. schlosseri* were collected at each site (n = 55 total) during a single sampling event in July 2024 to account for variation. Fish sampling was conducted using a  $1 \times 3$  m seine net with a 1 mm mesh size suitable for capturing small estuarine species. After collection, the samples were immediately placed in labeled plastic bottles containing 8-10% formalin solution for initial preservation, and in the laboratory, the samples were transferred to 75% ethanol for long-term storage and further morphometric and meristic analyses (Sotola et al. 2019; Jawad et al. 2020; Tran and Nguyen 2023). The samples were collected at the Bioecology Marine Laboratory, Universitas Sriwijaya (voucher code specimen: UNSRI, *Periophthalmodon schlosseri*, collected by Melki on 15 July 2024 at Sungsang Estuary, Indonesia).

# 107 Morphometric measurements

A total of seventeen morphometric measurements were recorded (Figure 2), including total length (TL), standard length (SL), eye diameter (ED), head diameter (HD), head length (HL), length of the dorsal fin 1 (LD1), the gap between 110 D1 and D2 (GD1D2), second dorsal fin length (LD2), and distance between anal and caudal fin (DAC), length of anal fin

(LA), least height of the pectoral fin (LPc), length of pectoral fin (PcF), the distance between pectoral and pelvic fin (DPI), 111

length of pelvic fin (LPF), the width of pelvic fin (WPF), and length of caudal fin (LCF), and width of caudal fin (WCF) 112

(Gangan et al. 2016; Rahman et al. 2022). Each measurement was measured to the nearest 0.1 centimeters, and body 113

114 weight was measured on a digital scale with 0.1 gram accuracy.

115



116 Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Sokefun et al. 2022; Rahman et al. 2022) 117

119 An allometric method (Rahman et al. 2022) was used to remove size-dependent variation from morphometric data. To 120 do so, all of them were standardized using the formula:  $M_{adj} = M(L_s/L_0)^b$ , where M is the original measurement,  $M_{adj}$  is the adjusted measurement,  $L_0$  is the fish's standard length,  $L_s$  is the mean standard length for all samples, and b is the slope of 121 the regression of logM on logL<sub>0</sub> for all samples. The correlation between the transformed variables and the standard length 122 of the samples was used to evaluate the results of the allometric method. 123

# 124

118

#### 125 **Environmental parameter measurements**

Environmental parameters were measured in situ at each sampling site where fish samples were collected to assess the 126 physicochemical characteristics of the habitat. Water temperature, pH and dissolved oxygen were measured using a 127 portable multiparameter instrument (Hanna Instruments Inc., USA) to ensure accurate and simultaneous measurements. 128 129 Salinity was measured using a hand refractometer (ATAGO Co. Ltd, Tokyo, Japan). All measurements were performed in triplicate to ensure the accuracy and reliability of the data. 130 131

#### 132 Data analysis

133 The following equation was used to approximate the length-weight relationships using the formula  $W= a \times TLb$  (Tran et al. 2021; Vilchez et al. 2024), where W is the body weight (g), TL is the total length (cm), and a and b were estimated 134 by the least-squares method based on logarithms using the formula Log(W) = log(a) + b log(TL) (Raeisi et al. 2011). Fish 135 136 may exhibit isometric growth, characterized by equal growth in all three dimensions (b=3), or positive allometric growth, 137 where width and height receive priority (b>3), or negative allometric growth, where length is prioritized (b<3) (Froese 2006). The effectiveness of linear regression can be quantified by the coefficient of determination (r2) (Tran et al. 2021). 138

The K of the fish was estimated using the equation  $K = (W) / (a \times TLb)$ , where W is the body weight (g), TL is the total 139 140 length (cm), and a and b are the regression coefficients. A non-parametric Kruskal-Wallis test with a 5% threshold of significance was employed to determine whether there were any significant variations in mean Wrm between species 141 142 because the assumptions of parametric statistics could not be met. For each statistical test, the significance level was set at 143 p<0.05.

144 Principal Component Analysis (PCA) was performed using XLSTAT version 2021.4.1 (Addinsoft, New York, USA) 145 integrated with Microsoft Excel. Prior to analysis, all morphometric and environmental data were standardized to eliminate 146 unit bias and ensure comparability between variables. PCA was used to identify patterns and correlations between 147 environmental parameters and morphometric traits of P. schlosseri across sampling sites. PCA reduces multidimensional 148 data into principal components that explain the maximum variance in the data set. A biplot of the first two principal 149 components was generated to visualize the distribution of active variables (environmental and morphometric parameters) 150 and active observations (sampling sites). Variables with similar directions and vector lengths were interpreted as having a 151 stronger influence or association within the same dimension.

152

# 153 154

# **RESULTS DAN DISCUSSIONS**

# 155 Environmental parameters

The environmental parameters of samples in all experiments conducted in the Sungsang coast area exhibited minimal fluctuation (Table 1). The environmental parameters that exert a substantial influence on the survival of mudskippers include temperature, salinity, acidity (pH), and dissolved oxygen content (DO) (Ansari et al. 2014; Ridho et al. 2021; Dewiyanti et al. 2022).

160 161

| Table 1. The environment | parameters in the sampling sites |
|--------------------------|----------------------------------|
|--------------------------|----------------------------------|

| Sampling site | Temperature (°C) | pH (water) | pH (soil) | DO (mg L <sup>-1</sup> ) | Salinity (ppt) |
|---------------|------------------|------------|-----------|--------------------------|----------------|
| 1             | 31.7±0.1         | 7.2±0.2    | 7.0±0.1   | 6.9±0.5                  | 20.0±0.0       |
| 2             | 31.7±0.2         | 7.1±0.1    | 6.8±0.3   | 6.3±0.3                  | 16.7±1.5       |
| 3             | 31.3±0.1         | 7.1±0.1    | 6.9±0.1   | 6.3±0.6                  | 16.0±0.0       |
| 4             | 31.9±0.2         | 7.1±0.1    | 7.0±0.2   | 7.8±0.5                  | 15.3±0.6       |
| 5             | 29.8±0.1         | 7.2±0.1    | 6.8±0.3   | 7.9±0.4                  | 15.0±0.0       |

162

The temperature of the water varied from  $29.8\pm0.1$  to  $31.9\pm0.2^{\circ}$ C. According to previous studies, the optimal water temperature range for mudskippers is between 23.5 and 35.5°C (Ridho et al. 2021; Dewiyanti et al. 2022; Arevalo et al. 2023). However, mudskippers demonstrated a preference for milder water temperatures, with a mean of  $26.7\pm2.1^{\circ}$ C (Nay et al. 2018). The pH levels of the water ranged from  $7.1\pm0.1$  to  $7.2\pm0.2$ , and the pH levels of the soil ranged from  $6.8\pm0.3$ to 7.00.2. According to several studies, the mudskipper exhibits optimal growth and reproductive capacity in aquatic environments with pH values ranging from 6 to 8 (Ridho et al. 2021; Dewiyanti et al. 2022; Darojat et al. 2023).

169 The present study examined the dissolved oxygen (DO) levels in the aquatic environment, with a range of  $6.3\pm0.3$  to  $7.9\pm0.4$  mg L<sup>-1</sup>. This finding is notable when compared to the results reported by Ridho et al. (2021), that the mudskipper 170 could survive at DO levels ranging from 4.2 to 6.2 mg L<sup>-1</sup>. In accordance with the findings of Dewiyanti et al. (2022), the 171 range of DO levels in this study was from 4.9 to 7 mg  $L^{-1}$ , indicating that mudskippers possess a considerable degree of 172 tolerance to variations in DO levels. The salinity levels in the study areas ranged from 15.0±0.0 to 20.0±0.0 ppt. In contrast, 173 174 Darojat et al. (2023) reported that mudskippers can survive in mangrove ecosystems with a salinity range of 1.7 to 2.58 ppt. Ridho et al. (2021) also reported a salinity range of 0 to 0.1 ppt. However, Dewiyanti et al. (2022) identified a higher 175 176 salinity range, spanning from 18 to 25 ppt, and a more pronounced range of 24.4 to 34.4 ppt (Taniwel et al. 2020). The significance of these salinity levels is underscored by the observation that mudskippers are euryhaline, indicating their 177 capacity to withstand a broad spectrum of salinities (Looi et al. 2021). However, pronounced fluctuations in salinity can 178 exert an influence on their physiological processes and selection of habitat (Looi et al. 2021). 179

Temperature, salinity, and dissolved oxygen (DO) levels represent critical physical parameters that significantly influence the viability and growth potential of giant mudskippers. These fish exhibit a remarkable capacity for adaptability in response to fluctuating environmental conditions, as evidenced by their increased oxygen uptake rates in response to elevated temperatures (Pattaratumrong and Pompha 2024). Furthermore, they employ behavioral strategies to mitigate exposure to extreme conditions.

# 186 Morphometric characteristic

187 The giant mudskipper *Periophthalmodon schlosseri* observed in this study had a mean total length (TL) of 20.08 cm, ranging from 15.00 cm to 22.60 cm, while the mean standard length (SL) was 17.34 cm, with a range of 13.00 cm to 20.00 188 cm (Table 2). The body size recorded at the sampling sites in the Sungsang estuary is comparable to previous findings in 189 the Musi River estuary, South Sumatra, Indonesia (Ridho et al. 2019, 2021). However, it is significantly larger than 190 191 individuals reported from Cu Lao Dung Island, Soc Trang Province, Vietnam, which ranged from 12.10 - 18.65 cm (Tran et al. 2022), and slightly larger than those from Tanjung Piai, Pontian, Johor, Malaysia, which ranged from approximately 192 193 20 cm (Hui et al. 2019). This difference may be due to several ecological factors, including higher habitat productivity, 194 greater availability of prey organisms, or potentially lower levels of anthropogenic disturbance in the Sungsang estuary. In 195 support of this, Dinh et al. (2020) suggested that food abundance plays an important role in shaping the growth of 196 mudskippers. Furthermore, Tran et al. (2021) reported that the diet composition of mudskippers varied with fish size, 197 season, and habitat, suggesting that local environmental conditions may significantly influence growth performance in 198 different populations.

199



Figure 3. Sample of mudskipper (A. Periophthalmodon schlosseri, B. Morphometric measurement)

Giant mudskippers display a distinctive body shape that is adapted for both swimming and terrestrial locomotion. Their bodies are generally elongated and laterally compressed, a trait that facilitates movement in both water and on land (Pattaratumrong and Pompha 2024). The total length of these creatures can exhibit significant variation based on environmental factors and habitat conditions. For instance, studies have documented lengths of up to 25 cm in certain specimens attributed to variations in habitat type and food availability (Zhou et al. 2023). In addition to morphometric measurements, giant mudskippers exhibit specific meristic traits that can be used to differentiate them from other mudskipper species. For instance, the dorsal fin composition, including the number of spines and soft rays, exhibits variation among populations, suggesting adaptations to local environmental conditions (Nor et al. 2023).

Table 2. Morphometric measurement results of P. schlosseri on Sungsang coast

| Morphometric Measurements | Ranged (cm)   | Mean ± sd (cm) |
|---------------------------|---------------|----------------|
| TL                        | 15.00 - 22.60 | 20.08±2.0      |
| SL                        | 13.00 - 20.00 | 17.34±1.7      |
| ED                        | 0.40 - 1.70   | 0.83±0.4       |
| HD                        | 2.40 - 4.80   | 3.44±0.6       |
| HL                        | 3.40 - 6.40   | 4.81±0.8       |
| LD1                       | 1.50 - 3.00   | 2.67±0.4       |
| $GD_1D_2$                 | 0.90 - 2.60   | $1.47\pm0.4$   |
| $LD_2$                    | 3.00 - 4.20   | 3.73±0.4       |
| DAC                       | 2.00 - 3.90   | 3.06±0.5       |
| LA                        | 2.60 - 4.30   | 3.49±0.4       |
| LPc right                 | 1.30 - 2.80   | $1.89\pm0.4$   |
| LPc left                  | 1.40 - 2.80   | $2.05\pm0.4$   |
| PcF right                 | 1.10 - 2.50   | 1.66±0.3       |
| PcF left                  | 1.50 - 3.00   | 1.91±0.5       |
| DPI right                 | 0.20 - 1.70   | $0.78\pm0.4$   |
| DPI left                  | 0.50 - 1.80   | $0.96\pm0.4$   |
| LPF                       | 0.80 - 2.80   | 1.63±0.7       |
| WPF                       | 1.50 - 3.00   | 2.36±0.5       |
| LCF                       | 2.00 - 4.70   | 3.40±0.8       |
| WCF                       | 1.30 - 3.00   | 2.32±0.5       |

# 214 Length-weight relationship

The length-weight relationship of the giant mudskipper (*P. schlosseri*) was determined through the analysis of 55 specimens collected from five sampling sites along the Sungsang coast. The total length (TL) ranged from 15.00 to 22.60 cm, and the body weight varied from 28.3 to 119.2 g (Table 3).

218 219

 Table 3. Range of total length (TL) and body weight (W) of P. schlosseri in Sungsang coast

| Sampling Site | TL (cm)     | W (g)        |
|---------------|-------------|--------------|
| 1             | 19.5 - 21.5 | 67.8 - 102.5 |
| 2             | 15.0 - 21.0 | 28.3 - 103.7 |
| 3             | 19.0 - 20.5 | 61.8 - 92.8  |

213

| 4       | 20.0 - 22.5 | 87.7 – 108.3 |
|---------|-------------|--------------|
| 5       | 19.5 - 22.6 | 82.1 - 119.2 |
| Average | 20.1        | 85.4         |

221 The findings of the regression analysis and the length-weight relationship graph (Figure 2) yielded the following equation: y = 0.0026x3.45. The b value of 3.45 indicates that the fish growth pattern is positive allometric (b > 3), 222 223 signifying that weight growth outpaces length increase. Positive allometric growth is indicated by a length-weight 224 relationship (LWR) where the exponent (b) is greater than 3. Studies have demonstrated that P. schlosseri exhibits such a relationship, with documented values of b indicating positive allometry (Ridho et al. 2019; Abiaobo et al. 2021; Looi et al. 225 2021; Mussa et al. 2024). For instance, a study conducted in the Musi River Estuary found that the correlation coefficient 226 227 for the length-weight relationship (LWR) of P. schlosseri was 98.2%, with an exponent value of 3.189, confirming its 228 positive allometric growth (Ridho et al. 2019). This suggests that as the fish grows, it becomes relatively heavier compared 229 to its length, which may be advantageous for buoyancy and mobility in its habitat. This positive allometric growth pattern 230 of P. schlosseri is consistent with findings from related species within the same family. For example, P. barbarus also 231 exhibited positive allometric growth in similar ecological contexts, reinforcing the notion that this growth strategy may be a common adaptive trait among mudskippers (Indarjo et al. 2020; Abiaobo et al. 2021). The implications of such growth 232 patterns are critical, as they can influence the species' reproductive strategies, survival rates, and overall fitness in 233 234 fluctuating environmental conditions typical of mangrove ecosystems (Dinh 2016). 235



Figure 2. Relationship between total length and body weight of *P. schlosseri* in Sungsang coast

In comparison with other species found in mangrove ecosystems, the allometric growth of *P. schlosseri* reflects typical trends in estuarine and intertidal species, where growth patterns are often influenced by environmental conditions such as temperature, food availability, and habitat structure (Chew et al. 2014; Looi et al. 2021). The positive allometry observed in the Sungsang population could be attributed to the productivity of the mangrove ecosystem, which provides abundant resources for these mudskippers. The Musi River estuary is home to a diverse array of mudskipper species, which exhibit various adaptations to their mangrove habitat. For instance, studies have documented the reproductive biology and feeding habits of mudskippers in this region, emphasizing their role in the local food web (Ridho et al. 2019; Ridho et al. 2021).

# 246 Condition factor

220

The K value exhibited a maximum at sampling site 1 (K= 1.04) and a minimum at sampling site 5 (K= 0.94) (Figure 3). The variation in K values across the sampling sites was not statistically significant, suggesting that the fish samples were healthy and well-nourished at the time of the study. The K values in the Sungsang coastal area are comparable to those found in the Tran De District, Soc Trang Province, Mekong Delta, Vietnam mangrove habitat, which range from 1.01 to 1.03 (Dinh 2016), and the West Coast of Peninsular Malaysia, which range from 0.41 to 1.29 (Looi et al. 2021).



# Figure 3. Condition factor of *P. schlosseri* in Sungsang coast

255 Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the length-256 weight relationship. The condition factor values indicated a range of nutritional status among the mudskippers, with most 257 individuals displaying average to good health (Froese 2006). However, some specimens with lower condition factors were 258 found to be lean, suggesting potential seasonal fluctuations in food availability that might influence the body mass-to-259 length ratio (Abdullah and Zain 2019; Tran et al. 2021; Nguyễn et al. 2022). Condition factors, which are used as an 260 indicator of fish health, have been shown to vary with environmental conditions. This indicates that abiotic factors, such as temperature and salinity, as well as biotic factors, such as prey availability, significantly affect the growth patterns of these 261 fishes (Dewiyanti et al., 2022; Dinh et al., 2022). 262

# 263 Principal component analysis (PCA)

Principal component analysis was employed to ascertain the correlation between seventeen *P. schlosseri* morphometric characteristics and environmental factors, including water pH and soil pH, dissolved oxygen (DO), temperature, and salinity. The analysis yielded significant findings concentrated on two primary axes: F1 by 55.47% and F2 by 24.70%, with 80.17% representing the maximum amount of information (Figure 4).



Figure 4. PCA was examined to determine morphometric characteristics related to environmental factors of *P. schlosseri* on Sungsang coast

273 The environmental parameter on the positive F1 axis is characterized by DO, which for sampling site 5 is high at 7.9 274 mg  $L^{-1}$ . According to Kumar et al. (2021) and Mulyasari (2023), a very strong correlation relationship can mean that as the 275 value of the comparison character increases, the length of a morphometric character in fish will also increase. 276 Consequently, elevated levels of dissolved oxygen at the Sungsang coast could potentially influence the growth of 277 morphometric characteristics in P. schlosseri. A study by Khater et al. (2021) and Heriyati et al. (2022) indicated that low 278 DO levels can lead to a reduction in fish appetite and growth. The findings indicate that salinity exerts minimal influence 279 on the morphometric growth of *P. schlosseri*. The classification of mudskippers as euryhaline organisms is attributed to 280 their capacity to respond to variations in salt concentration (Taniwel et al. 2020; Kim et al. 2021; Hamidah et al. 2024).

The positive F2 axis is characterized by sampling site 1, which is associated with the environmental parameter component of soil pH and the morphometric characteristics of WPF, defined as the width of the pelvic fins utilized during 283 locomotion by mudskippers. This parameter is believed to be closely related to their biological functions (Hidayat et al. 284 2022; Quigley et al. 2022). The pH value of the soil at sampling site 1 is 7, indicating a high value within the threshold of 285 P. schlosseri life. The measurement of soil pH is crucial as the mudskipper habitat is located in the sediment. A low pH value in the mudskipper habitat prompts the fish to allocate their energy toward environmental adjustments rather than 286 287 growth and foraging (Smith and Nobriga 2023).

288 This study analyzed the giant mudskipper *P. schlosseri* on Sungsang coast, revealing positive allometric growth (b>3) 289 and healthy condition factors. Dissolved oxygen and pH exhibited a strong influence on morphometric characteristics, 290 while temperature and salinity supported optimal habitats. The findings emphasize the critical role of mangroves in 291 sustaining *P. schlosseri* populations and offer insights into mangrove ecosystem management. This study highlights that 292 dissolved oxygen and pH are the most influential environmental variables affecting the morphometric variation of P. 293 schlosseri, suggesting their potential as key indicators in mangrove ecosystem monitoring.

#### 295 Acknowledgements

294

303

304

296 We would like to express our sincere gratitude to abah badrun for his assistance in collecting mudskippers, which was 297 very important for this research. We would also like to thank Gusti Ayu for her patience and help in setting up the research 298 site.

#### 299 References

- 300 Abdullah MIC, Zain KM. 2019. Length-weight relationships, condition factor and growth parameters of Periophthalmus chrysospilos (Bleeker, 1852) 301 302 (Gobiiformes: Gobiidae), in Bayan Bay, Penang, Malaysia. Sains Malays 48 (2): 271-279. DOI: 10.17576/jsm-2019-4802-02.
  - Abiaobo N, Asuquo IE, Ejiogu IN, James EJ. 2021. Aspects of the biology of Periophthalmus barbarus (mudskipper), from Jaja Creek, Niger Delta, Nigeria. Ecol Evol Biology 6 (1): 15. DOI: 10.11648/j.eeb.20210601.14.
  - Ansari AA, Trivedi S, Saggu S, Rehman H. 2014. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. J Entomol Zool Stud 2 (6): 22–33.
- 305 306 307 Arevalo E, Cabral HN, Villeneuve B, Possémé C, Lepage M. 2023. Fish larvae dynamics in temperate estuaries: A review on processes, patterns and factors that determine recruitment. Fish Fish 24 (3): 466-487. DOI: 10.1111/faf.12740. 308 309 310 311 312 313
  - Arulnayagam A, Khim JS, Park J. 2021. Floral and faunal diversity in Sri Lankan mangrove forests: A systematic review. Sustainability 13 (17). DOI: 10.3390/su13179487.
  - Chew SF, Hiong KC, Lam SP, Ong SW, Wee WL, Wong WP, Ip YK. 2014. Functional roles of Na+/K+-ATPase in active ammonia excretion and seawater acclimation in the giant mudskipper, Periophthalmodon schlosseri. Front Physiol 5. DOI: 10.3389/fphys.2014.00158.
  - Corush JB, Zhang J. 2022. One size does not fit all: Variation in anatomical traits associated with emersion behavior in mudskippers (Gobiidae: Oxudercinae). Front Ecol Evol 10: 01-08. DOI: 10.3389/fevo.2022.967067.
  - Darojat AZ, Marhendra APW, Kurniawan N. 2023. Identification of mudskipper species in mangrove area of Luwu Timur, Luwu Utara, and Wajo South Sulawesi Indonesia. Biotropika: J Tropical Biol 11 (2): 74-83. DOI: 10.21776/ub.biotropika.2023.011.02.02.
  - Dewiyanti I, Melanie K, Almuniro S, Damora A, Nufadillah N, Batubara, AS. 2022. Growth patterns and condition factor of the mudskipper (Periophthalmus gracilis) in mangrove ecosystem rehabilitation areas in Banda Aceh and Aceh Besar, Indonesia. Fish Aquat Life 30 (2): 85-94. DOI: 10.2478/aopf-2022-0008.
  - Dinh QM. 2016. Growth and body condition variation of the giant mudskipper Periophthalmodon schlosseri in dry and wet seasons. Tap Chi Sinh Hoc 38 (3). DOI: 10.15625/0866-7160/v38n3.7425.
  - Dinh QM, Tran LT, Tran TTM, To DK, Nguyen TTK, Tran DD. 2020. Variation in diet composition of the mudskipper, Periophthalmodon septemradiatus, from Hau River, Vietnam. Bull Mar Sci 96 (3): 487-500. DOI: 10.5343/bms.2018.0067.
  - Dinh QM, Nguyen THD, Truong NT, Doan DX, Nguyen TTK. 2022. Monthly variations in growth pattern and condition factor of Periophthalmodon septemradiatus (gobiiformes: periophthalminae) living along the Bassac River in Viet Nam. PeerJ 10: e13880. DOI: 10.7717/peerj.13880.
  - Fauziyah F, Nurhayati N, Bernas SM, Putera A, Suteja Y, Agustiani F. 2019. Biodiversity of fish resources in Sungsang estuaries of South Sumatra; IOP Conference Series: Earth and Environmental Science 278 (1): 012025. DOI: 10.1088/1755-1315/278/1/012025.
  - Froese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. J Appl Ichthyol 22 (4): 241-253. DOI: 10.1111/j.1439-0426.2006.00805.x.
  - Gangan SS, Kumar R, Ramteke KK, Kumar AP, Jaiswar AK. 2016. Study of morphological variation discernible by multivariate analysis between the species of genus Setipinna (Teleostei: Clupeiformes). Ecol Enviro and Conserv 22 (September): S11-S16.
  - Hamidah A, Murni P, Said M. 2024. The diversity of mudskipper fish family Gobiidae in mangrove area, Seberang District, Tanjung Jabung Regency, West Jambi. J Surv Fish Sci 11 (1). DOI: 10.53555/sfs.v11i01.2045.
  - Hasan V, South J, Katz A, Ottoni FP. 2022. First record of the Small-eyed loter Prionobutis microps (Weber, 1907) (Teleostei: Eleotridae: Butinae) in Java, Indonesia. Cybium 46(1): 49-51. DOI: 10.26028/CYBIUM/2022-461-008.
  - Heriyati E, Rustadi R, Isnansetyo A, Triyatmo B, Istiqomah I, Deendarlianto D, Budhijanto W. 2022. Microbubble aeration in a recirculating aquaculture system (RAS) increased dissolved oxygen, fish culture performance, and stress resistance of Red Tilapia (Oreochromis sp.). Trends Sci 19 (20): 6251. DOI: 10.48048/tis.2022.6251.
  - Hidayat S, Wicaksono A, Raharjeng ARP, Jin DSM, Alam P, Retnoaji B. 2022. The morphologies of mudskipper pelvic fins in relation to terrestrial and climbing behaviour; Proceedings of the Zoological Society 75 (1): 83-93. The University of Edinburgh, 8 February 2022. DOI: 10.1007/s12595-021-00422-1.
  - Hui NY, Mohamed M, Othman MNA, Tokiman L. 2019. Diversity and behaviour of mudskippers of Tanjung Piai, Pontian, Johor. IOP Conference Series: Earth and Environmental Science 269 (1). DOI: 10.1088/1755-1315/269/1/012037.
  - Indarjo A, Salim G, Zein M, Susiyanti S, Soejarwo PA, Nugraeni CD, Bija S, Pham YTH. 2020. Characteristics of Von Bertalanfy growth, allometric, condition index and mortality of Periophthalmus barbarus in mangrove and probiotics conservation area (KKMB), Tarakan, North Kalimantan. I J M S 25 (1): 31-38. DOI: 10.14710/ik.ijms.25.1.31-38.
  - Iqbal M, Halim A, Adriani D, Pormansyah, Saputra RF. 2018. Range extension of Periophthalmodon septemradiatus (Gobiidae) in southern Sumatra, Indonesia. Cybium 42 (4): 376-378. DOI: 10.26028/cybium/2018-424-009.

IUCN. 2023. Periophthalmodon schlosseri. The IUCN Red Threatened 2023: e.T196314A153206425. List of Species www.iucnredlist.org/species/196314/153206425.

Jawad LA, Koya A, Gnohossou P. 2020. Fixation, preservation and freezing effects on morphometrics of two fish species collected from Lake Ganvie, Benin, West Africa. Thalassia Sal 42, 75-82. DOI: 10.1285/i15910725v42p75.

Jordan P, Fröhle P. 2022. Bridging the gap between coastal engineering and nature conservation?: A review of coastal ecosystems as nature-based solutions for coastal protection. J Coast Conserv 26 (2). DOI: 10.1007/s11852-021-00848-x.

Khater ES, Bahnasawy AH, Elghobashy H, Shaban Y, El-Sheikh FM, El-Reheem SA, Aboegela M. 2021. Mathematical model for predicting oxygen concentration in Tilapia fish farms. Sci Rep 11 (1). DOI: 10.1038/s41598-021-03604-1.

Kim J, Lee C, Yoo D, Kim H. 2021. Genetic adaptations in mudskipper and tetrapod give insights into their convergent water-to-land transition. Animals 11 (2): 584. DOI: 10.3390/ani11020584.

Kumar GR, Bano F, Serajuddin M. 2021. Effect of formalin preservation on studies on morphology and condition factor of the freshwater Shark Wallago attu (Bloch and Schneider, 1801) using truss network system. Indian J Fish 68 (3). DOI: 10.21077/ijf.2021.68.3.98695-16.

Looi LJ, Aris AZ, Isa NM, Yusoff, FM, Haris H. 2021. Elemental composition and health risk assessment of giant mudskipper (Periophthalmodon schlosseri) from the intertidal zone of the west coast of Peninsular Malaysia. Front Mar Sci 7. DOI: 10.3389/fmars.2020.618284.

Mai HV, Tran LX, Dinh QM, Tran DD, Murata M, Sagara H, Yamada A, Shirai K, Ishimatsu A. 2019. Land invasion by the mudskipper, Periophthalmodon septemradiatus, in fresh and saline waters of the Mekong River. Sci Rep 9 (1). DOI: 10.1038/s41598-019-50799-5.

Melki, Isnansetyo A, Widada J, Murwantoko M. 2018a. The significance of water quality parameters on the diversity of ammonia-oxidizing bacteria in the water surface of Musi River, Indonesia. AACL Bioflux 11 (6), 1908-1918.

Melki, Isnansetyo A, Widada J, Murwantoko M. 2018b. Distribution of ammonium-oxidizing bacteria in sediment with relation to water quality at the Musi River, Indonesia. Hayati J Biosci 25 (4), 198-205. DOI: 10.4308/hjb.25.4.198.

Mulyasari N, Subaryono N, Utomo BSB, Taufik I, Kusmini II, Yosmaniar N. 2023. Morphometric and genetic characterization of dominant fish species in Progo River, Yogyakarta, Indonesia. Sci World J 38 (2): 111-120. DOI: 10.1155/2023/7197251.

Mussa ZJ, Aziz BAAA, Saleh SM, Abbas AH, Al-Asadi MK, Jumah AAK. 2024. Mudskippers a good bioindicator for polluted soils in the mudflat region of Southern Iraq. Mesop J Mar Sci 38 (2): 111-119. DOI: 10.58629/mjms.v38i2.354.

Nathaniel AM, Gbobo BMFO, Raimi MO. 2024. Food and feeding of Atlantic mudskipper Periophthalmus barbarus in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria. Qeios. DOI: 10.32388/QNW7VZ.

Nay TJ, Gervais CR, Hoey AS, Johansen JL, Steffensen JF, Rummer JL. 2018. The emergence emergency: A mudskipper's response to temperatures. J Therm Biol 78 (September): 65-72. DOI: 10.1016/j.jtherbio.2018.09.005.

Nguyễn NT, Ha LM, Nguyen ATN, Chu NH, Tran HD, Hưng NP, Ta TT. 2022. Variation in the allometry of morphometric characteristics, growth, and condition factors of wild Bostrychus sinensis (Butidae) in Northern Vietnam. Pak J Zool 55 (2). DOI: 10.17582/journal.pjz/20200917140936.

Nor NM, Saifuzzaman S, Azmir IA, Hussin N. 2023. Morphological characteristics and reproductive organs assessment of blue-spotted mudskipper Boleophthalmus boddarti in Peninsular Malaysia. Biotropia 30 (1): 21-36. DOI: 10.11598/btb.2023.30.1.1561.

Pace CM, Gibb AC. 2009. Mudskipper pectoral fin kinematics in aquatic and terrestrial environments. J Exp Biol, 212(14), 2279-2286. DOI: 10.1242/jeb.029041.

Parenti LR, Jaafar Z. 2017. The natural distribution of mudskippers. In Fishes Out of Water (pp. 37-68). CRC Press.

Pattaratumrong MS, Pompha T. 2024. Habitat of the amphibious mudskipper Periophtalmodon schlosseri in Songkhla Lake, Thailand. Biodiversitas 25 (5): 1875–1881. DOI: 10.13057/biodiv/d250503

Putri WAE, Melki. 2020. Study of the water quality of the Musi River estuary, South Sumatra. J Mar Aquat Sci 6 (1): 36. DOI: 10.24843/jmas.2020.v06.i01.p05. [Indonesian].

Quigley ZMG, Blob RW, Kawano S. 2022. Kinematic comparisons between mudskipper fins and Salamander limbs during terrestrial locomotion. J Exp Zool A Ecol Integr Physiol 337 (6): 612-625. DOI: 10.1002/jez.2594.

Raeisi H, Daliri M, Paighambari SY, Shabani MJ, Bibak M, Davoodi R. 2011. Length-weight relationships, condition factors and relative weight of five fish species of Bushehr waters, Northern Persian Gulf. Afr J Biotechnol 10 (82): 19181–19186. DOI: 10.5897/AJB11.2650.

Rahman MAF, Azmir IA, Hussin NJ. 2022. Morphological study of selected mudskipper species (Family: Oxudercidae) and development of key pictorial. Iran J Ichthyol 9 (4): 180-194. DOI: 10.22034/iji.v9i4.808.

Ridho MR, Patriono E, Rahmawati D, Pratama R, Avesena M. 2021. Short communication: Investigating gonad length and fecundity in mudskippers (gobiidae) at the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 22 (10): 4413-4420. DOI: 10.13057/biodiv/d221034.

Ridho MR, Patriono E, Solikha M. 2019. Food habits of three species of mudskippers in the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 20 (8): 2368-2374. DOI: 10.13057/biodiv/d200835.

Santoso HB, Suhartono E, Yunita R, Biyatmoko D. 2020. Mudskipper fish as a bio-indicator for heavy metals pollution in a coastal wetland. Egypt J Aquat Biol Fish 24 (7): 1073–1095. DOI: 10.21608/ejabf.2020.144402.

Santoso HB, Krisdianto K, Yunita R. 2024. Iron bioaccumulation and ecological implications in the coastal swamp wetlands ecosystem of South Kalimantan: insights from giant mudskipper fish as bioindicators. J Degrad Min Lands Manag, 11(3), 5539-5550. DOI: 10.15243/jdmlm.2024.113.5539.

Septinar H, Putri YP, Midia KR, Bianto B. 2023. Mangrove forest conservation efforts through nurseries in Sungsang IV village, Banyuasin Regency. Enviro Sci J: Jurnal Ilmu Lingkungan, 77–88. DOI: 10.31851/esjo.v1i2.11920. [Indonesian].

Setyawan AD, Winarno K. 2006. The direct exploitation in the mangrove ecosystem in Central Java and the land use in its surrounding; degradation and its restoration effort. Biodiversitas 7 (3): 282–291. DOI: 10.13057/biodiv/d070318.

Simon KD, Bakar Y, Mazlan AG, Zaidi CC, Samat A, Arshad A, Temple SE, Brown-Peterson NJ. 2012. Aspects of the reproductive biology of two archer fishes Toxotes chatareus, (Hamilton 1822) and Toxotes jaculatrix (Pallas 1767). Environ Biol Fishes 93 (4): 491-503. DOI: 10.1007/s10641-011-9944-6.

Smith WE, Nobriga MK. 2023. A bioenergetics-based index of habitat suitability: spatial dynamics of foraging constraints and food limitation for a rare estuarine fish. Trans Am Fish Soc 152 (5): 650-671. DOI: 10.1002/tafs.10427.

Sokefun O, Gan HM, Tan MP. 2022. Morphometrical characterization of the Atlantic mudskipper species (Periophthalmus barbarus) (Linnaeus, 1766) (Perciformes; Gobiiae) from Abonema in Port Harcourt, Rivers State, Nigeria. Int J Fish Aquac 10 (3): 72<mark>-</mark>76. DOI: 10.22271/fish.2022.v10.i3a.2719.

Sotola VA, Craig CA, Pfaff PJ, Maikoetter JD, Martin NH, Bonner TH. 2019. Effect of preservation on fish morphology over time: Implications for morphological studies. PLoS ONE 14(3): e0213915. DOI: 10.1371/journal. pone.0213915.

Steppan SJ, Meyer AA, Barrow LN, Alhajeri BH, Al-Zaidan ASY, Gignac PM, Erickson GM. 2022. Phylogenetics and the evolution of terrestriality in mudskippers (Gobiidae: Oxudercinae). Mol Phylogenetics Evol 169: 107416. DOI: 10.1016/j.ympev.2022.107416.

Su J, Friess DA, Gasparatos A. 2021. A meta-analysis of the ecological and economic outcomes of mangrove restoration. Nat Commun 12 (1). DOI: 10.1038/s41467-021-25349-1.

Taniwel D, Leiwakabessy F, Rumahlatu D. 2020. Short communication: density and length-weight relationship of mudskipper (Periophthalmus spp.) in the mangrove area of Kairatu Beach, Maluku, Indonesia. Biodiversitas 21 (11). DOI: 10.13057/biodiv/d211155.

Tran HD, Nguyen HH, Ha LM. 2021. Length-weight relationship and condition factor of the mudskipper (Periophthalmus modestus) in the Red River Delta. Reg Stud Mar Sci 46: 101903. DOI: 10.1016/j.rsma.2021.101903.

- Tran LX, Maekawa Y, Soyano K, Ishimatsu A. 2020. Morphology of the feeding apparatus in the herbivorous mudskipper, Boleophthalmus pectinirostris (Linnaeus, 1758). Zoomorphology 139 (2): 231–243. DOI: 10.1007/s00435-020-00476-3.
- Tran LX, Nguyen TTK, Vo TT. 2022. Morphological comparison of the cranial movement apparatus in mudskippers (Gobiidae: Oxudercinae). Zool 154 (August): 126042. DOI: 10.1016/j.zool.2022.126042.
- Tran LX, Nguyen TTK. 2023. Morfology of the buccal and opercular sealing apparatus in mudskippers (Gobiidae: Oxudercinae). J Ichthyol 63 (4):605-615. DOI: 10.1134/S0032945223040197.
- Valen FS, Hasan V, Ottoni FP, Nafisyah AL, Erwinda M, Annisa AN, Adis MA. 2022. First country record of the bearded gudgeon Pogoneleotris heterolepis (Günther, 1869) (Teleostei: Eleotridae) from Indonesia. IOP Conf. Ser.: Earth Environ. Sci. 1036 (012074). DOI: 10.1088/1755-1315/1036/1/012074.
- Vilchez M, Dattilo J, Brewer SK. 2024. Length-weight relationships of native and non-native fishes in the lower Red River Cathment, USA. J Appl Ichthyol 2024: 5. DOI: 10.1155/2024/5578825.
- Waleed TA, Abdel-Maksoud YK, Kanwar RS, Sewilam H. 2024. Mangroves in Egypt and the Middle East: current status, threats, and opportunities. Int J Environ Sci Technol. DOI: 10.1007/s13762-024-05788-1.
- Wirabuana PYAP, Baskorowati L, Pamungkas B, Mulyana B, South J, Purnobasuki H, Andriyono S, Hasan V. 2025. Mangroves, fauna compositions and carbon sequestration after ten years restoration on Flores Island, Indonesia. Sci Rep 15 (4866). DOI:10.1038/s41598-025-87307-x.
- You X, Sun M, Li J, Bian C, Chen J, Yi Y, Yu H, Shi Q. 2018. Mudskippers and their genetic adaptations to an amphibious lifestyle. Animals 8 (2). DOI: 10.3390/ani8020024.
- Zhang Z, Fu Y, Zhao H, Zhang X. 2022. Social enrichment affects fish growth and aggression depending on fish species: applications for aquaculture. Front Mar Sci 9. DOI:10.3389/fmars.2022.1011780.
- Zhou H, Donatelli CM, Laneuville O, Standen EM. 2023. Skeletal anatomy of the pectoral fin in mudskipper species from terrestrial and aquatic habitats. J Morphol, 284(8). DOI: 10.1002/jmor.21612.
- Ziadi-Künzli F, Maeda K, Puchenkov P, Bandi M. 2024. Anatomical insights into fish terrestrial locomotion: a study of barred mudskipper (Periophthalmus argentilineatus) fins based on uct 3d reconstructions. J Anat, 245(4), 593-624. DOI: 10.1111/joa.14071.
- 446 447 448 Zulkifli SZ, Mohamat-Yusuff F, Ismail A, Miyazaki N. 2012. Food preference of the giant mudskipper Periophthalmodon schlosseri (Teleostei: Gobiidae). Knowl Manag Aquat Ecosyst 405. DOI: 10.1051/kmae/2012013.

449

# Table of Responses

| Lines | Reviewer Comments/Suggest  | Answer   |
|-------|--|--|
| 24-25 | Add references. Ex:<br>https://sfi-cybium.fr/fr/first-record-small-eyed-<br>loter-prionobutis-microps-weber-1907-<br>teleostei-eleotridae-butinae-java<br>https://iopscience.iop.org/article/10.1088/1755<br>-1315/1036/1/012074 | The mangrove ecosystem is an important area due to its<br>role in providing a habitat for a wide variety of aquatic<br>and terrestrial biota, as evidenced by the discovery of<br>rare and previously unrecorded fish species such as the<br>bearded gudgeon <i>Pogoneleotris heterolepis</i> in the<br>Kapuas River estuary (Valen et al. 2022) and the small-<br>eyed gudgeon <i>Prionobutis microps</i> in the Solo River<br>estuary (Hasan et al. 2022), highlighting the ecological<br>importance of these transitional zones as critical habitats<br>for endemic and specialized aquatic species.  |
| 25-27 | add references. Ex:<br>https://www.nature.com/articles/s41598-025-<br>87307-x<br>https://smujo.id/biodiv/article/view/521  | (in lines 24-28)<br>This ecosystem is important from a variety of angles,<br>including its environmental functions, such as protecting<br>estuaries and coastlines from storms, stabilizing the<br>shore, and reducing coastal soil erosion and flooding, as<br>shown by successful restoration in Central Java<br>(Setyawan and Winarno 2006) and Flores Island<br>(Wirabuana et al. 2025). Restored mangroves in Pasar<br>Banggi prevented erosion. In Flores, 10-year-old<br>mangroves improved sediment retention and wave<br>absorption.  |
| 35-37 | add an explanation of the conservation status<br>of this species based on the IUCN Red List,<br>and also add the global distribution<br>information  | (in lines 28-32)<br>According to the IUCN Red List of Threatened Species,<br>this species is currently listed as Least Concern (LC),<br>indicating that it is not under any immediate threat of<br>population decline (IUCN 2023). <i>Periophthalmodon</i><br><i>schlosseri</i> is widely distributed throughout the Indo-West<br>Pacific region, including coastal and estuarine areas of<br>Southeast Asia, northern Australia and parts of South<br>Asia (Ansari et al. 2014; Parenti and Jaafar 2017).   |
| 48-49 | add reference. Ex:<br>https://smujo.id/biodiv/article/view/17613   | (In Intes 41-45)<br>The giant mudskipper <i>Periophthalmodon schlosseri</i><br>serves as a valuable bioindicator species, with its<br>population dynamics reflecting both habitat quality and<br>environmental stressors. Studies in Songkhla Lake,<br>Thailand, demonstrate its sensitivity to ecosystem<br>degradation, showing highest densities in undisturbed<br>mangrove-associated mudflats and complete absence in<br>seawall-modified habitats without mangroves<br>(Pattaratumrong and Pompha 2024). This pattern mirrors<br>findings from the Sungsang estuary, where mudskipper<br>presence correlates with heavy metal pollution levels,<br>making them effective biomarkers for coastal<br>contamination (Santoso et al. 2020, 2024). Their<br>ecological significance extends to reproductive biology,<br>as population structure and fecundity studies reveal<br>seasonal spawning synchronized with the southwest<br>monsoon (Simon et al. 2012; Ridho et al. 2021), linking<br>life-history traits directly to environmental cycles. |

| 74        | provide all detailed location and general description of each site in the Table | Together, t<br>an integrat<br>to habitat i<br>influences<br>(in lines 52<br>The descri<br>Table 1 | these studies es<br>ive indicator or<br>ntegrity, pollut<br>across its rang<br>3-62)<br>ption of these s | stablish the g<br>f ecosystem h<br>tion pressures<br>e.<br>sampling loca | iant mudskipper as<br>health, responding<br>s, and climatic  |
|-----------|---|---|--|--|--|
|           | description of each site in the Table   | (in line 84)<br>Table 1. D<br>Sungsang  | )<br>escription of sa<br>estuaries   | ampling locat  | tions in the   |
|           |   | Sampling  | Posit  | ion  |  |
|           |   | sites and<br>names  | Longitudes (E)   | Latitudes (S)  | Description  |
|           |   | 1 –<br>Sungsang<br>IV   | 104° 53' 22.65"  | 2° 22' 00.07"  | Fisherman's village,<br>but the population is<br>not as large as in sites<br>2, 3 and 4. There is a<br>healthy mangrove<br>ecosystem and this site<br>is the mouth of the<br>estuary |
|           |   | 2 –<br>Sungsang<br>III  | 104° 53' 50.17"  | 2° 21' 56.30"  | A fisherman village<br>area with a moderate<br>population, known for<br>its active fishing<br>community  |
|           |   | 3 –<br>Sungsang<br>II   | 104° 54' 01.76"  | 2° 21' 54.56"  | Similar to Sungsang<br>III, it's a fisherman<br>village with a high<br>population density and<br>active fishing activitie  |
|           |   | 4 –<br>Sungsang I   | 104° 54' 14.22"  | 2° 21' 47.61"  | A fisherman village<br>with a relatively larger<br>population, also<br>known for its<br>significant fishing<br>activities  |
|           |   | 5 – Marga<br>Sungsang   | 104° 54' 21.17"  | 2° 21' 33.41"  | Fisherman's village,<br>but the population is<br>not as large as in sites<br>2, 3 and 4. There is a<br>good mangrove<br>ecosystem and this site<br>is closer to the river            |
|           |   | (in line 96)  | )  |  |  |
| 91,<br>92 | is there voucher specimen code?<br>Please mention the catalog no                | The sampl<br>Laboratory<br>specimen:<br>collected b<br>Indonesia)                                 | es were collect<br>7, Universitas S<br>UNSRI, <i>Perio</i><br>9y Melki on 15                             | ed at the Bio<br>Griwijaya (vo<br><i>phthalmodon</i><br>July 2024 at     | ecology Marine<br>ucher code<br><i>schlosseri</i> ,<br>Sungsang Estuary,   |
| 05        | Add references  | (in lines 10  | )4-105)  | las ware inte  | nadiataly placed in  |
| 90        | Add references.   | labeled pla<br>solution fo  | stic bottles con<br>r initial preserv  | ntaining 8-10<br>vation, and in  | % formalin<br>the laboratory, the  |

|     |   | samples were transferred to 75% ethanol for long-term<br>storage and further morphometric and meristic analyses<br>(Sotola et al. 2019; Jawad et al. 2020; Tran and Nguyen<br>2023).   |
|-----|---|--|
|     |   | (in lines 101-104)   |
|     |   | added to reference:<br>Tran LX, Nguyen TTK. 2023. Morfology of the buccal<br>and opercular sealing apparatus in mudskippers<br>(Gobiidae: Oxudercinae). J Ichthyol 63 (4):605–615.<br>DOI: 10.1134/S0032945223040197.  |
|     |   | (in lines 428-429)   |
| 103 | Measurement data cannot be presented directly<br>before being equalized by dividing by SL and<br>then multiplying by 100% | An allometric method (Rahman et al. 2022) was used to<br>remove size-dependent variation from morphometric<br>data. To do so, all of them were standardized using the<br>formula: $M_{adj} = M(L_s/L_o)^b$ , where M is the original<br>measurement, $M_{adj}$ is the adjusted measurement, $L_o$ is the<br>fish's standard length, $L_s$ is the mean standard length for<br>all samples, and b is the slope of the regression of logM<br>on logL <sub>o</sub> for all samples. The correlation between the<br>transformed variables and the standard length of the<br>samples was used to evaluate the results of the allometric<br>method. |
|     |   |  |
| 104 | Provide a figure of measurements  | (In lines 119-123)<br>A total of seventeen morphometric measurements were  |
|     |   | recorded (Figure 2)  |
|     |   | (in line 108)  |
| 178 | Provide the figure of specimen  | A         B         Figure 3. Sample of mudskipper (A. Periophthalmodon  |
|     |   | <i>schlosseri</i> , B. Morphometric measurement)<br>(in lines 199-201)   |
| 179 | Complete the name in the start of paragraph   | The giant mudskipper Periophthalmodon schlosseri   |
|     |   | (in line 187)  |
| 204 | See in the method comment   | has been adjusted to the method  |
|     |   |  |

| 280  | Be consistent! Without () | the giant mudskipper P. schlosseri  |  |
|------|---------------------------|---|--|
|      |                           | (in line 288)   |  |
| 283  | italic                    | P. schlosseri   |  |
|      |                           | (in line 291)   |  |
| 293, | see guideline             | has been revised  |  |
| 299  |                           | (in lines 301, 305, 334, 351, 379, 380, 382, 384, 400, 403, 405, 407, 412, 446) |  |



# [biodiv] Editor Decision

Smujo Editors via SMUJO <support@smujo.com>

1 pesan

20 April 2025 pukul 12.11

Balas Ke: Smujo Editors <editors@smujo.id> Kepada: Melki Melki <melki@unsri.ac.id>, Fadhilah Dzakiyyah Ananta <FD\_ananta@gmail.com>, Isnaini <Isnaini@mipa.unsri.ac.id>, Fitri Agustriani <fitri\_agustriani@yahoo.com>, Rezi Apri <rezi\_apri@unsri.ac.id>, Hartoni <hartoni@mipa.unsri.ac.id>, Ellis Nurjualisti Ningsih <ellis.nurjualisti@gmail.com>, Jeni Meiyerani <jenimeiyerani24@gmail.com>

Melki Melki, Fadhilah Dzakiyyah Ananta, Isnaini, Fitri Agustriani, Rezi Apri, Hartoni, Ellis Nurjualisti Ningsih, Jeni Meiyerani:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia". Complete your revision with a Table of Responses containing your answers to reviewer comments (for multiple comments) and/or enable Track Changes. We are waiting for your revision in the system (https://smujo.id/biodiv), do not send it via email.

Our decision is: Revisions Required

Reviewer A:

Determine from the beginning using the scientific name or common name, the scientific name and common name are introduced only in the title, the beginning of the abstract and the beginning of the introduction. In the next section, just include the scientific name or common name. See in the comments

Recommendation: Revisions Required

\_\_\_\_\_

Biodiversitas Journal of Biological Diversity

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.

A-21288 round 2nd.doc 704K

# Analysis of morphology and population dynamics of giant mudskipper *Periophthalmodon schlosseri* (Pallas, 1770) (Gobiiformes: Oxudercidae) at Sungsang estuaries, South Sumatra, Indonesia

Abstract. The Giant Mudskipper Periophthalmodon schlosseri (Pallas, 1770) Periophthalmodon schlosseri (Pallas, 1770) is one of the 8 most abundant mudskipper species, plaving a vital role in the biomass of mangrove ecosystems. Mudskipper fish are also found in the Sungsang coast, an estuary of the Musi River that is fed by river water from three provinces in Indonesia: South Sumatra, Lampung, and 10 11 12 Bengkulu. This study aimed This study aimed to analyze the morphology and population dynamics of mudskippers along with their environmental parameters in Sungsang coastal South Sumatra. For this study, mudskipper specimens were collected from five sampling sites along the Sungsang coast and analyzed for morphometric characteristics, length-weight relationships, and their correlations with 13 key environmental parameters like temperature, pH, and dissolved oxygen. The analysis of fifty-five specimens revealed an average 14 15 total length of 20.08 cm, a standard length of 17.34 cm, and an average weight of 85.4 g. The growth pattern exhibited positive allometry (b>3), suggesting that as these fish grow, their body weight increases faster faster than their length. Condition factor analysis 16 indicated that the fish sampled were healthy and in good nutritional condition. The principal component analysis (PCA) further 17 highlighted a strong association between dissolved oxygen and pH levels with the morphometric characteristics of the mudskippers, 18 explaining 55.47% of the variation on the F1 axis and 24.70% on the F2 axis. This robust correlation between environmental factors and morphometric characteristics underscores the reliability of our findings. These findings provide crucial insights into the ecological 19 20 health of the Giant Mudskipper and its dependence on specific environmental factors in the mangrove habitat are of utmost importance.

21 Keywords: Environmental parameter, Length-weight relationship, Morphometric, Mudskipper, Sungsang coast

22 Running title: Morphology and Population Dynamics of Mudskipper

23

1

2

3 4

5 6

## INTRODUCTION

24 The mangrove ecosystem is an important area due to its role in providing a habitat for a wide variety of aquatic and terrestrial biota, as evidenced by the discovery of rare and previously unrecorded fish species such as the bearded 25 26 gudgeon Pogoneleotris heterolepis in the Kapuas River estuary (Valen et al. 2022) and the small-eyed gudgeon Prionobutis microps in the Solo River estuary (Hasan et al. 2022), highlighting the ecological importance of these 27 28 transitional zones as critical habitats for endemic and specialized aquatic species. This ecosystem is important from a 29 variety of angles, including its environmental functions, such as protecting estuaries and coastlines from storms, stabilizing 30 the shore, and reducing coastal soil erosion and floodin., as shown by successful restoration in Central Java (Setyawan an Winarno 2006) and Flores Island (Wirabuana et al. 2025). Restored mangroves in Pasar Banggi prevented erosion. In 31 32 Flores, 10-year-old mangroves improved sediment retention and wave absorption. Additionally, it serves as a nursery 33 habitat and breeding ground for a wide range of biota, and it provides sources that include essential commodities for both 34 subsistence and commerce (Arulnayagam et al. 2021; Su et al. 2021; Jordan and Fröhle 2022; Waleed et al. 2024).

During periods of low tide, mangrove swamps and tidal flats formed in creeks, estuaries, and coastal waterways 35 36 provide habitat for mudskippers (Mai et al. 2019; Ridho et al. 2019; Santoso et al. 2020; Darojat et al. 2023; Nathaniel et al. 37 2024). Mudskippers exhibit physiological, morphological, and behavioral adaptations that allow them to thrive in both 38 aquatic and terrestrial environments (You et al. 2018; Tran et al. 2020; Corush and Zhang 2022; Steppan et al. 2022). Various factors, including food availability, habitat selection, human disturbance, and others influence the geographical 39 40 distribution of each species. A notable example is the giant mudskipper Periophthalmodon schlosseri, which contributes 41 significantly to the biomass value of the mangrove ecosystem (Zulkifli et al. 2012; Dewiyanti et al. 2022). According to 42 the IUCN Red List of Threatened Species, this species is currently listed as Least Concern (LC), indicating that it is not under any immediate threat of population decline (IUCN 2023). Periophthalmodon schlosseri is widely distributed 43 44 throughout the Indo-West Pacific region, including coastal and estuarine areas of Southeast Asia, northern Australia and parts of South Asia (Ansari et al. 2014; Parenti and Jaafar 2017). 45

Giant mudskippers are distinguished by their unique morphologies, which facilitate movement in both aquatic and terrestrial environments. Their pectoral fins are specialized for navigating on land, a crucial adaptation for survival in the intertidal zone (Pace and Gibb 2009; Zhou et al. 2023). The anatomical structure of these fins is not only important for movement but also reflects the evolutionary transition from aquatic to terrestrial life (Ziadi-Künzli et al. 2024). For Commented [VH1]: Delete

50 example, the robust fin morphology allows mudskippers to generate thrust on land, which is crucial for escaping predators 51 and foraging for food (Pace and Gibb 2009). Furthermore, studies have indicated that pelvic fin morphology varies among 52 mudskipper species, affecting their climbing behavior and overall movement (Hidayat et al. 2022).

53 The giant mudskipper P.\_schlosseri serves as a valuable bioindicator species, with its population dynamics reflecting 54 both habitat quality and environmental stressors. Studies in Songkhla Lake, Thailand, demonstrate its sensitivity to 55 ecosystem degradation, showing highest densities in undisturbed mangrove-associated mudflats and complete absence in 56 57 seawall-modified habitats without mangroves (Pattaratumrong and Pompha 2024). This pattern mirrors findings from the Sungsang estuary, where mudskipper presence correlates with heavy metal pollution levels, making them effective 58 biomarkers for coastal contamination (Santoso et al. 2020, 2024). Their ecological significance extends to reproductive 59 biology, as population structure and fecundity studies reveal seasonal spawning synchronized with the southwest monsoon 60 (Simon et al. 2012; Ridho et al. 2021), linking life-history traits directly to environmental cycles. Together, these studies 61 establish the giant mudskipper as an integrative indicator of ecosystem health, responding to habitat integrity, pollution 62 pressures, and climatic influences across its range.

The biodiversity of fish species in the Sungsang estuary, including the giant mudskipper, is influenced by a variety of environmental factors. Numerous studies have documented the species diversity and community composition in this region, emphasizing the importance of mangrove ecosystems as critical habitats for mudskippers and other aquatic species (Fauziyah et al. 2019). However, the ongoing threat of human activities, such as deforestation and pollution, poses a significant threat to the ecosystem, thereby impacting mudskipper populations and their role. Consequently, conservation efforts are imperative to safeguard the habitat and ensure the long-term sustainability of mudskippers in South Sumatra (Septinar et al. 2023).

A number of studies have been conducted on the foraging behavior of mudskippers in South Sumatra, encompassing research on their dietary habits (Ridho et al. 2019), gonad length and fecundity (Ridho et al. 2021), and range extension of *P. septemradiatus* (Iqbal et al. 2018). However, research on the length-weight relationship of *P. schlosseri* remains scarce, with most studies being based on field observations. Sungsang coast, located in the estuary of the Musi River, is a wellknown site for mudskippers. Despite numerous studies on the biology and ecology of mudskippers in Southeast Asia, data on length-weight relationships and morphometric-environment interactions of *P. schlosseri* in the Sungsang estuary remain scarce. This study aims to fill this gap by analyzing the length-weight relationships and morphometric-environment interactions of *P. schlosseri* in the Sungsang estuary.

#### MATERIALS AND METHODS

#### Study area

79 80

81 82

83

84

85

86

87

88

89

90

91

92

The research was carried out at five stations in the study area in the Sungsang estuaries of South Sumatra, Indonesia (Figure 1). The description of these sampling locations is shown in Table 1. The Musi River is a major river with multiple uses for its resources. It flows through three provinces on Indonesia's Sumatra Island: South Sumatra, Lampung, and Bengkulu. The coast of Sungang is situated within the Musi River estuary, where the river meets the sea (Melki et al. 2018a, b). Local fishermen depend on the rich aquatic life in the river and its estuary for their livelihoods. The Musi River estuary is home to a variety of fish species, including freshwater stingrays, catfish, and other fish, which are not only a source of food but also contribute to the local economy and food security (Putri and Melki 2020). The mangrove ecosystem within the Musi Estuary is in a state of optimal health, providing an ideal environment for the proliferation of mudskippers (Iqbal et al. 2018; Ridho et al. 2019; Ridho et al. 2021).

**Commented [VH2]:** No need to include two names, choose one, common name or scientific name only?



Figure 1. The study area of P. schlosseri in Sungsang coast

| Sampling sites and | Position                     |                            | Description  |
|--------------------|------------------------------|----------------------------|--|
| names              | Longitudes (E)               | Latitudes (S)              | Description  |
| 1 – Sungsang IV    | 104° 53' 22.65"              | 2° 22' 00.07"              | Fisherman's village, but the population is not as<br>large as in sites 2, 3 and 4. There is a healthy<br>mangrove ecosystem and this site is the mouth<br>of the estuary |
| 2 – Sungsang III   | <mark>104° 53' 50.17"</mark> | <mark>2° 21' 56.30"</mark> | A fisherman village area with a moderate<br>population, known for its active fishing<br>community  |
| 3 – Sungsang II    | <mark>104° 54' 01.76"</mark> | <mark>2° 21' 54.56"</mark> | Similar to Sungsang III, it's a fisherman village<br>with a high population density and active<br>fishing activitie  |
| 4 – Sungsang I     | 104° 54' 14.22"              | <mark>2° 21' 47.61"</mark> | A fisherman village with a relatively larger<br>population, also known for its significant fishing<br>activities   |
| 5 – Marga Sungsang | 104° 54' 21.17"              | 2° 21' 33.41"              | Fisherman's village, but the population is not as<br>large as in sites 2, 3 and 4. There is a good<br>mangrove ecosystem and this site is closer to<br>the river         |

#### 97 98

### Sampling and preservation

99 A total of eleven individuals of *P. schlosseri* were collected at each site (n = 55 total) during a single sampling event in 100 July 2024 to account for variation. Fish sampling was conducted using a  $1 \times 3$  m seine net with a 1 mm mesh size suitable 101 for capturing small estuarine species. After collection, the samples were immediately placed in labeled plastic bottles 102 containing 8-10% formalin solution for initial preservation, and in the laboratory, the samples were transferred to 75% ethanol for long-term storage and further morphometric and meristic analyses (Sotola et al. 2019; Jawad et al. 2020; Tran and Nguyen 2023). The samples were collected at the Bioecology Marine Laboratory, Universitas Sriwijaya (voucher code specimen: UNSRI, *Periophthalmodon schlosseri*, collected by Melki on 15 July 2024 at Sungsang Estuary, Indonesia). 103 104 105 106

#### 107 Morphometric measurements

A total of seventeen morphometric measurements were recorded (Figure 2), including total length (TL), standard 108109 length (SL), eye diameter (ED), head diameter (HD), head length (HL), length of the dorsal fin 1 (LD1), the gap between

Commented [VH3]: P. schlosseri

D1 and D2 (GD1D2), second dorsal fin length (LD2), and distance between anal and caudal fin (DAC), length of anal fin
(LA), least height of the pectoral fin (LPc), length of pectoral fin (PcF), the distance between pectoral and pelvic fin (DPI),
length of pelvic fin (LPF), the width of pelvic fin (WPF), and length of caudal fin (LCF), and width of caudal fin (WCF)
(Gangan et al. 2016; Rahman et al. 2022). Each measurement was measured to the nearest 0.1 centimeters, and body
weight was measured on a digital scale with 0.1 gram accuracy.

115



Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Sokefun et al. 2022; Rahman et al. 2022)

118 119 An allometric method (Rahman et al. 2022) was used to remove size-dependent variation from morphometric data. To 120 do so, all of them were standardized using the formula:  $M_{adj} = M(L_s/L_o)^b$ , where M is the original measurement,  $M_{adj}$  is the 121 adjusted measurement,  $L_o$  is the fish's standard length,  $L_s$  is the mean standard length for all samples, and b is the slope of 122 the regression of logM on logL<sub>o</sub> for all samples. The correlation between the transformed variables and the standard length 123 of the samples was used to evaluate the results of the allometric method.

# 124

## 125 Environmental parameter measurements

Environmental parameters were measured in situ at each sampling site where fish samples were collected to assess the physicochemical characteristics of the habitat. Water temperature, pH and dissolved oxygen were measured using a portable multiparameter instrument (Hanna Instruments Inc., USA) to ensure accurate and simultaneous measurements. Salinity was measured using a hand refractometer (ATAGO Co. Ltd, Tokyo, Japan). All measurements were performed in triplicate to ensure the accuracy and reliability of the data.

#### 132 Data analysis

The following equation was used to approximate the length-weight relationships using the formula  $W= a \times TLb$  (Tran et al. 2021; Vilchez et al. 2024), where W is the body weight (g), TL is the total length (cm), and a and b were estimated by the least-squares method based on logarithms using the formula Log (W)= log (a)+b log (TL) (Raeisi et al. 2011). Fish may exhibit isometric growth, characterized by equal growth in all three dimensions (b=3), or positive allometric growth, where width and height receive priority (b>3), or negative allometric growth, where length is prioritized (b<3) (Froese 2006). The effectiveness of linear regression can be quantified by the coefficient of determination (r2) (Tran et al. 2021).

The K of the fish was estimated using the equation  $K = (W) / (a \times TLb)$ , where W is the body weight (g), TL is the total length (cm), and a and b are the regression coefficients. A non-parametric Kruskal-Wallis test with a 5% threshold of significance was employed to determine whether there were any significant variations in mean Wrm between species because the assumptions of parametric statistics could not be met. For each statistical test, the significance level was set at p<0.05.

Principal Component Analysis (PCA) was performed using XLSTAT version 2021.4.1 (Addinsoft, New York, USA) 144 145 integrated with Microsoft Excel. Prior to analysis, all morphometric and environmental data were standardized to eliminate 146 unit bias and ensure comparability between variables. PCA was used to identify patterns and correlations between environmental parameters and morphometric traits of P. schlosseri across sampling sites. PCA reduces multidimensional 147 148 data into principal components that explain the maximum variance in the data set. A biplot of the first two principal 149 components was generated to visualize the distribution of active variables (environmental and morphometric parameters) 150 and active observations (sampling sites). Variables with similar directions and vector lengths were interpreted as having a 151 stronger influence or association within the same dimension.

#### RESULTS DAN DISCUSSIONS

#### 155 **Environmental parameters**

156 The environmental parameters of samples in all experiments conducted in the Sungsang coast area exhibited minimal 157 fluctuation (Table 1). The environmental parameters that exert a substantial influence on the survival of mudskippers 158 include temperature, salinity, acidity (pH), and dissolved oxygen content (DO) (Ansari et al. 2014; Ridho et al. 2021; 159 Dewivanti et al. 2022). 160

Table 1 The environmental parameters in the sampling sites 161

| rubic I. The environmental parameters in the sampling sites |                  |            |           |                          |                |
|---|------------------|------------|-----------|--------------------------|----------------|
| Sampling site   | Temperature (°C) | pH (water) | pH (soil) | DO (mg L <sup>-1</sup> ) | Salinity (ppt) |
| 1   | 31.7±0.1         | 7.2±0.2    | 7.0±0.1   | 6.9±0.5                  | 20.0±0.0       |
| 2   | 31.7±0.2         | 7.1±0.1    | 6.8±0.3   | 6.3±0.3                  | 16.7±1.5       |
| 3   | 31.3±0.1         | 7.1±0.1    | 6.9±0.1   | 6.3±0.6                  | 16.0±0.0       |
| 4   | 31.9±0.2         | 7.1±0.1    | 7.0±0.2   | 7.8±0.5                  | 15.3±0.6       |
| 5   | 29.8±0.1         | 7.2±0.1    | 6.8±0.3   | 7.9±0.4                  | 15.0±0.0       |
|   |                  |            |           |                          |                |

162

152

153 154

The temperature of the water varied from 29.8±0.1 to 31.9±0.2°C. According to previous studies, the optimal water 163 temperature range for mudskippers is between 23.5 and 35.5°C (Ridho et al. 2021; Dewiyanti et al. 2022; Arevalo et al. 164 165 2023). However, mudskippers demonstrated a preference for milder water temperatures, with a mean of 26.7±2.1°C (Nay et al. 2018). The pH levels of the water ranged from 7.1±0.1 to 7.2±0.2, and the pH levels of the soil ranged from 6.8±0.3 166 167 to 7.00.2. According to several studies, the mudskipper exhibits optimal growth and reproductive capacity in aquatic environments with pH values ranging from 6 to 8 (Ridho et al. 2021; Dewiyanti et al. 2022; Darojat et al. 2023). 168

169 The present study examined the dissolved oxygen (DO) levels in the aquatic environment, with a range of  $6.3\pm0.3$  to  $7.9\pm0.4$  mg L<sup>-1</sup>. This finding is notable when compared to the results reported by Ridho et al. (2021), that the mudskipper 170 could survive at DO levels ranging from 4.2 to 6.2 mg L<sup>-1</sup>. In accordance with the findings of Dewiyanti et al. (2022), the range of DO levels in this study was from 4.9 to 7 mg L<sup>-1</sup>, indicating that mudskippers possess a considerable degree of 171 172 173 tolerance to variations in DO levels. The salinity levels in the study areas ranged from 15.0±0.0 to 20.0±0.0 ppt. In contrast, Darojat et al. (2023) reported that mudskippers can survive in mangrove ecosystems with a salinity range of 1.7 to 2.58 ppt. 174 Ridho et al. (2021) also reported a salinity range of 0 to 0.1 ppt. However, Dewiyanti et al. (2022) identified a higher 175 salinity range, spanning from 18 to 25 ppt, and a more pronounced range of 24.4 to 34.4 ppt (Taniwel et al. 2020). The 176 177 significance of these salinity levels is underscored by the observation that mudskippers are euryhaline, indicating their capacity to withstand a broad spectrum of salinities (Looi et al. 2021). However, pronounced fluctuations in salinity can 178 179 exert an influence on their physiological processes and selection of habitat (Looi et al. 2021).

180 Temperature, salinity, and dissolved oxygen (DO) levels represent critical physical parameters that significantly 181 influence the viability and growth potential of giant mudskippers. These fish exhibit a remarkable capacity for adaptability in response to fluctuating environmental conditions, as evidenced by their increased oxygen uptake rates in response to 182 elevated temperatures (Pattaratumrong and Pompha 2024). Furthermore, they employ behavioral strategies to mitigate 183 184 exposure to extreme conditions. 185

#### 186 Morphometric characteristic

The giant mudskipper observed in this study had a mean total length (TL) of 20.08 cm, ranging from 15.00 cm to 22.60 187 cm, while the mean standard length (SL) was 17.34 cm, with a range of 13.00 cm to 20.00 cm (Table 2). The body size 188 189 recorded at the sampling sites in the Sungsang estuary is comparable to previous findings in the Musi River estuary, South 190 Sumatra, Indonesia (Ridho et al. 2019, 2021). However, it is significantly larger than individuals reported from Cu Lao Dung Island, Soc Trang Province, Vietnam, which ranged from 12.10 - 18.65 cm (Tran et al. 2022), and slightly larger 191 than those from Tanjung Piai, Pontian, Johor, Malaysia, which ranged from approximately 20 cm (Hui et al. 2019). This 192 193 difference may be due to several ecological factors, including higher habitat productivity, greater availability of prey 194 organisms, or potentially lower levels of anthropogenic disturbance in the Sungsang estuary. In support of this, Dinh et al. 195 (2020) suggested that food abundance plays an important role in shaping the growth of mudskippers. Furthermore, Tran et 196 al. (2021) reported that the diet composition of mudskippers varied with fish size, season, and habitat, suggesting that local 197 environmental conditions may significantly influence growth performance in different populations.

198

Commented [VH4]: Periophthalmodon schlosseri

199 200 201 Figure 3. Sample of mudskipper (A. Periophthalmodon schlosseri, B. Morphometric measurement)

202 Giant mudskippers display a distinctive body shape that is adapted for both swimming and terrestrial locomotion. Their 203 bodies are generally elongated and laterally compressed, a trait that facilitates movement in both water and on land 204 (Pattaratumrong and Pompha 2024). The total length of these creatures can exhibit significant variation based on 205 environmental factors and habitat conditions. For instance, studies have documented lengths of up to 25 cm in certain 206 specimens attributed to variations in habitat type and food availability (Zhou et al. 2023). In addition to morphometric 207 measurements, giant mudskippers exhibit specific meristic traits that can be used to differentiate them from other 208 mudskipper species. For instance, the dorsal fin composition, including the number of spines and soft rays, exhibits variation among populations, suggesting adaptations to local environmental conditions (Nor et al. 2023). 209 210 211 212

Table 2. Morphometric measurement results of P. schlosseri on Sungsang coast

| Morphometric Measurements | Ranged (cm)   | Mean ± sd (cm) |
|---------------------------|---------------|----------------|
| TL                        | 15.00 - 22.60 | 20.08±2.0      |
| SL                        | 13.00 - 20.00 | 17.34±1.7      |
| ED                        | 0.40 - 1.70   | 0.83±0.4       |
| HD                        | 2.40 - 4.80   | 3.44±0.6       |
| HL                        | 3.40 - 6.40   | 4.81±0.8       |
| LD1                       | 1.50 - 3.00   | 2.67±0.4       |
| $GD_1D_2$                 | 0.90 - 2.60   | 1.47±0.4       |
| $LD_2$                    | 3.00 - 4.20   | 3.73±0.4       |
| DAC                       | 2.00 - 3.90   | 3.06±0.5       |
| LA                        | 2.60 - 4.30   | 3.49±0.4       |
| LPc right                 | 1.30 - 2.80   | 1.89±0.4       |
| LPc left                  | 1.40 - 2.80   | 2.05±0.4       |
| PcF right                 | 1.10 - 2.50   | 1.66±0.3       |
| PcF left                  | 1.50 - 3.00   | 1.91±0.5       |
| DPI right                 | 0.20 - 1.70   | 0.78±0.4       |
| DPI left                  | 0.50 - 1.80   | 0.96±0.4       |
| LPF                       | 0.80 - 2.80   | 1.63±0.7       |
| WPF                       | 1.50 - 3.00   | 2.36±0.5       |
| LCF                       | 2.00 - 4.70   | 3.40±0.8       |
| WCF                       | 1.30 - 3.00   | 2.32±0.5       |

#### 213 Length-weight relationship

214 The length-weight relationship of the giant mudskipper (P. schlosseri) was determined through the analysis of 55 specimens collected from five sampling sites along the Sungsang coast. The total length (TL) ranged from 15.00 to 22.60 cm, and the body weight varied from 28.3 to 119.2 g (Table 3). 215 216

217 218

Commented [VH5]: See previous comment

| Table 3. Range of total length (TL) and body weight (W) of P. schlosseri in Sungsang coast |             |              |  |
|--|-------------|--------------|--|
| Sampling Site  | TL (cm)     | W (g)        |  |
| 1  | 19.5 - 21.5 | 67.8 - 102.5 |  |
| 2  | 15.0 - 21.0 | 28.3 - 103.7 |  |
| 3  | 19.0 - 20.5 | 61.8 - 92.8  |  |

| 4       | 20.0 - 22.5 | 87.7 - 108.3 |
|---------|-------------|--------------|
| 5       | 19.5 - 22.6 | 82.1 - 119.2 |
| Average | 20.1        | 85.4         |

219 220

The findings of the regression analysis and the length-weight relationship graph (Figure 2) yielded the following 221 222 223 equation: y = 0.0026x3.45. The b value of 3.45 indicates that the fish growth pattern is positive allometric (b > 3), signifying that weight growth outpaces length increase. Positive allometric growth is indicated by a length-weight relationship (LWR) where the exponent (b) is greater than 3. Studies have demonstrated that P. schlor ri exhibits such a 224 relationship, with documented values of b indicating positive allometry (Ridho et al. 2019; Abiaobo et al. 2021; Looi et al. 225 2021; Mussa et al. 2024). For instance, a study conducted in the Musi River Estuary found that the correlation coefficient 226 227 for the length-weight relationship (LWR) of P, schlossert was 98.2%, with an exponent value of 3.189, confirming its positive allometric growth (Ridho et al. 2019). This suggests that as the fish grows, it becomes relatively heavier compared 228 to its length, which may be advantageous for buoyancy and mobility in its habitat. This positive allometric growth pattern 229 of P. schlosseri is consistent with findings from related species within the same family. For example, P. barbarus also 230 exhibited positive allometric growth in similar ecological contexts, reinforcing the notion that this growth strategy may be 231 a common adaptive trait among mudskippers (Indarjo et al. 2020; Abiaobo et al. 2021). The implications of such growth 232 patterns are critical, as they can influence the species' reproductive strategies, survival rates, and overall fitness in 233 234 fluctuating environmental conditions typical of mangrove ecosystems (Dinh 2016).



Formatted: Highlight

Formatted: Highlight

235 236 237

Figure 2. Relationship between total length and body weight of P. schlosseri in Sungsang coast

238 239 In comparison with other species found in mangrove ecosystems, the allometric growth of P. schlosseri reflects typical trends in estuarine and intertidal species, where growth patterns are often influenced by environmental conditions such as 240 temperature, food availability, and habitat structure (Chew et al. 2014; Looi et al. 2021). The positive allometry observed 241 in the Sungsang population could be attributed to the productivity of the mangrove ecosystem, which provides abundant 242 resources for these mudskippers. The Musi River estuary is home to a diverse array of mudskipper species, which exhibit 243 various adaptations to their mangrove habitat. For instance, studies have documented the reproductive biology and feeding 244 habits of mudskippers in this region, emphasizing their role in the local food web (Ridho et al. 2019; Ridho et al. 2021).

#### 245 **Condition factor**

246 The K value exhibited a maximum at sampling site 1 (K= 1.04) and a minimum at sampling site 5 (K= 0.94) (Figure 3). 247 The variation in K values across the sampling sites was not statistically significant, suggesting that the fish samples were 248 healthy and well-nourished at the time of the study. The K values in the Sungsang coastal area are comparable to those 249 found in the Tran De District, Soc Trang Province, Mekong Delta, Vietnam mangrove habitat, which range from 1.01 to

250 1.03 (Dinh 2016), and the West Coast of Peninsular Malaysia, which range from 0.41 to 1.29 (Looi et al. 2021).



251 252 253 Figure 3. Condition factor of P. schlosseri in Sungsang coast

254 Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the length-255 weight relationship. The condition factor values indicated a range of nutritional status among the mudskippers, with most 256 individuals displaying average to good health (Froese 2006). However, some specimens with lower condition factors were 257 found to be lean, suggesting potential seasonal fluctuations in food availability that might influence the body mass-to-258 length ratio (Abdullah and Zain 2019; Tran et al. 2021; Nguyễn et al. 2022). Condition factors, which are used as an 259 indicator of fish health, have been shown to vary with environmental conditions. This indicates that abiotic factors, such as 260 temperature and salinity, as well as biotic factors, such as prey availability, significantly affect the growth patterns of these 261 fishes (Dewiyanti et al., 2022; Dinh et al., 2022).

#### 262 Principal component analysis (PCA)

263 Principal component analysis was employed to ascertain the correlation between seventeen P. schlosseri morphometric 264 characteristics and environmental factors, including water pH and soil pH, dissolved oxygen (DO), temperature, and 265 salinity. The analysis yielded significant findings concentrated on two primary axes: F1 by 55.47% and F2 by 24.70%, 266 with 80.17% representing the maximum amount of information (Figure 4). 267



Figure 4. PCA was examined to determine morphometric characteristics related to environmental factors of P. schlosseri on Sungsang coast

268 269 270 271 272 273 274 275 276 The environmental parameter on the positive F1 axis is characterized by DO, which for sampling site 5 is high at 7.9  $mg L^{-1}$ . According to Kumar et al. (2021) and Mulyasari (2023), a very strong correlation relationship can mean that as the value of the comparison character increases, the length of a morphometric character in fish will also increase. Consequently, elevated levels of dissolved oxygen at the Sungsang coast could potentially influence the growth of morphometric characteristics in P. schlosseri. A study by Khater et al. (2021) and Heriyati et al. (2022) indicated that low 277 DO levels can lead to a reduction in fish appetite and growth. The findings indicate that salinity exerts minimal influence 278 on the morphometric growth of *P. schl* eri. The classification of mudskippers as euryhaline organisms is attributed to 279 their capacity to respond to variations in salt concentration (Taniwel et al. 2020; Kim et al. 2021; Hamidah et al. 2024).

Formatted: Highlight

280 The positive F2 axis is characterized by sampling site 1, which is associated with the environmental parameter 281 component of soil pH and the morphometric characteristics of WPF, defined as the width of the pelvic fins utilized during 282 locomotion by mudskippers. This parameter is believed to be closely related to their biological functions (Hidayat et al. 283 2022; Quigley et al. 2022). The pH value of the soil at sampling site 1 is 7, indicating a high value within the threshold of 284 giant mudskipper life. The measurement of soil pH is crucial as the mudskipper habitat is located in the sediment. A low 285 pH value in the mudskipper habitat prompts the fish to allocate their energy toward environmental adjustments rather than 286 growth and foraging (Smith and Nobriga 2023).

287 This study analyzed the giant mudskipper P. eri-on Sungsang coast, revealing positive allometric growth (b>3) 288 and healthy condition factors. Dissolved oxygen and pH exhibited a strong influence on morphometric characteristics, 289 while temperature and salinity supported optimal habitats. The findings emphasize the critical role of mangroves in 290 P. schlosseri-giant mudskipper populations and offer insights into mangrove ecosystem management. This sustaining 291 study highlights that dissolved oxygen and pH are the most influential environmental variables affecting the morphometric 292 variation of P. schlosseri, suggesting their potential as key indicators in mangrove ecosystem monitoring. 293

#### 294 Acknowledgements

295 We would like to express our sincere gratitude to abah badrun for his assistance in collecting mudskippers, which was 296 very important for this research. We would also like to thank Gusti Ayu for her patience and help in setting up the research 297 site.

#### 298 References

- 299 300 Abdullah MIC, Zain KM. 2019. Length-weight relationships, condition factor and growth parameters of Periophthalmus chrysospilos (Bleeker, 1852)
  - (Gobiiformes: Gobiidae), in Bayan Bay, Penang, Malaysia. Sains Malays 48 (2): 271 279. DOI: 10.17576/jsm-2019-4802-02.
    Abiaobo N, Asuquo IE, Ejiogu IN, James EJ. 2021. Aspects of the biology of *Periophthalmus barbarus* (mudskipper), from Jaja Creek, Niger Delta, Nigeria. Ecol Evol Biology 6 (1): 15. DOI: 10.11648/j.eeb.20210601.14.
- Ansari AA, Trivedi S, Saggu S, Rehman H. 2014. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. J Entomol Zool Stud 2 (6): 22–33.
  - Arevalo E, Cabral HN, Villeneuve B, Possémé C, Lepage M. 2023. Fish larvae dynamics in temperate estuaries: A review on processes, patterns and factors that determine recruitment. Fish Fish 24 (3): 466–487. DOI: 10.1111/faf.12740.
  - Arulnayagam A, Khim JS, Park J. 2021. Floral and faunal diversity in Sri Lankan mangrove forests: A systematic review. Sustainability 13 (17). DOI: 10.3390/su13179487. Chew SF, Hiong KC, Lam SP, Ong SW, Wee WL, Wong WP, Ip YK. 2014. Functional roles of Na+/K+-ATPase in active ammonia excretion and
  - seaware aclimation in the giant mudskipper, Periophthalmood schlosseri. Front Physiol 5. DOI: 10.3389/fphys.2014.00158.
    Corush JB, Zhang J. 2022. One size does not fit all: Variation in anatomical traits associated with emersion behavior in mudskippers (Gobiidae: Oxudercinae). Front Ecol Evol 10: 01–08. DOI: 10.3389/fevo.2022.967067.
  - Oxudercinae), Front Ecol Evol 10: 01–08. DOI: 10.3389/fevo.2022/96/06/.
     Darojat AZ, Marhendra APW, Kurniawan N. 2023. Identification of mudskipper species in mangrove area of Luwu Timur, Luwu Utara, and Wajo South Sulawesi Indonesia. Biotropika: J Tropical Biol 11 (2): 74–83. DOI: 10.21776/ub.biotropika.2023.011.02.02.
     Dewiyanti I, Melanie K, Almuniro S, Damora A, Nufadillah N, Batubara, AS. 2022. Growth patterns and condition factor of the mudskipper (*Periophthalmus gracilis*) in mangrove ecosystem rehabilitation areas in Banda Aceh and Aceh Besar, Indonesia. Fish Aquat Life 30 (2): 85–94.
     DOI: 10.2178/cms/G022.0020
  - DOI: 10.2478/aopf-2022-0008.
  - Dinh QM. 2016. Growth and body condition variation of the giant mudskipper *Periophthalmodon schlosseri* in dry and wet seasons. Tap Chi Sinh Hoc 38 (3). DOI: 10.15625/0866-7160/v38n3.7425.

  - <sup>56</sup> (3). DOI: 10.1202/10806/100/V3505.1/42.5.
     Dinh QM, Tran LT, Tran TTM, To DK, Nguyen TTK, Tran DD, 2020. Variation in diet composition of the mudskipper, *Periophthalmodon septemradiatus*, from Hau River, Vietnam. Bull Mar Sci 96 (3): 487–500. DOI: 10.5343/bms.2018.0067.
     Dinh QM, Nguyen THD, Truong NT, Doan DX, Nguyen TTK. 2022. Monthly variations in growth pattern and condition factor of *Periophthalmodon septemradiatus* (gobiiformes: periophthalminae) living along the Bassac River in Viet Nam. PeerJ 10: e13880. DOI: 10.7717/peerj.13880.
     Fauziyah F, Nurhayati N, Bernas SM, Putera A, Suteia Y, Agustani F. 2019. Biodiversity of fish resources in Sungsang estuaries of South Sumatra; IOP Conference Series: Earth and Environmental Science 278 (1): 012025, DOI: 10.1088/1755-1315/278/1/012025.
  - Froese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. J Appl Ichthyol 22 (4): 241-253. DOI: 10.1111/j.1439-0426.2006.00805.x.
  - Cangan SS, Kumar R, Ramteke KK, Kumar AP, Jaiswar AK. 2016. Study of morphological variation discernible by multivariate analysis between the species of genus Setipinna (Teleostei: Clupeiformes). Ecol Enviro and Conserv 22 (September): S11–S16.
  - Hamidah A, Murni P, Said M. 2024. The diversity of mudskipper fish family Gobiidae in mangrove area, Seberang District, Tanjung Jabung Regency, West Jambi. J Surv Fish Sci 11 (1). DOI: 10.53555/sfs.v11i01.2045. Hasan V, South J, Katz A, Ottoni FP, 2022, First record of the Small-eved loter Prionobutis microps (Weber, 1907) (Teleostei: Eleotridae: Butinae) in
  - Java, Indonesia. Cybium 46(1): 49–51. DOI: 10.26028/CYBIUM.2022-461-008. Heriyati E, Rustadi R, Isnansetyo A, Triyatmo B, Istiqomah I, Deendarlianto D, Budhijanto W. 2022. Microbubble aeration in a recirculating aquaculture
  - system (RAS) increased dissolved oxygen, fish culture performance, and stress resistance of Red Tilapia (*Oreochromis* sp.). Trends Sci 19 (20): 6251. DOI: 10.48048/tis.2022.6251. Hidayat S, Wicaksono A, Raharjeng ARP, Jin DSM, Alam P, Retnoaji B. 2022. The morphologies of mudskipper pelvic fins in relation to terrestrial and
  - climbing behaviour; Proceedings of the Zoological Society 75 (1): 83–93. The University of Edinburgh, 8 February 2022. DOI: 10.1007/s12595-021-00422-1
  - Hui NY, Mohamed M, Othman MNA, Tokiman L. 2019. Diversity and behaviour of mudskippers of Tanjung Piai, Pontian, Johor. IOP Conference Series: Earth and Environmental Science 269 (1). DOI: 10.1088/1755-1315/269/1/012037.

Commented [VH6]: See previous comment

Commented [VH7]: See previous comment

Formatted: Highlight

- Indarjo A, Salim G, Zein M, Susiyanti S, Soejarwo PA, Nugraeni CD, Bija S, Pham YTH. 2020. Characteristics of Von Bertalanfy growth, allometric condition index and mortality of *Periophihalmus barbarus* in mangrove and probiotics conservation area (KKMB), Tarakan, North Kalimantan. IJ M S 25 (1): 31–38. DOI: 10.14710/ik.ijms.25.1.31-38.
- M S 25 (1): 51–56. DOI: 10.147101K1JIIK.251.51-56.
  Iqbal M, Halim A, Adriani D, Pormansyah, Saputra RF. 2018. Range extension of *Periophthalmodon septemradiatus* (Gobiidae) in southern Sumatra, Indonesia. Cybium 42 (4): 376–378. DOI: 10.26028/cybium/2018-424-009.
- Periophthalmodon schlosseri. The IUCN Red List of Threatened Species 2023: e.T196314A153206425. IUCN. 2023. New Just St. Jernophilationa and Station Process Real List of Theatened Species 2023. C1190314/15/200425. www.iucnedilist.org/species/196314/153206425.
  Jawad LA, Koya A, Gnohossou P. 2020. Fixation, preservation and freezing effects on morphometrics of two fish species collected from Lake Ganvie,
- Benin, West Africa. Thalassia Sal 42, 75–82. DOI: 10.1285/i15910725v42p75.
  Jordan P, Fröhle P. 2022. Bridging the gap between coastal engineering and nature conservation?: A review of coastal ecosystems as nature-based solutions for coastal protection. J Coast Conserv 26 (2). DOI: 10.1007/s11852-021-00848-x.
- Khater ES, Bahnasawy AH, Elghobashy H, Shaban Y, El-Sheikh FM, El-Reheem SA, Abocgela M. 2021. Mathematical model for predicting oxyger concentration in Tilapia fish farms. Sci Rep 11 (1). DOI: 10.1038/s41598-021-03604-1.
- Kim J, Lee C, Yoo D, Kim H. 2021. Genetic adaptations in mudskipper and tetrapod give insights into their convergent water-to-land transition. Animals 11 (2): 584. DOI: 10.3390/ani11020584 Kumar GR, Bano F, Serajuddin M. 2021. Effect of formalin preservation on studies on morphology and condition factor of the freshwater Shark Wallago
- attu (Bloch and Schneider, 1801) using truss network system. Indian J Fish 68 (3). DOI: 10.21077/ijf.2021.68.3.98695-16. Looi LJ, Aris AZ, Isa NM, Yusoff, FM, Haris H. 2021. Elemental composition and health risk assessment of giant mudskipper (*Periophthalmodon*)

- Looi LJ, Aris AZ, Isa NM, Yusoff, FM, Haris H. 2021. Elemental composition and health risk assessment of giant mudskipper (*Periophthalmodon schlosseri*) from the intertidal zone of the west coast of Peninsular Malaysia. Front Mar Sci 7. DOI: 10.3389/fmars.2020.618284.
   Mai HV, Tran LX, Dinh QM, Tran DD, Murata M, Sagara H, Yamada A, Shirai K, Ishimatsu A. 2019. Land invasion by the mudskipper, *Periophthalmodon septemradiatus*, in fresh and saline waters of the Mekong River, Sci Rep 9 (1). DOI: 10.1038/s41598-019-50789-5.
   Melki, Isnansetyo A, Widada J, Murwantoko M. 2018a. The significance of water quality parameters on the diversity of ammonia-oxidizing bacteria in the water surface of Musi River, Indonesia. AACL Bioflux 11 (6), 1908–1918.
   Melki, Isnansetyo A, Widada J, Murwantoko M. 2018b. Distribution of ammonium-oxidizing bacteria in sediment with relation to water quality at the Musi River, Indonesia. Hayati J Biosci 25 (4), 198–205. DOI: 10.4308/hjb.25.4.198.
   Mulyasari N, Subaryono N, Utomo BSB, Taufik I, Kusmini II, Yosmaniar N. 2023. Morphometric and genetic characterization of dominant fish species in Progo River, Yogyakarta, Indonesia. Sci World J 38 (2): 111–120. DOI: 10.1155/2023/7197251.
   Mussa ZJ, Aziz BAAA, Saleh SM, Abbas AH, Al-Asadi MK, Jumah AAK. 2024. Mudskippers a good bioindicator for polluted soils in the mudflat region of Southerm Trao. Meson J Mar Sci 38 (2): 111–120. DOI: 10.0512/2023/7197251.

- Mussa ZJ, AZZ BAAA, Saleh SM, Abdas AH, Al-Asadi MK, Juman AAK. 2024. Mudskipper's a good bioindicator for polluted solis in the mudriat region of Southern Iraq. Mesop J Mar Sci 38 (2): 111–119. DOI: 10.58629/mjms.v38i2.354.
  Nathaniel AM, Gbobo BMFO, Raimi MO. 2024. Food and feeding of Atlantic mudskipper *Periophthalmus barbarus* in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria. Qeios. DOI: 10.3828/QMV7/Z.
  Nay TJ, Gervais CR, Hoey AS, Johansen JJ, Steffensen JF, Rummer JL. 2018. The emergence emergency: A mudskipper's response to temperatures. J Therm Biol 78 (September): 65–72. DOI: 10.1016/j.jtherbio.2018.09.005.
- Nguyễn NT, 178 (September), 05–72, DOI. 10.1010/j.ujer00.2018.057602. Nguyễn NT, 18 LM, Nguyen ATN, Chu NH, Tran HD, Hung NY, Ta TT. 2022. Variation in the allometry of morphometric characteristics, growth, and condition factors of wild *Bostrychus sinensis* (Butidae) in Northern Vietnam. Pak J Zool 55 (2). DOI: 10.17582/journal.pjz/20200917140936.
- Nor NM, Saifuzzaman S, Azmir IA, Hussin N. 2023. Morphological characteristics and reproductive organs assessment of blue-spotted mudskipper Boleophthalmus boddarti in Peninsular Malaysia. Biotropia 30 (1): 21–36. DOI: 10.11598/btb.2023.30.1.1561.
   Pace CM, Gibb AC. 2009. Mudskipper pectoral fin kinematics in aquatic and terrestrial environments. J Exp Biol, 212(14), 2279–2286. DOI:
- 10.1242/jeb.029041. Parenti LR, Jaafar Z. 2017. The natural distribution of mudskippers. In Fishes Out of Water (pp. 37–68). CRC Press
- Pattaratumrong MS, Pompha T. 2024. Habitat of the amphibious mudskipper Periophtalmodon schlosseri in Songkhla Lake, Thailand. Biodiversitas 25
- Pattaratumrong MS, Pompha T. 2024. Habitat of the amphibious mudskipper *Periophtalmodon schlosseri* in Songkhla Lake, Thailand. Biodiversitas 25 (5): 1875–1881. DOI: 10.13057/biodiv/d250503
   Putri WAE, Melki. 2020. Study of the water quality of the Musi River estuary, South Sumatra. J Mar Aquat Sci 6 (1): 36. DOI: 10.24843/jmas.2020.v06.i01.p05. [Indonesian].
   Quigley ZMG, Blob RW, Kawano S. 2022. Kinematic comparisons between mudskipper fins and Salamander limbs during terrestrial locomotion. J Exp Zool A Ecol Integr Physiol 337 (6): 612–625. DOI: 10.102/jez.2594.
   Raeisi H, Daliri M, Paighambari SY, Shabani MJ, Bibak M, Davoodi R. 2011. Length-weight relationships, condition factors and relative weight of five fish species of Bushehr waters, Northern Persian Gulf. Afr J Biotechnol 10 (82): 19181–19186. DOI: 10.2650.
   Pathwan MAE. A musin L. 2022. Membediogical Charles and Charl

- Rahman MAF, Azmir IA, Hussin NJ. 2022. Morphological study of selected mudskipper species (Family: Oxudercidae) and development of key pictorial. Iran J Ichthyol 9 (4): 180–194. DOI: 10.22034/jji.v9i4.808.
- Ridho MR, Patriono E, Rahmawati D, Pratama R, Avesena M. 2021. Short communication: Investigating gonal length and fecundity in mudskippers (gobiidae) at the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 22 (10): 4413–4420. DOI: 10.13057/biodiv/d221034. Ridho MR, Patriono E, Solikha M. 2019. Food habits of three species of mudskippers in the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 2010 (2010):
- 20 (8): 2368–2374. DOI: 10.13057/biodiv/d200835.
  Santoso HB, Suhartano E, Yunita R, Biyatmoko D. 2020. Mudskipper fish as a bio-indicator for heavy metals pollution in a coastal wetland. Egypt J Aquat Biol Fish 24 (7): 1073–1095. DOI: 10.21608/ejabf.2020.144402.
  Santoso HB, Kristianto K, Yunita R. 2024. Iron bioaccumulation and ecological implications in the coastal swamp wetlands ecosystem of South Kellowerk and the coastal swamp wetlands of South Sout
- Kalimantan: insights from giant mudskipper fish as bioindicators. J Degrad Min Lands Manag, 11(3), 5539-5550. DOI: 10.15243/jdmlm.2024.113.5539. Septinar H, Putri YP, Midia KR, Bianto B. 2023. Mangrove forest conservation efforts through nurseries in Sungsang IV village, Banyuasin Regency.
- Enviro Sci J: Jurnal Ilmu Lingkungan, 77–88. DOI: 10.31851/esjo.v1i2.11920. [Indonesian].
  Setyawan AD, Winarno K. 2006. The direct exploitation in the mangrove ecosystem in Central Java and the land use in its surrounding; degradation and its restoration effort. Biodiversitas 7 (3): 282–291. DOI: 10.13057/biodiv/d070318.
- Simon KD, Bakar Y, Mazlan AG, Zaidi CC, Samat A, Arshad A, Temple SE, Brown-Peterson NJ. 2012. Aspects of the reproductive biology of two archer fishes *Toxotes chatareus*, (Hamilton 1822) and *Toxotes jaculatrix* (Pallas 1767). Environ Biol Fishes 93 (4): 491–503. DOI: 10.1007/s10641-011-9944-6.
- Smith WE, Nobriga MK. 2023. A bioenergetics-based index of habitat suitability: spatial dynamics of foraging constraints and food limitation for a rare estuarine fish. Trans Am Fish Soc 152 (5): 650-671. DOI: 10.1002/tafs.10427
- Sokefun O, Gan HM, Tan MP. 2022. Morphometrical characterization of the Atlantic mudskipper species (*Periophthalmus barbarus*) (Linnaeus, 1766) (Perciformes; Gobiiae) from Abonema in Port Harcourt, Rivers State, Nigeria. Int J Fish Aquac 10 (3): 72–76. DOI: 10.22271/fish.2022.v10.i3a.2719.
- Sotola VA, Craig CA, Pfaff PJ, Maikoetter JD, Martin NH, Bonner TH. 2019. Effect of preservation on fish morphology over time: Implications for morphological studies. PLoS ONE 14(3): e0213915. DOI: 10.1371/journal. pone.0213915.
   Steppan SJ, Meyer AA, Barrow LN, Alhajeri BH, Al-Zaidan ASY, Gignac PM, Erickson GM. 2022. Phylogenetics and the evolution of terrestriality in mudskippers (Gobiidae: Oxudercinae). Mol Phylogenetics Evol 169: 107416. DOI: 10.1016/j.ympev.2022.107416.

Su J, Friess DA, Gasparatos A. 2021. A meta-analysis of the ecological and economic outcomes of mangrove restoration. Nat Commun 12 (1). DOI:

Su J, Fress DA, Oasparatos A. 2021. A meta-analysis of the ecological and economic outcomes of mangrove restoration. Nat Commun 12 (1): DOI: 10.1038/s41467-021-25349-1.
 Taniwel D, Leiwakabessy F, Rumahlatu D. 2020. Short communication: density and length-weight relationship of mudskipper (*Periophthalmus* spp.) in the mangrove area of Kairatu Beach, Maluku, Indonesia. Biodiversitas 21 (11). DOI: 10.13057/biodiv/d211155.
 Tran HD, Ryuyen HH, Ha LM. 2021. Length-weight relationship and condition factor of the mudskipper (*Periophthalmus modestus*) in the Red River Delta. Reg Stud Mar Sci 46: 101903. DOI: 10.1016/j.rsma.2021.101903.

Tran LX, Maekawa Y, Soyano K, Ishimatsu A. 2020. Morphology of the feeding apparatus in the herbivorous mudskipper, *Boleophthalmus pectinirostris* (Linnaeus, 1758). Zoomorphology 139 (2): 231–243. DOI: 10.1007/s00435-020-00476-3.

Tran LX, Nguyen TTK, Vo T1. 2022. Morphological comparison of the cranial movement apparatus in mudskippers (Gobiidae: Oxudercinae). Zool 154 (August): 126042. DOI: 10.1016/j.zool.2022.126042.

Tra LX, Nguyen TTK, 2023. Morfology of the buccal and opercular sealing apparatus in mudskippers (Gobiidae: Oxudercinae). J Ichthyol 63 (4):605–615. DOI: 10.1134/S0032945223040197.
Valen FS, Hasan V, Ottoni FP, Nafisyah AL, Erwinda M, Annisa AN, Adis MA. 2022. First country record of the bearded gudgeon *Pogoneleotris* 

heterolepis (Günther, 1869) (Teleostei: Eleotridae) from Indonesia. IOP Conf. Ser.: Earth Environ. Sci. 1036 (012074). DOI: 10.1088/1755-1315/1036/1/012074.

Vilchez M, Dattilo J, Brewer SK. 2024. Length-weight relationships of native and non-native fishes in the lower Red River Cathment, USA. J Appl Ichthyol 2024: 5. DOI: 10.1155/2024/5578825. Waleed TA, Abdel-Maksoud YK, Kanwar RS, Sewilam H. 2024. Mangroves in Egypt and the Middle East: current status, threats, and opportunities. Int J

Environ Sci Technol. DOI: 10.1007/s13762-024-05788-1. Wirabuana PYAP, Baskorowati L, Pamungkas B, Mulyana B, South J, Purnobasuki H, Andriyono S, Hasan V. 2025. Mangroves, fauna compositions

and carbon sequestration after ten years restoration on Flores Island, Indonesia. Sci Rep 15 (4866). DOI:10.1038/s41598-025-87307-x. You X, Sun M, Li J, Bian C, Chen J, Yi Y, Yu H, Shi Q. 2018. Mudskippers and their genetic adaptations to an amphibious lifestyle. Animals 8 (2). DOI: 10.3390/ani8020024.

Zhang Z, Fu Y, Zhao H, Zhang X. 2022. Social enrichment affects fish growth and aggression depending on fish species: applications for aquaculture. Front Mar Sci 9. DOI:10.3389/fmars.2022.1011780.

Zhou H, Donatelli CM, Laneuville O, Standen EM. 2023. Skeletal anatomy of the pectoral fin in mudskipper species from terrestrial and aquatic habitats.

J Morphol, 284(8). DOI: 10.1002/jmor.21612. Ziadi-Künzli F, Maeda K, Puchenkov P, Bandi M. 2024. Anatomical insights into fish terrestrial locomotion: a study of barred mudskipper

# Table of Responses

| Lines | Reviewer Comments/Suggest  | Answer   |
|-------|--|--|
| 7     | Delete   | The sentence has been deleted<br>"Periophthalmodon schlosseri (Pallas, 1770)"                      |
| 53    | No need to include two names, choose one, common name or scientific name only? | Chosen common name from "mudskipper <i>P. schlosseri</i> " to "The giant mudskipper"               |
| 105   | P. schlosseri  | The sentences have been changed from<br>"Periophthalmodon schlosseri" to "P. schlosseri"           |
| 187   | Periophthalmodon schlosseri  | The sentences have been changed from "The giant mudskipper " to <i>Periophthalmodon schlosseri</i> |
| 214   | See previous comment<br>"the giant mudskipper ( <i>P. schlosseri</i> )"        | The sentences have been changed to "P. schlosseri"   |
| 223   | Highlight "P. schlosseri"  | Fixed sentence "P. schlosseri"   |
| 226   | Highlight "P. schlosseri"  | Fixed sentence "P. schlosseri"   |
| 278   | Highlight "P. schlosseri"  | Fixed sentence "P. schlosseri"   |
| 284   | See previous comment<br>"P. schlosseri"  | The sentences have been changed from " <i>P. schlosseri</i> " to "The giant mudskipper"            |
| 287   | See previous comment<br>"P. schlosseri"  | The sentences have been changed from " <i>P. schlosseri</i> " to "The giant mudskipper"            |
| 290   | See previous comment<br>"P. schlosseri"  | The sentences have been changed from " <i>P. schlosseri</i> " to "giant mudskipper"                |
| 300   | Highlight "–"  | Sign has been replaced   |



# [biodiv] New notification from Biodiversitas Journal of Biological Diversity

1 pesan

# Ayu Astuti via SMUJO <support@smujo.com>

Balas Ke: Ayu Astuti <sectioneditor6@smujo.id>, Ahmad Dwi Setyawan <editors@smujo.id> Kepada: Melki Melki <melki@unsri.ac.id>

3 Mei 2025 pukul 23.24

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "uncorrected proof" regarding the submission "Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia".

Link: https://smujo.id/biodiv/authorDashboard/submission/21288

Ahmad Dwi Setyawan

**Biodiversitas Journal of Biological Diversity** 

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.

**BIODIVERSITAS** Volume 26, Number 5, May 2025 Pages: xxxx ISSN: 1412-033X E-ISSN: 2085-4722 DOI: 10.13057/biodiy/d2605xx

# Analysis of morphology and population dynamics of giant mudskipper Periophthalmodon schlosseri (Gobiiformes: Oxudercidae) at Sungsang estuaries, South Sumatra, Indonesia

MELKI", FADHILAH DZAKIYYAH ANANTA, ISNAINI, FITRI AGUSTRIANI, REZI APRI, HARTONI, ELLIS NURJUALISTI NINGSIH, JENI MEIYERANI

Department of Marine Science, Universitas Sriwijaya. Jl. Raya Palembang-Prabumulih Km. 32, Indralaya 30862, South Sumatra, Indonesia. Tel./fax.: +62-711-580086, \*email: melki@unsri.ac.id

Manuscript received: 16 February 2025. Revision accepted: xxx 2025.

**Abstract.** *Melki, Ananta FD, Isnaini, Agustriani F, Apri R, Hartoni, Ningsih EN, Meiyerani J.* 2025. *Analysis of morphology and population dynamics of giant mudskipper* Periophthalmodon schlosseri (*Gobiljormes: Oxudercidae*) at *Sungsang Estuaries, South Sumatra, Indonesia. Biodiversitas* 26: *xxxx*. The Giant Mudskipper Periophthalmodon schlosseri is one of the most abundant mudskipper species, playing a vital role in the biomass of mangrove ecosystems. Mudskipper fish are also found in the Sungsang coast, an estuary of the Musi River that is fed by river water from three provinces in Indonesia: South Sumatra, Lampung, and Bengkulu. This study aimed to analyze the morphology and population dynamics of mudskippers along with their environmental parameters in Sungsang coastal South Sumatra. For this study, mudskipper specimens were collected from five sampling sites along the Sungsang coast and analyzed for morphometric characteristics, length-weight relationships, and their correlations with key environmental parameters like temperature, pH, and dissolved oxygen. The analysis of fifty-five specimens revealed an average total length of 20.08 cm, a standard length of 17.34 cm, and an average weight of 85.4 g. The growth pattern exhibited positive allometry (b>3), suggesting that as these fish grow, their body weight increases faster than their length. Condition factor analysis indicated that the fish sampled were healthy and in good nutritional condition. The principal component analysis (PCA) further highlighted a strong association between dissolved oxygen and pH levels with the morphometric characteristics of the mudskippers, explaining 55.47% of the variation on the F1 axis and 24.70% on the F2 axis. This robust correlation between environmental factors and morphometric characteristics underscores the reliability of our findings. These findings provide crucial insights into the ecological health of the Giant Mudskipper and its dependence on specific environmental factors in the mangrove habitat are of ut

Keywords: Environmental parameter, length-weight relationship, morphometric, mudskipper, Sungsang coast

#### INTRODUCTION

The mangrove ecosystem is an important area due to its role in providing a habitat for a wide variety of aquatic and terrestrial biota, as evidenced by the discovery of rare and previously unrecorded fish species such as the bearded gudgeon Pogoneleotris heterolepis in the Kapuas River estuary (Valen et al. 2022) and the small-eyed gudgeon Prionobutis microps in the Solo River estuary (Hasan et al. 2022), highlighting the ecological importance of these transitional zones as critical habitats for endemic and specialized aquatic species. This ecosystem is important from a variety of angles, including its environmental functions, such as protecting estuaries and coastlines from storms, stabilizing the shore, and reducing coastal soil erosion and flooding, as shown by successful restoration in Central Java (Setyawan and Winarno 2006) and Flores Island (Wirabuana et al. 2025). Restored mangroves in Pasar Banggi prevented erosion. In Flores, 10-year-old mangroves improved sediment retention and wave absorption. Additionally, it serves as a nursery habitat and breeding ground for a wide range of biota, and it provides sources that include essential commodities for both subsistence and

commerce (Arulnayagam et al. 2021; Su et al. 2021; Jordan and Fröhle 2022; Waleed et al. 2024).

During periods of low tide, mangrove swamps and tidal flats formed in creeks, estuaries, and coastal waterways provide habitat for mudskippers (Mai et al. 2019; Ridho et al. 2019; Santoso et al. 2020; Darojat et al. 2023; Nathaniel 2024). Mudskippers exhibit physiological, et al. morphological, and behavioral adaptations that allow them to thrive in both aquatic and terrestrial environments (You et al. 2018; Tran et al. 2020; Corush and Zhang 2022; Steppan et al. 2022). Various factors, including food availability, habitat selection, human disturbance, and others influence the geographical distribution of each species. A notable example is the giant mudskipper contributes Periophthalmodon schlosseri, which significantly to the biomass value of the mangrove ecosystem (Zulkifli et al. 2012; Dewiyanti et al. 2022). According to the IUCN Red List of threatened species, this species is currently listed as Least Concern (LC), indicating that it is not under any immediate threat of population decline (IUCN 2023). Periophthalmodon schlosseri is widely distributed throughout the Indo-West Pacific region, including coastal and estuarine areas of Southeast Asia,
Northern Australia, and parts of South Asia (Ansari et al. 2014; Parenti and Jaafar 2017).

Giant mudskippers are distinguished by their unique morphologies, which facilitate movement in both aquatic and terrestrial environments. Their pectoral fins are specialized for navigating on land, a crucial adaptation for survival in the intertidal zone (Pace and Gibb 2009; Zhou et al. 2023). The anatomical structure of these fins is not only important for movement but also reflects the evolutionary transition from aquatic to terrestrial life (Ziadi-Künzli et al. 2024). For example, the robust fin morphology allows mudskippers to generate thrust on land, which is crucial for escaping predators and foraging for food (Pace and Gibb 2009). Furthermore, studies have indicated that pelvic fin morphology varies among mudskipper species, affecting their climbing behavior and overall movement (Hidayat et al. 2022).

The giant mudskipper serves as a valuable bioindicator species, with its population dynamics reflecting both habitat quality and environmental stressors. Studies in Songkhla Lake, Thailand, demonstrate its sensitivity to ecosystem degradation, showing highest densities in undisturbed mangrove-associated mudflats and complete absence in seawall-modified habitats without mangroves (Pattaratumrong and Pompha 2024). This pattern mirrors findings from the Sungsang estuary, where mudskipper presence correlates with heavy metal pollution levels, making them effective biomarkers for coastal contamination (Santoso et al. 2020, 2024). Their ecological significance extends to reproductive biology, as population structure and fecundity studies reveal seasonal spawning synchronized with the southwest monsoon (Simon et al. 2012; Ridho et al. 2021), linking life-history traits directly to environmental cycles. Together, these studies establish the giant mudskipper as an integrative indicator of ecosystem health, responding to habitat integrity, pollution pressures, and climatic influences across its range.

The biodiversity of fish species in the Sungsang estuary, including the giant mudskipper, is influenced by a variety of environmental factors. Numerous studies have documented the species diversity and community composition in this region, emphasizing the importance of mangrove ecosystems as critical habitats for mudskippers and other aquatic species (Fauziyah et al. 2019). However, the ongoing threat of human activities, such as deforestation and pollution, poses a significant threat to the ecosystem, thereby impacting mudskipper populations and their role. Consequently, conservation efforts are imperative to safeguard the habitat and ensure the longterm sustainability of mudskippers in South Sumatra (Septinar et al. 2023).

Several studies have been conducted on the foraging behavior of mudskippers in South Sumatra, encompassing research on their dietary habits (Ridho et al. 2019), gonad length and fecundity (Ridho et al. 2021), and range extension of P. septemradiatus (Iqbal et al. 2018). However, research on the length-weight relationship of P. schlosseri remains scarce, with most studies being based on field observations. Sungsang coast, located in the estuary of the Musi River, is a well-known site for mudskippers. Despite numerous studies on the biology and ecology of mudskippers in Southeast Asia, data on length-weight relationships and morphometric-environment interactions of P. schlosseri in the Sungsang estuary remain scarce. This study aims to fill this gap by analyzing the lengthweight relationships and morphometric-environment interactions of P. schlosseri in the Sungsang estuary.

### MATERIALS AND METHODS

### Study area

The research was carried out at five stations in the study area in the Sungsang estuaries of South Sumatra, Indonesia (Figure 1). The description of these sampling locations is shown in Table 1. The Musi River is a major river with multiple uses for its resources. It flows through three provinces on Indonesia's Sumatra Island: South Sumatra, Lampung, and Bengkulu. The coast of Sungang is situated within the Musi River estuary, where the river meets the sea (Melki et al. 2018a, b). Local fishermen depend on the rich aquatic life in the river and its estuary for their livelihoods. The Musi River estuary is home to a variety of fish species, including freshwater stingrays, catfish, and other fish, which are not only a source of food but also contribute to the local economy and food security (Putri and Melki 2020). The mangrove ecosystem within the Musi Estuary is in a state of optimal health, providing an ideal environment for the proliferation of mudskippers (Iqbal et al. 2018; Ridho et al. 2019; Ridho et al. 2021).

Table 1. Description of sampling locations in the Sungsang estuaries, South Sumatra, Indonesia

| Sampling sites   | Position       |               | Description  |  |
|------------------|----------------|---------------|--|--|
| and names        | Longitudes (E) | Latitudes (S) | - Description  |  |
| 1-Sungsang IV    | 104°53'22.65"  | 2°22'00.07"   | Fisherman's village, but the population is not as large as in sites 2, 3 and 4.  |  |
|                  |                |               | There is a healthy mangrove ecosystem, and this site is the mouth of the estuary |  |
| 2-Sungsang III   | 104°53'50.17"  | 2°21'56.30"   | A fisherman village area with a moderate population, known for its active        |  |
|                  |                |               | fishing community  |  |
| 3-Sungsang II    | 104°54'01.76"  | 2°21'54.56"   | Similar to Sungsang III, it's a fisherman village with a high population density |  |
|                  |                |               | and active fishing activities  |  |
| 4-Sungsang I     | 104°54'14.22"  | 2°21'47.61"   | A fisherman village with a relatively larger population, also known for its      |  |
|                  |                |               | significant fishing activities   |  |
| 5-Marga Sungsang | 104°54'21.17"  | 2°21'33.41"   | Fisherman's village, but the population is not as large as in sites 2, 3 and 4.  |  |
|                  |                |               | There is a good mangrove ecosystem, and this site is closer to the river         |  |

### MELKI et al. - Morphology and population dynamics of Periophthalmodon schlosseri



Figure 1. The study area of Periophthalmodon schlosseri in Sungsang coast, South Sumatra, Indonesia

### Sampling and preservation

A total of eleven individuals of *P. schlosseri* were collected at each site (n: 55 total) during a single sampling event in July 2024 to account for variation. Fish sampling was conducted using a  $1 \times 3$  m seine net with a 1 mm mesh size suitable for capturing small estuarine species. After collection, the samples were immediately placed in labeled plastic bottles containing 8-10% formalin solution for initial preservation, and in the laboratory, the samples were transferred to 75% ethanol for long-term storage and further morphometric and meristic analyses (Sotola et al. 2019; Jawad et al. 2020; Tran and Nguyen 2023). The samples were collected at the Bioecology Marine Laboratory, Universitas Sriwijaya (voucher code specimen: UNSRI, *P. schlosseri*, collected by Melki on 15 July 2024 at Sungsang Estuary, Indonesia).

### Morphometric measurements

A total of seventeen morphometric measurements were recorded (Figure 2), including total length (TL), standard length (SL), eye diameter (ED), head diameter (HD), head length (HL), length of the dorsal fin 1 (LD1), the gap between D1 and D2 (GD1D2), second dorsal fin length (LD2), and distance between anal and caudal fin (DAC), length of anal fin (LA), least height of the pectoral fin (LPc), length of pectoral fin (PcF), the distance between pectoral and pelvic fin (DPI), length of pelvic fin (LPF), the width of pelvic fin (WPF), and length of caudal fin (LCF), and width of caudal fin (WCF) (Gangan et al. 2016; Rahman et al. 2022). Each measurement was measured to the nearest 0.1 cm, and body weight was measured on a digital scale with 0.1 g accuracy.



Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Rahman et al. 2022; Sokefun et al. 2022)

An allometric method (Rahman et al. 2022) was used to remove size-dependent variation from morphometric data. To do so, all of them were standardized using the formula:  $M_{adj} = M(L_s/L_o)^b$ , where M is the original measurement,  $M_{adj}$  is the adjusted measurement,  $L_o$  is the fish's standard length,  $L_s$  is the mean standard length for all samples, and b is the slope of the regression of logM on logL<sub>o</sub> for all samples. The correlation between the transformed variables and the standard length of the samples was used to evaluate the results of the allometric method.

### **Environmental parameter measurements**

Environmental parameters were measured in situ at each sampling site where fish samples were collected to assess the physicochemical characteristics of the habitat.

3

Water temperature, pH and dissolved oxygen were measured using a portable multiparameter instrument (Hanna Instruments Inc., USA) to ensure accurate and simultaneous measurements. Salinity was measured using a hand refractometer (ATAGO Co. Ltd, Tokyo, Japan). All measurements were performed in triplicate to ensure the accuracy and reliability of the data.

#### Data analysis

The following equation was used to approximate the length-weight relationships using the formula  $W = a \times TLb$  (Tran et al. 2021; Vilchez et al. 2024), where W is the body weight (g), TL is the total length (cm), and a and b were estimated by the least-squares method based on logarithms using the formula Log (W) = log (a)+b log (TL) (Raeisi et al. 2011). Fish may exhibit isometric growth, characterized by equal growth in all three dimensions (b=3), or positive allometric growth, where width and height receive priority (b>3), or negative allometric growth, where length is prioritized (b<3) (Froese 2006). The effectiveness of linear regression can be quantified by the coefficient of determination (r2) (Tran et al. 2021).

The K of the fish was estimated using the equation  $K = (W) / (a \times TLb)$ , where W is the body weight (g), TL is the total length (cm), and a and b are the regression coefficients. A non-parametric Kruskal-Walli's test with a 5% threshold of significance was employed to determine whether there were any significant variations in mean Wrm between species because the assumptions of parametric statistics could not be met. For each statistical test, the significance level was set at p<0.05.

Principal Component Analysis (PCA) was performed using XLSTAT version 2021.4.1 (Addinsoft, New York, USA) integrated with Microsoft Excel. Prior to analysis, all morphometric and environmental data were standardized to eliminate unit bias and ensure comparability between variables. PCA was used to identify patterns and correlations between environmental parameters and morphometric traits of P. schlosseri across sampling sites. PCA reduces multidimensional data into principal components that explain the maximum variance in the data set. A biplot of the first two principal components was generated to visualize the distribution of active variables (environmental and morphometric parameters) and active observations (sampling sites). Variables with similar directions and vector lengths were interpreted as having a stronger influence or association within the same dimension.

### RESULTS DAN DISCUSSIONS

### **Environmental parameters**

The environmental parameters of samples in all experiments conducted in the Sungsang coast area exhibited minimal fluctuation (Table 2). The environmental parameters that exert a substantial influence on the survival of mudskippers include temperature, salinity, acidity (pH), and dissolved oxygen content (DO) (Ansari et al. 2014; Ridho et al. 2021; Dewiyanti et al. 2022).

The temperature of the water varied from  $29.8\pm0.1^{\circ}$ C to  $31.9\pm0.2^{\circ}$ C. According to previous studies, the optimal water temperature range for mudskippers is between  $23.5^{\circ}$ C and  $35.5^{\circ}$ C (Ridho et al. 2021; Dewiyanti et al. 2022; Arevalo et al. 2023). However, mudskippers demonstrated a preference for milder water temperatures, with a mean of  $26.7\pm2.1^{\circ}$ C (Nay et al. 2018). The pH levels of the water ranged from  $7.1\pm0.1$  to  $7.2\pm0.2$ , and the pH levels of the soil ranged from  $6.8\pm0.3$  to  $7.0\pm0.2$ . According to several studies, the mudskipper exhibits optimal growth and reproductive capacity in aquatic environments with pH values ranging from 6 to 8 (Ridho et al. 2021; Dewiyanti et al. 2022; Darojat et al. 2023).

The present study examined the dissolved oxygen (DO) levels in the aquatic environment, with a range of 6.3±0.3 to 7.9 $\pm$ 0.4 mg  $\hat{L}^{-1}$ . This finding is notable when compared to the results reported by Ridho et al. (2021), that the mudskipper could survive at DO levels ranging from 4.2 to 6.2 mg L<sup>-1</sup>. In accordance with the findings of Dewiyanti et al. (2022), the range of DO levels in this study was from 4.9 to 7 mg L-1, indicating that mudskippers possess a considerable degree of tolerance to variations in DO levels. The salinity levels in the study areas ranged from 15.0±0.0 to 20.0±0.0 ppt. In contrast, Darojat et al. (2023) reported that mudskippers can survive in mangrove ecosystems with a salinity range of 1.7 to 2.58 ppt. Ridho et al. (2021) also reported a salinity range of 0 to 0.1 ppt. However, Dewiyanti et al. (2022) identified a higher salinity range, spanning from 18 to 25 ppt, and a more pronounced range of 24.4 to 34.4 ppt (Taniwel et al. 2020). The significance of these salinity levels is underscored by the observation that mudskippers are euryhaline, indicating their capacity to withstand a broad spectrum of salinities (Looi et al. 2021). However, pronounced fluctuations in salinity can exert an influence on their physiological processes and selection of habitat (Looi et al. 2021).

**Commented [mm1]:** was replaced with Table 2

Table 2. The environmental parameters in the sampling sites

| Sampling site | Temperature (°C) | pH (water) | pH (soil) | DO (mg L <sup>-1</sup> ) | Salinity (ppt) |
|---------------|------------------|------------|-----------|--------------------------|----------------|
| 1             | 31.7±0.1         | 7.2±0.2    | 7.0±0.1   | 6.9±0.5                  | 20.0±0.0       |
| 2             | 31.7±0.2         | 7.1±0.1    | 6.8±0.3   | 6.3±0.3                  | 16.7±1.5       |
| 3             | 31.3±0.1         | 7.1±0.1    | 6.9±0.1   | 6.3±0.6                  | 16.0±0.0       |
| 4             | 31.9±0.2         | 7.1±0.1    | 7.0±0.2   | 7.8±0.5                  | 15.3±0.6       |
| 5             | 29.8±0.1         | 7.2±0.1    | 6.8±0.3   | 7.9±0.4                  | 15.0±0.0       |
|               |                  |            |           |                          |                |

Commented [mm2]: was replaced with Table 2

4

### MELKI et al. - Morphology and population dynamics of Periophthalmodon schlosseri

Temperature, salinity, and dissolved oxygen (DO) levels represent critical physical parameters that significantly influence the viability and growth potential of giant mudskippers. These fish exhibit a remarkable capacity for adaptability in response to fluctuating environmental conditions, as evidenced by their increased oxygen uptake rates in response to elevated temperatures (Pattaratumrong and Pompha 2024). Furthermore, they employ behavioral strategies to mitigate exposure to extreme conditions.

### Morphometric characteristic

Periophthalmodon schlosseri observed in this study had a mean total length (TL) of 20.08 cm, ranging from 15.00 cm to 22.60 cm, while the mean standard length (SL) was 17.34 cm, with a range of 13.00 cm to 20.00 cm (Figure 3 and Table 3). The body size recorded at the sampling sites in the Sungsang estuary is comparable to previous findings in the Musi River estuary, South Sumatra, Indonesia (Ridho et al. 2019, 2021). However, it is significantly larger than individuals reported from Cu Lao Dung Island, Soc Trang Province, Vietnam, which ranged from 12.10-18.65 cm (Tran et al. 2022), and slightly larger than those from Tanjung Piai, Pontian, Johor, Malaysia, which ranged from approximately 20 cm (Hui et al. 2019). This difference may be due to several ecological factors, including higher habitat productivity, greater availability of prey organisms, or potentially lower levels of anthropogenic disturbance in the Sungsang estuary. In support of this, Dinh et al. (2020) suggested that food abundance plays an important role in shaping the growth of mudskippers. Furthermore, Tran et al. (2021) reported that the diet composition of mudskippers varied with fish size, season, and habitat, suggesting that local environmental conditions may significantly influence growth performance in different populations.



Figure 3. Sample of mudskipper. A. Periophthalmodon schlosseri; B. Morphometric measurement

Giant mudskippers display a distinctive body shape that is adapted for both swimming and terrestrial locomotion. Their bodies are generally elongated and laterally compressed, a trait that facilitates movement in both water and on land (Pattaratumrong and Pompha 2024). The total length of these creatures can exhibit significant variation based on environmental factors and habitat conditions. For instance, studies have documented lengths of up to 25 cm in certain specimens attributed to variations in habitat type and food availability (Zhou et al. 2023). In addition to morphometric measurements, giant mudskippers exhibit specific meristic traits that can be used to differentiate them from other mudskipper species. For instance, the dorsal fin composition, including the number of spines and soft rays, exhibits variation among populations, suggesting adaptations to local environmental conditions (Nor et al. 2023).

5

### Length-weight relationship

The length-weight relationship of *P. schlosseri* was determined through the analysis of 55 specimens collected from five sampling sites along the Sungsang coast. The total length (TL) ranged from 15.00 to 22.60 cm, and the body weight varied from 28.3 to 119.2 g (Table 4).

The findings of the regression analysis and the lengthweight relationship graph (Figure 4) yielded the following equation: y: 0.0026x3.45. The b value of 3.45 indicates that the fish growth pattern is positive allometric (b>3), signifying that weight growth outpaces length increase. Positive allometric growth is indicated by a length-weight relationship (LWR) where the exponent (B) is greater than 3. Studies have demonstrated that P. schlosseri exhibits such a relationship, with documented values of b indicating positive allometry (Ridho et al. 2019; Abiaobo et al. 2021; Looi et al. 2021; Mussa et al. 2024). For instance, a study conducted in the Musi River Estuary found that the correlation coefficient for the length-weight relationship (LWR) of P. schlosseri was 98.2%, with an exponent value of 3.189, confirming its positive allometric growth (Ridho et al. 2019). This suggests that as the fish grows, it becomes relatively heavier compared to its length, which may be advantageous for buoyancy and mobility in its habitat. This positive allometric growth pattern of P. schlosseri is consistent with findings from related species within the same family. For example, P. barbarus also exhibited positive allometric growth in similar ecological contexts, reinforcing the notion that this growth strategy may be a common adaptive trait among mudskippers (Indarjo et al. 2020; Abiaobo et al. 2021). The implications of such growth patterns are critical, as they can influence the species' reproductive strategies, survival rates, and overall fitness in fluctuating environmental conditions typical of mangrove ecosystems (Dinh 2016).

In comparison with other species found in mangrove ecosystems, the allometric growth of *P. schlosseri* reflects typical trends in estuarine and intertidal species, where growth patterns are often influenced by environmental conditions such as temperature, food availability, and habitat structure (Chew et al. 2014; Looi et al. 2021). The positive allometry observed in the Sungsang population

Commented [mm3]: has been added the words "Figure 3 and" Commented [mm4]: was replaced with Table 3

Commented [mm5]: was replaced with Table 4

Commented [mm6]: was replaced with Figure 4

could be attributed to the productivity of the mangrove ecosystem, which provides abundant resources for these mudskippers. The Musi River estuary is home to a diverse array of mudskipper species, which exhibit various adaptations to their mangrove habitat. For instance, studies have documented the reproductive biology and feeding habits of mudskippers in this region, emphasizing their role in the local food web (Ridho et al. 2019; Ridho et al. 2021).

### **Condition factor**

The K value exhibited a maximum at sampling site 1 (K: 1.04) and a minimum at sampling site 5 (K: 0.94) (Figure 5). The variation in K values across the sampling sites was not statistically significant, suggesting that the fish samples were healthy and well-nourished at the time of the study. The K values in the Sungsang coastal area are comparable to those found in the Tran De District, Soc Trang Province, Mekong Delta, Vietnam mangrove habitat, which range from 1.01 to 1.03 (Dinh 2016), and the West Coast of Peninsular Malaysia, which range from 0.41 to 1.29 (Looi et al. 2021).



Figure 4, Relationship between total length and body weight of *Periophthalmodon schlosseri* in Sungsang coast, South Sumatra, Indonesia



**Commented [mm10]:** was replaced with Figure 4

 Table
 3.
 Morphometric
 measurement
 results
 of

 Periophthalmodon schlosseri
 on Sungsang coast, South Sumatra,
 Indonesia

| Morphometric<br>measurements | Ranged (cm) | Mean±sd (cm) |  |
|------------------------------|-------------|--------------|--|
| TL                           | 15.00-22.60 | 20.08±2.0    |  |
| SL                           | 13.00-20.00 | 17.34±1.7    |  |
| ED                           | 0.40-1.70   | 0.83±0.4     |  |
| HD                           | 2.40-4.80   | 3.44±0.6     |  |
| HL                           | 3.40-6.40   | 4.81±0.8     |  |
| LD1                          | 1.50-3.00   | 2.67±0.4     |  |
| GD1D2                        | 0.90-2.60   | 1.47±0.4     |  |
| LD <sub>2</sub>              | 3.00-4.20   | 3.73±0.4     |  |
| DAC                          | 2.00-3.90   | 3.06±0.5     |  |
| LA                           | 2.60-4.30   | 3.49±0.4     |  |
| LPc right                    | 1.30-2.80   | 1.89±0.4     |  |
| LPc left                     | 1.40-2.80   | 2.05±0.4     |  |
| PcF right                    | 1.10-2.50   | 1.66±0.3     |  |
| PcF left                     | 1.50-3.00   | 1.91±0.5     |  |
| DPI right                    | 0.20-1.70   | 0.78±0.4     |  |
| DPI left                     | 0.50-1.80   | 0.96±0.4     |  |
| LPF                          | 0.80-2.80   | 1.63±0.7     |  |
| WPF                          | 1.50-3.00   | 2.36±0.5     |  |
| LCF                          | 2.00-4.70   | 3.40±0.8     |  |
| WCF                          | 1.30-3.00   | 2.32±0.5     |  |
|                              |             |              |  |

 Table 4
 Range of total length (TL) and body weight (W) of

 Periophthalmodon schlosseri in Sungsang coast, South Sumatra,

 Indonesia

| Sampling Site | TL (cm)   | W (g)      |
|---------------|-----------|------------|
| 1             | 19.5-21.5 | 67.8-102.5 |
| 2             | 15.0-21.0 | 28.3-103.7 |
| 3             | 19.0-20.5 | 61.8-92.8  |
| 4             | 20.0-22.5 | 87.7-108.3 |
| 5             | 19.5-22.6 | 82.1-119.2 |
| Average       | 20.1      | 85.4       |



Figure 5. Condition factor of *Periophthalmodon schlosseri* in Sungsang coast, South Sumatra, Indonesia

Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the length-weight relationship. The condition factor values indicated a range of nutritional status among the mudskippers, with most individuals displaying average to good health (Froese 2006). However, some specimens with lower condition factors were found to be lean, suggesting potential seasonal fluctuations in food availability that might influence the body mass-to-length ratio (Abdullah and Zain 2019; Tran et al. 2021; Nguyễn et al. 2022). Condition factors, which are used as an indicator of fish health, have been shown to vary with environmental conditions. This indicates that abiotic factors, such as temperature and salinity, as well as biotic factors, such as prey availability, significantly affect the growth patterns of these fishes (Dewiyanti et al. 2022; Dinh et al. 2022).

Commented [mm8]: was replaced with Table 3

**Commented [mm11]:** was replaced with Figure 5

Commented [mm9]: was replaced with Table 4

### Principal component analysis (PCA)

Principal component analysis was employed to ascertain the correlation between seventeen *P. schlosseri* morphometric characteristics and environmental factors, including water pH and soil pH, dissolved oxygen (DO), temperature, and salinity. The analysis yielded significant findings concentrated on two primary axes: F1 by 55.47% and F2 by 24.70%, with 80.17% representing the maximum amount of information (Figure 6).

The environmental parameter on the positive F1 axis is characterized by DO, which for sampling site 5 is high at 7.9 mg L<sup>-1</sup>. According to Kumar et al. (2021) and Mulyasari (2023), a very strong correlation relationship can mean that as the value of the comparison character increases, the length of a morphometric character in fish will also increase. Consequently, elevated levels of dissolved oxygen at the Sungsang coast could potentially influence the growth of morphometric characteristics in P. schlosseri. A study by Khater et al. (2021) and Heriyati et al. (2022) indicated that low DO levels can lead to a reduction in fish appetite and growth. The findings indicate that salinity exerts minimal influence on the morphometric growth of P. schlosseri. The classification of mudskippers as euryhaline organisms is attributed to their capacity to respond to variations in salt concentration (Taniwel et al. 2020; Kim et al. 2021; Hamidah et al. 2024).

The positive F2 axis is characterized by sampling site 1, which is associated with the environmental parameter component of soil pH and the morphometric characteristics of WPF, defined as the width of the pelvic fins utilized during locomotion by mudskippers. This parameter is believed to be closely related to their biological functions (Hidayat et al. 2022; Quigley et al. 2022). The pH value of the soil at sampling site 1 is 7, indicating a high value within the threshold of the giant mudskipper life. The measurement of soil pH is crucial as the mudskipper habitat is located in the sediment. A low pH value in the mudskipper habitat prompts the fish to allocate their energy toward environmental adjustments rather than growth and foraging (Smith and Nobriga 2023).



Figure 6, PCA was examined to determine morphometric characteristics related to environmental factors of *Periophthalmodon schlosseri* on Sungsang coast, South Sumatra, Indonesia

This study analyzed the giant mudskipper on Sungsang coast, revealing positive allometric growth (b>3) and healthy condition factors. Dissolved oxygen and pH exhibited a strong influence on morphometric characteristics, while temperature and salinity supported optimal habitats. The findings emphasize the critical role of mangroves in sustaining giant mudskipper populations and offer insights into mangrove ecosystem management. This study highlights that dissolved oxygen and pH are the most influential environmental variables affecting the morphometric variation of *P. schlosseri*, suggesting their potential as key indicators in mangrove ecosystem monitoring.

### ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to abah badrun for his assistance in collecting mudskippers, which was very important for this research. We would also like to thank Gusti Ayu for her patience and help in setting up the research site.

### REFERENCES

- Abdullah MIC, Zain KM. 2019. Length-weight relationships, condition factor and growth parameters of *Periophthalmus chrysospilos* (Bleeker, 1852) (Gobiiformes: Gobiidae), in Bayan Bay, Penang, Malaysia. Sains Malays 48 (2): 271-279. DOI: 10.17576/jsm-2019-4802-02.
- Abiaobo N, Asuquo IE, Ejiogu IN, James EJ. 2021. Aspects of the biology of *Periophthalmus barbarus* (mudskipper), from Jaja Creek, Niger Delta, Nigeria. Ecol Evol Biol 6 (1): 15. DOI: 10.11648/j.eeb.20210601.14.
- Ansari AA, Trivedi S, Saggu S, Rehman H. 2014. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. J Entomol Zool Stud 2 (6): 22-33. Arevalo E, Cabral HN, Villeneuve B, Possémé C, Lepage M. 2023. Fish
- Arevalo E, Cabral HN, Villeneuve B, Possémé C, Lepage M. 2023. Fish larvae dynamics in temperate estuaries: A review on processes, patterns and factors that determine recruitment. Fish Fish 24 (3): 466-487. DOI: 10.1111/faf.12740.
- Arulnayagam A, Khim JS, Park J. 2021. Floral and faunal diversity in Sri Lankan mangrove forests: A systematic review. Sustainability 13 (17): 9487. DOI: 10.3390/su13179487.
- Chew SF, Hiong KC, Lam SP, Ong SW, Wee WL, Wong WP, Ip YK. 2014. Functional roles of Na+/K+-ATPase in active ammonia excretion and seawater acclimation in the giant mudskipper, *Periophthalmodon schlosseri*. Front Physiol 5: 158. DOI: 10.3389/fphys.2014.00158.
- Corush JB, Zhang J. 2022. One size does not fit all: Variation in anatomical traits associated with emersion behavior in mudskippers (Gobiidae: Oxudercinae). Front Ecol Evol 10: 0108. DOI: 10.3389/fevo.2022.967067.
- Darojat AZ, Marhendra APW, Kurniawan N. 2023. Identification of mudskipper species in mangrove area of Luwu Timur, Luwu Utara, and Wajo South Sulawesi Indonesia. Biotropika 11 (2): 74-83. DOI: 10.21776/ub.biotropika.2023.011.02.02.Dewiyanti I, Melanie K, Almuniro S, Damora A, Nufadillah N, Batubara
- Dewiyanti I, Melanie K, Almuniro S, Damora A, Nufadillah N, Batubara AS. 2022. Growth patterns and condition factor of the mudskipper (*Periophthalmus gracilis*) in mangrove ecosystem rehabilitation areas in Banda Aceh and Aceh Besar, Indonesia. Fish Aquat Life 30 (2): 85-94. DOI: 10.2478/aopf-2022-0008.
- Dinh QM. 2016. Growth and body condition variation of the giant mudskipper *Periophthalmodon schlosseri* in dry and wet seasons. Tap Chi Sinh Hoc 38 (3): 7425. DOI: 10.15625/0866-7160/v38n3.7425.
- Dinh QM, Tran LT, Tran TTM, To DK, Nguyen TTK, Tran DD. 2020. Variation in diet composition of the mudskipper, *Periophthalmodon*

Commented [mm13]: was replaced with Figure 6

**Commented [mm12]:** was replaced with Figure 6

7

septemradiatus, from Hau River, Vietnam. Bull Mar Sci 96 (3): 487-500. DOI: 10.5343/bms.2018.0067. Dinh QM, Nguyen THD, Truong NT, Doan DX, Nguyen TTK. 2022.

- Monthly variations in growth pattern and condition factor of Periophthalmodon septemradiatus (Gobiiformes: Periophthalminae) living along the Bassac River in Viet Nam. PeerJ 10: e13880. DOI: 10.7717/peerj.13880. Fauziyah F, Nurhayati N, Bernas SM, Putera A, Suteja Y, Agustiani F.
- 2019. Biodiversity of fish resources in Sungsang estuaries of South Sumatra; IOP Conference Series: Earth and Environmental Science 278 (1): 012025. DOI: 10.1088/1755-1315/278/1/012025.
- ese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis, and recommendations. J Appl Ichthyol 22 (4): 241-253. DOI: 10.1111/j.1439-0426.2006.00805.x. Gangan SS, Kumar R, Ramteke KK, Kumar AP, Jaiswar AK. 2016. Study
- of morphological variation discernible by multivariate analysis between the species of genus Setipinna (Teleostei: Clupeiformes).
   Ecol Environ Conserv 22: S11-S16.
   Hamidah A, Murni P, Said M. 2024. The diversity of mudskipper fish family Gobildae in mangrove area, Seberang District, Tanjung Jabung
- Regency, West Jambi. J Surv Fish Sci 11 (1): 2045. DOI: 10.53555/sfs.v11i01.2045. Hasan V, South J, Katz A, Ottoni FP. 2022. First record of the Small-eyed
- Ider Prionobulis microps (Weber, 1907) (Teleostei: Eleotridae: Butinae) in Java, Indonesia. Cybium 46 (1): 49-51. DOI: 10.26028/CYBIUM/2022-461-008.
- Heriyati E, Rustadi R, Isnansetyo A, Triyatmo B, Istiqomah I, Deendarlianto D, Budhijanto W. 2022. Microbubble aeration in a Recirculating Aquaculture System (RAS) increased dissolved oxygen, fish culture performance, and stress resistance of Red Tilapia (*Oreochromis* sp.). Trends Sci 19 (20): 6251. DOI: (Oreochromis sp.). 10.48048/tis.2022.6251.
- Hidayat S, Wicaksono A, Raharjeng ARP, Jin DSM, Alam P, Retnoaji B. 2022. The morphologies of mudskipper pelvic fins in relation to terrestrial and climbing behaviour. Proceedings of the Zoological Society. The University of Edinburgh, Edinburgh, 8 February 2022.
- Hui NY, Mohamed M, Othman MNA, Tokiman L. 2019. Diversity and behaviour of mudskippers of Tanjung Piai, Pontian, Johor. IOP Conf Ser Earth Environ Sci 269 (1): 012037. DOI: 10.1088/1755-1315/269/1/012037.
- Indario A. Salim G. Zein M. Susivanti S. Soeiarwo PA. Nugraeni CD. Bija S, Pham YTH. 2020. Characteristics of Von Bertalanfy growth, allometric, condition index and mortality of *Periophthalmus barbarus* anometric, condition index and instanty of Prophramma barbarbar in mangrove and probiotics conservation area (KKMB), Tarakan, North Kalimantan. Ilmu Kelautan 25 (1): 31-38. DOI: 10.14710/ik.ijms.25.1.31-38.
- Iqbal M, Halim A, Adriani D, Pormansyah, Saputra RF. 2018. Range extension of *Periophthalmodon septemradiatus* (Gobiidae) in southern Sumatra, Indonesia. Cybium 42 (4): 376-378. DOI: 10.26028/cybium/2018-424-009.
- 10.20028(cynum/2018-424-009).
  IUCN. 2023. Periophtalmodom schlosseri. The IUCN Red List of Threatened Species 2023: e.T196314A153206425.
  www.iucnredlist.org/species/196314/153206425.
  Jawad LA, Koya A, Gnohossou P. 2020. Fixation, preservation and freezing effects on morphometrics of two fish species collected from treezing effects on morphometrics of two fish species collected from
- Lake Ganvie, Benin, West Africa. Thalass Sal 42: 75-82. DOI: 10.1285/i15910725v42p75
- Jordan P, Fröhle P. 2022. Bridging the gap between coastal engineering and nature conservation?: A review of coastal ecosystems as nature-based solutions for coastal protection. J Coast Conserv 26 (2): 4. DOI: 10.1007/s11852-021-00848-x.
- Khater ES, Bahnasawy AH, Elghobashy H, Shaban Y, El-Sheikh FM, El-Reheem SA, Aboegela M. 2021. Mathematical model for predicting oxygen concentration in Tilapia fish farms. Sci Rep 11: 24130. DOI: 10.1038/s41598-021-03604-1.
- Kim J, Lee C, Yoo D, Kim H. 2021. Genetic adaptations in mudskipper and tetrapod give insights into their convergent water-to-land transition. Animals 11 (2): 584. DOI: 10.3390/ani11020584.
- Kumar GR, Bano F, Serajuddin M. 2021. Effect of formalin preservation on studies on morphology and condition factor of the freshwater Shark Wallago attu (Bloch and Schneider, 1801) using truss network system. Indian J Fish 68: 3. DOI: 10.21077/ijf.2021.68.3.98695-16.
- Looi LJ, Aris AZ, Isa NM, Yusoff, FM, Haris H. 2021. Elemental composition and health risk assessment of giant mudskipper (*Periophthalmodon schlosseri*) from the intertial zone of the west

coast of Peninsular Malaysia. Front Mar Sci 7: 618284. DOI: 10.3389/fmars.2020.618284. Mai HV, Tran LX, Dinh QM, Tran DD, Murata M, Sagara H, Yamada A,

- Shirai K, Ishimatsu A. 2019. Land invasion by the mudskipper, Periophthalmodon septemradiatus, in fresh and saline waters of the Mekong River. Sci Rep 9: 14227. DOI: 10.1038/s41598-019-50799-
- Melki, Isnansetyo A, Widada J, Murwantoko M. 2018a. The significance of water quality parameters on the diversity of ammonia-oxidizing bacteria in the water surface of Musi River, Indonesia. AACL Bioflux 11 (6): 1908-1918.
- Melki, Isnansetyo A, Widada J, Murwantoko M. 2018b. Distribution of ammonium-oxidizing bacteria in sediment with relation to water quality at the Musi River, Indonesia. Hayati 25 (4): 198-205. DOI: 10.4308/hjb.25.4.198.
- Mulyasari N, Subaryono N, Utomo BSB, Taufik I, Kusmini II, Yosmania N. 2023. Morphometric and genetic characterization of dominant fish species in Progo River, Yogyakarta, Indonesia. Sci World J 38 (2): 111-120. DOI: 10.1155/2023/7197251.
- Mussa ZJ, Aziz BAAA, Saleh SM, Abbas AH, Al-Asadi MK, Jumah AAK. 2024. Mudskippers a good bioindicator for polluted soils in the mudflat region of Southern Iraq. Mesop J Mar Sci 38 (2): 111-119. DOI: 10.58629/mjms.v38i2.354.
- Nathaniel AM, Gbobo BMFO, Raimi MO. 2024. Food and feeding of Atlantic mudskipper Periophthalmus barbarus in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria. Qeios ID: QNW7VZ. DOI: 10.32388/QNW7VZ. Nay TJ, Gervais CR, Hoey AS, Johansen JL, Steffensen JF, Rummer JL.
- 2018. The emergence emergency: A mudskipper's response temperatures. J Therm Biol 78: 65-72. DO 10.1016/j.jtherbio.2018.09.005. DOI:
- Nguyễn NT, Ha LM, Nguyen ATN, Chu NH, Tran HD, Hưng NP, Ta TT. 2022. Variation in the allometry of morphometric characteristics, 2022. Valiatori in de anoncej of morponterire entratectistes, growth, and condition factors of wild *Bostrychus sinensis* (Butidae) in Northern Vietnam. Pak J Zool 55 (2): 1-10. DOI: 10.17582/journal.piz/20200917140936.
- Nor NM, Saifuzzaman S, Azmir IA, Hussin N. 2023. Morphological characteristics and reproductive organs assessment of blue-spotted mudskipper *Boleophthalmus boddarti* in Peninsular Malaysia Biotropia 30 (1): 21-36. DOI: 10.11598/btb.2023.30.1.1561.
- 10.1242/jeb.029041.
- enti LR, Jaafar Z. 2017. The natural distribution of mudskippers. In Pa Jaafar Z, Murdy EO (eds). Fishes Out of Water. CRC Press, Florida.
- Pattaratumrong MS, Pompha T. 2024. Habitat of the amphibious mudskipper *Periophtalmodon schlosseri* in Songkhla Lake, Thailand. Biodiversitas 25 (5): 1875-1881. DOI: 10.13057/biodiv/d250503.
- Putri WAE, Melki. 2020. Study of the water quality of the Musi River estuary, South Sumatra. J Mar Aquat Sci 6 (1): 36. DOI:
- Quigley ZMG, Blob RW, Kawano S. 2022. Kinematic comparisons between mudskipper fins and Salamander limbs during terrestrial locomotion. J Exp Zool A Ecol Integr Physiol 337 (6): 612-625. DOI: 10.1002/jez.2594.
- Raeisi H. Daliri M. Paighambari SY. Shabani MJ. Bibak M. Davoodi R Kacisi H, Dani M, Fargiandoni S F, Shabah MJ, Diodoni M, Davodni S, Shabah M, Davodni S, Shabah M, Davodni S, Shabah M, Davodni S, Shabah K, Sh
- selected mudskipper species (Family: Oxudercidae) and develop of key pictorial. Iran J Ichthyol 9 (4): 180-194. 10.22034/iji.v9i4.808. DOI
- Ridho MR, Patriono E, Rahmawati D, Pratama R, Avesena M. 2021. Short communication: Investigating gonad length and fecundity in mudskippers (Gobiidae) at the Musi River Estuary, South Sumatra 4413-4420. Indonesia Biodiversitas 22 (10): 10.13057/biodiv/d221034.
- Ridho MR, Patrione E, Solikha M. 2019. Food habits of three species of mudskippers in the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 20 (8): 2368-2374. DOI: 10.13057/biodiv/d200835.
- toso HB, Suhartono E, Yunita R, Biyatmoko D. 2020. Mudskipper fish as a bio-indicator for heavy metals pollution in a coastal wetland. Egypt J Aquat Biol Fish 24 (7): 1073-1095. DOI: 10.21608/ejabf.2020.144402.

### MELKI et al. - Morphology and population dynamics of Periophthalmodon schlosseri

- Santoso HB, Krisdianto K, Yunita R. 2024. Iron bioaccumulation and cool of the second s John Karakara, J. Degran Will Lands Wandg 11 (3): 3539-3530. DOI: 10.15243/jdmlm.2024.113.5539.Septinar H, Putri YP, Midia KR, Bianto B. 2023. Mangrove forest
- conservation efforts through nurseries in Sungsang IV village, Banyuasin Regency. Jurnal Ilmu Lingkungan 1 (2): 77-88. DOI: 10.31851/esjo.v1i2.11920. [Indonesian] Setyawan AD, Winarno K. 2006. The direct exploitation in the mangrove
- ecosystem in Central Java and the land use in its surrounding; Degradation and its restoration effort. Biodiversitas 7 (3): 282-291. DOI: 10.13057/biodiv/d070318.
- Simon KD, Bakar Y, Mazlan AG, Zaidi CC, Samat A, Arshad A, Temple SE, Brown-Peterson NJ. 2012. Aspects of the reproductive biology of two archer fishes Toxotes chatareus, (Hamilton 1822) and Toxotes Smith WE, Nobriga MK. 2023. A bioenergetics-based index of habitat suitability: Spatial dynamics of foraging constraints and food
- limitation for a rare estuarine fish. Trans Am Fish Soc 152 (5): 650-671. DOI: 10.1002/tafs.10427. Sokefun O, Gan HM, Tan MP. 2022. Morphometrical characterization of
- the Atlantic mudskipper species (*Periophthalmus barbarus*) (Linnaeus, 1766) (Perciformes; Gobiiae) from Abonema in Port Harcourt, Rivers State, Nigeria. Intl J Fish Aquac 10 (3): 72-76. DOI: 10.22271/fish.2022.v10.i3a.2719. Sotola VA, Craig CA, Pfaff PJ, Maikoetter JD, Martin NH, Bonner TH.
- 2019. Effect of preservation on fish morphology over time: Implications for morphological studies. Plos One 14 (3): e0213915.
- DOI: 10.1371/journal. pone.0213915.
  Steppan SJ, Meyer AA, Barrow LN, Alhajeri BH, Al-Zaidan ASY, Gignac PM, Erickson GM. 2022. Phylogenetics and the evolution of the statement of the terrestriality in mudskippers (Gobildae: Oxudercinae). Me Phylogenet Evol 169: 107416. DOI: 10.1016/j.ympev.2022.107416. Mol
- Su J, Friess DA, Gasparatos A. 2021. A meta-analysis of the ecological and economic outcomes of mangrove restoration. Nat Commun 12: 5050. DOI: 10.1038/s41467-021-25349-1.
- SUSU. DOI: 10.1038/s4140/-021-25349-1.
  Taniwel D, Leiwakabessy F, Rumahlatu D. 2020. Short communication:
  Density and length-weight relationship of mudskipper (*Periophthalmus* spp.) in the mangrove area of Kairatu Beach, Maluku, Indonesia. Biodiversitas 21 (11): 5465-5473. DOI:
  10.13057/biodiv/d211155.
- Tran HD, Nguyen HH, Ha LM. 2021. Length-weight relationship and condition factor of the mudskipper (*Periophthalmus modestus*) in the Red River Delta. Reg Stud Mar Sci 46: 101903. DOI: 10.1016/j.rsma.2021.101903.

- Tran LX, Maekawa Y, Soyano K, Ishimatsu A. 2020. Morphology of the Feeding apparatus in the herbivorous mudskipper, *Boleophthalmus* pectinirostris (Linnaeus, 1758). Zoomorphology 139 (2): 231-243. DOI: 10.1007/s00435-020-00476-3.
- Tran LX, Nguyen TTK, Vo TT. 2022. Morphological comparison of the cranial movement apparatus in mudskippers (Gobiidae: Oxudercinae)
- Zoology 154: 126042. DOI: 10.1016/j.zool.2022.126042. Tran LX, Nguyen TTK. 2023. Morfology of the buccal and opercular
- Han LX, Feguyen TRC 2023, Montology of the buccar and operchan sealing apparatus in mudskippers (Gobidae: Oxudercinae). J Ichthyol 63 (4): 605-615. DOI: 10.1134/S0032945223040197.
  Valen FS, Hasan V, Ottoni FP, Nafisyah AL, Erwinda M, Annisa AN, Adis MA. 2022. First country record of the bearded gudgeon *Pogoneleotris heterolepis* (Giinther, 1869) (Teleostei: Eleotridae) from Indonesia. IOP Conf Ser Earth Environ Sci 1036: 012074. DOI: 10.1098/1055.1212(0361)(0362) 10.1088/1755-1315/1036/1/012074. Vilchez M, Dattilo J, Brewer SK. 2024. Length-weight relationships of
- native and non-native fishes in the lower Red River Cathment, USA. J Appl Ichthyol 2024: 5578825. DOI: 10.1155/2024/5578825.
- Waleed TA, Abdel-Maksoud YK, Kanwar RS, Sewilam H. 2024. Mangroves in Egypt and the Middle East: Current status, threats, and opportunities. Intl J Environ Sci Technol 22: 1225-1262. DOI: 10.1007/s13762-024-05788-1. Wirabuana PYAP, Baskorowati L, Pamungkas B, Mulyana B, South J,
- Jurnobasuki H, Andriyono S, Hasan V. 2025. Margroves, fauna compositions and carbon sequestration after ten years restoration on Flores Island, Indonesia. Sci Rep 15: 4866. DOI: 10.1038/s41598-Determined. 025-87307-x. You X, Sun M, Li J, Bian C, Chen J, Yi Y, Yu H, Shi Q. 2018.
- Mudshipers and their genetic adaptations to an amphibious lifestyle. Animals 8 (2): 24. DOI: 10.3390/ani8020024.
  Zhang Z, Fu Y, Zhao H, Zhang X. 2022. Social enrichment affects fish
- growth and aggression depending on fish species: Applications for aquaculture. Front Mar Sci 9: 1011780. DOI: 10.3389/fmars.2022.1011780.
- Zhou H, Donatelli CM, Laneuville O, Standen EM. 2023. Skeletal anatomy of the pectoral fin in mudskipper species from terrestrial and aquatic habitats. J Morphol 284 (8): e21612. DOI: aquatic habitats. J 10.1002/jmor.21612. Morphol
- Ziadi-Künzli F, Maeda K, Puchenkov P, Bandi M. 2024. Anatomical (Periophthalmus argentilineatus) fins based on µct 3d 3d reconstructions. J Anat 245 (4): 593-624. DOI: 10.1111/joa.14071.
- Zulkifli SZ, Mohamat-Yusuff F, Ismail A, Miyazaki N. 2012. Food preference of the giant mudskipper *Periophthalmodon schlosseri* (Teleostei: Gobiidae). Knowl Manag Aquat Ecosyst 405: 7. DOI: 10.1051/kmae/2012013



## [biodiv] New notification from Biodiversitas Journal of Biological Diversity 1 pesan

DEWI NUR PRATIWI via SMUJO <support@smujo.com>

4 Mei 2025 pukul 16.06 Balas Ke: DEWI NUR PRATIWI <biodiv07@gmail.com>, Ahmad Dwi Setyawan <editors@smujo.id> Kepada: Melki Melki <melki@unsri.ac.id>

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "BILLING" regarding the submission "Analysis of Morphology and Population Dynamics of Giant Mudskipper at Sungsang, South Sumatra, Indonesia".

Link: https://smujo.id/biodiv/authorDashboard/submission/21288

Ahmad Dwi Setyawan

**Biodiversitas Journal of Biological Diversity** 

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.

## Biodiversitas & Nusantara Biosci.

### Society for Indonesian Biodiversity

Jl. Ir. Sutami 36 A Surakarta 57126 Tel./Fax. 0271-663375, email: unsjournals@gmail.com http://biodiversitas.mipa.uns.ac.id/ http://biosains.mipa.uns.ac.id/nusbioscience.htm

### **BILL TO**

### MELKI

Department of Marine Science, Universitas Sriwijaya Jl. Raya Palembang-Prabumulih Km. 32, Indralaya 30862, South Sumatra, Indonesia Tel./fax.: +62-711-580086 email: melki@unsri.ac.id

### Title:

Analysis of morphology and population dynamics of giant mudskipper Periophthalmodon schlosseri (Gobiiformes: Oxudercidae) at Sungsang estuaries, South Sumatra, Indonesia

| DESCRIPTION   | TAXED     | AMOUNT (IDR) |
|---|-----------|--------------|
| Payment for manuscript publication  |           | 6.000.000,00 |
| Payment for English improvement   |           | -            |
| Cost reduction for manuscript presented in the SIB Meeting                  |           | -            |
|   |           |              |
|   |           |              |
|   |           |              |
|   |           |              |
|   |           |              |
|   |           |              |
|   |           |              |
|   |           |              |
|   |           |              |
|   | Subtotal  | 6.000.000,00 |
|   | Taxable   | -            |
| OTHER COMMENTS  | Tax rate  | 0,000%       |
| 1. Currency exchange: USD 1 = IDR 16,000                                    | Tax due   | -            |
| 2. Total bill: IDR 6,000,000,-  | Other     | -            |
| 3. Transfer to  | TOTAL IDR | 6.000.000,00 |
| Acc. No: 9191919987   |           |              |
| Bank name : Bank Syariah Indonesia (BSI), Karanganyar Palur 1 Branch Office |           |              |
| Beneficiary name : CV SMUJO INTERNATIONAL                                   |           |              |
| Swift code : BSMDIDJA   |           |              |
| 4. Send the proof of payment via OJS  |           |              |
| and a carbon copy (CC) to unsjournals@gmail.com                             |           |              |
|   |           |              |



04/05/2025

263

263 11/05/2025

DATE

CUSTOMER ID DUE DATE

Tgl/Bln/Th WAKTU 08:54:23 KCP - KCP INDRALAYA FT25126ZY5RM BANK SYAR AHORAN TUNAI INDO M VESI 919491990 NAMA REK: CV SMUJO INTERNATIONAL SETORAN: Rp. 6,000,000.00 TERBILANC: Enam Juta Rupiah BERITA : PEMBAYARAN JURNAL AN MELKI Teller Penohon (Applicant) Nama : FARIDATUNKCE Telp : 0852 63005 400

# O 6 MAY 2025

Dengan ditandatanganinya bukti transiksi ini maka pemohon setuju atas data transaksi yang tertera di atas dan oleh karenanya membebaskan Syariah Indonesia serta pegawainya atas tuntutan berupa apapun dari pihak manapun sehubungan dengan transaksi ini.

By signing on this receipt, applicant agrees of the transaction data stated and due to that releases Bank Syariah Indonesia and its employees form any claims by any parties.

Lembar 1:untuk Teller Lemba

Lembar 2:untuk Nasabah



## [biodiv] Editor Decision

2 pesan

Gilang D. Nugroho via SMUJO <support@smujo.com>

26 Mei 2025 pukul 07.14

Melki melki <melki@unsri.ac.id>

Balas Ke: "Gilang D. Nugroho" <sectioneditor7@smujo.id>

Kepada: MELKI <melki@unsri.ac.id>, FADHILAH DZAKIYYAH ANANTA <FD\_ananta@gmail.com>, ISNAINI <lsnaini@mipa.unsri.ac.id>, FITRI AGUSTRIANI <fitri\_agustriani@yahoo.com>, REZI APRI <rezi\_apri@unsri.ac.id>, HARTONI <hartoni@mipa.unsri.ac.id>, ELLIS NURJUALISTI NINGSIH <ellis.nurjualisti@gmail.com>, JENI MEIYERANI <jenimeiyerani24@gmail.com>

MELKI, FADHILAH DZAKIYYAH ANANTA, ISNAINI, FITRI AGUSTRIANI, REZI APRI, HARTONI, ELLIS NURJUALISTI NINGSIH, JENI MEIYERANI:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Analysis of morphology and population dynamics of giant mudskipper *Periophthalmodon schlosseri* (Gobiiformes: Oxudercidae) at Sungsang Estuaries, South Sumatra, Indonesia".

Our decision is to: Accept Submission

Letter of Acceptance: https://smujo.id/loa/21288

Biodiversitas Journal of Biological Diversity

Caution: This e-mail (including attachments, if any) is sent by system and only intended for the recipients listed above. If you are not the intended recipient, then you are not permitted to use, distribute, distribute, or duplicate this e-mail and all its attachments. Please cooperate to immediately notify Smujo International and delete this e-mail and all attachments. This email was sent due to, your email is listed as participant on Biodiversitas Journal of Biological Diversity.

Gilang D. Nugroho via SMUJO <support@smujo.com>

26 Mei 2025 pukul 07.17

Balas Ke: "Gilang D. Nugroho" <sectioneditor7@smujo.id>

Kepada: MELKI <melki@unsri.ac.id>, FADHILAH DZAKIYYAH ANANTA <FD\_ananta@gmail.com>, ISNAINI <Isnaini@mipa.unsri.ac.id>, FITRI AGUSTRIANI <fitri\_agustriani@yahoo.com>, REZI APRI <rezi\_apri@unsri.ac.id>, HARTONI <hartoni@mipa.unsri.ac.id>, ELLIS NURJUALISTI NINGSIH <ellis.nurjualisti@gmail.com>, JENI MEIYERANI <jenimeiyerani24@gmail.com>

### MELKI, FADHILAH DZAKIYYAH ANANTA, ISNAINI, FITRI AGUSTRIANI, REZI APRI, HARTONI, ELLIS NURJUALISTI NINGSIH, JENI MEIYERANI:

The editing of your submission, "Analysis of morphology and population dynamics of giant mudskipper *Periophthalmodon schlosseri* (Gobiiformes: Oxudercidae) at Sungsang Estuaries, South Sumatra, Indonesia," is complete. We are now sending it to production.

[Kutipan teks disembunyikan]

## Analysis of morphology and population dynamics of giant mudskipper *Periophthalmodon schlosseri* (Gobiiformes: Oxudercidae) at Sungsang Estuaries, South Sumatra, Indonesia

### MELKI", FADHILAH DZAKIYYAH ANANTA, ISNAINI, FITRI AGUSTRIANI, REZI APRI, HARTONI, ELLIS NURJUALISTI NINGSIH, JENI MEIYERANI

Department of Marine Science, Universitas Sriwijaya. Jl. Raya Palembang-Prabumulih Km. 32, Indralaya 30862, South Sumatra, Indonesia. Tel./fax.: +62-711-580086, \*email: melki@unsri.ac.id

Manuscript received: 16 February 2025. Revision accepted: 6 May 2025.

Abstract. Melki, Ananta FD, Isnaini, Agustriani F, Apri R, Hartoni, Ningsih EN, Meiyerani J. 2025. Analysis of morphology and population dynamics of giant mudskipper Periophthalmodon schlosseri (Gobiiformes: Oxudercidae) at Sungsang Estuaries, South Sumatra, Indonesia. Biodiversitas 26: 2269-2277. The giant mudskipper Periophthalmodon schlosseri is one of the most abundant mudskipper species, playing a vital role in the biomass of mangrove ecosystems. Mudskipper fish are also found in the Sungsang Coast, an estuary of the Musi River that is fed by river water from three provinces in Indonesia: South Sumatra, Lampung, and Bengkulu. This study aimed to analyze the morphology and population dynamics of mudskippers along with their environmental parameters in Sungsang Coastal, South Sumatra. For this study, mudskipper specimens were collected from five sampling sites along the Sungsang Coast and analyzed for morphometric characteristics, length-weight relationships, and their correlations with key environmental parameters like temperature, pH, and dissolved oxygen. The analysis of fifty-five specimens revealed an average total length of 20.08 cm, a standard length of 17.34 cm, and an average weight of 85.4 g. The growth pattern exhibited positive allometry (b>3), suggesting that as these fish grow, their body weight increases faster than their length. Condition factor analysis indicated that the fish sampled were healthy and in good nutritional condition. The Principal Component Analysis (PCA) further highlighted a strong association between dissolved oxygen and pH levels with the morphometric characteristics of the mudskippers, explaining 55.47% of the variation on the F1 axis and 24.70% on the F2 axis. This robust correlation between environmental factors and morphometric characteristics underscores the reliability of our findings. These findings provide crucial insights into the ecological health of the Giant Mudskipper and its dependence on specific environmental factors in the mangrove habitat are of utmost importance.

Keywords: Environmental parameter, length-weight relationship, morphometric, mudskipper, Sungsang Coast

### **INTRODUCTION**

The mangrove ecosystem is an important area due to its role in providing a habitat for a wide variety of aquatic and terrestrial biota, as evidenced by the discovery of rare and previously unrecorded fish species such as the bearded gudgeon Pogoneleotris heterolepis in the Kapuas River Estuary, Kalimantan, Indonesia (Valen et al. 2022) and the small-eyed gudgeon Prionobutis microps in the Solo River Estuary, Java, Indonesia (Hasan et al. 2022), highlighting the ecological importance of these transitional zones as critical habitats for endemic and specialized aquatic species. This ecosystem is important from a variety of angles, including its environmental functions, such as protecting estuaries and coastlines from storms, stabilizing the shore, and reducing coastal soil erosion and flooding, as shown by successful restoration in Central Java (Setyawan and Winarno 2006) and Flores Island, Indonesia (Wirabuana et al. 2025). Restored mangroves in Pasar Banggi, Central Java, prevented erosion. In Flores, 10-year-old mangroves improved sediment retention and wave absorption. Additionally, it serves as a nursery habitat and breeding ground for a wide range of biota, and it provides sources that include essential commodities for both subsistence and

commerce (Arulnayagam et al. 2021; Su et al. 2021; Jordan and Fröhle 2022; Waleed et al. 2024).

During periods of low tide, mangrove swamps and tidal flats formed in creeks, estuaries, and coastal waterways provide habitat for mudskippers (Mai et al. 2019; Ridho et al. 2019; Santoso et al. 2020; Darojat et al. 2023; Nathaniel Mudskippers exhibit physiological, et al 2024). morphological, and behavioral adaptations that allow them to thrive in both aquatic and terrestrial environments (You et al. 2018; Tran et al. 2020; Corush and Zhang 2022; Steppan et al. 2022). Various factors, including food availability, habitat selection, human disturbance, and others influence the geographical distribution of each species. A notable example is the giant mudskipper Periophthalmodon schlosseri, which contributes significantly to the biomass value of the mangrove ecosystem (Zulkifli et al. 2012; Dewiyanti et al. 2022). According to the IUCN Red List of threatened species, this species is currently listed as Least Concern (LC), indicating that it is not under any immediate threat of population decline (IUCN 2023). Periophthalmodon schlosseri is widely distributed throughout the Indo-West Pacific region, including coastal and estuarine areas of Southeast Asia, Northern Australia, and parts of South Asia (Ansari et al. 2014; Parenti and Jaafar 2017).

Giant mudskippers are distinguished by their unique morphologies, which facilitate movement in both aquatic and terrestrial environments. Their pectoral fins are specialized for navigating on land, a crucial adaptation for survival in the intertidal zone (Pace and Gibb 2009; Zhou et al. 2023). The anatomical structure of these fins is not only important for movement but also reflects the evolutionary transition from aquatic to terrestrial life (Ziadi-Künzli et al. 2024). For example, the robust fin morphology allows mudskippers to generate thrust on land, which is crucial for escaping predators and foraging for food (Pace and Gibb 2009). Furthermore, studies have indicated that pelvic fin morphology varies among mudskipper species, affecting their climbing behavior and overall movement (Hidayat et al. 2022).

The giant mudskipper serves as a valuable bioindicator species, with its population dynamics reflecting both habitat quality and environmental stressors. Studies in Songkhla Lake, Thailand, demonstrate its sensitivity to ecosystem degradation, showing highest densities in undisturbed mangrove-associated mudflats and complete absence in seawall-modified habitats without mangroves (Pattaratumrong and Pompha 2024). This pattern mirrors findings from the Sungsang Estuary, where mudskipper presence correlates with heavy metal pollution levels, them effective biomarkers making for coastal contamination (Santoso et al. 2020, et al. 2024). Their ecological significance extends to reproductive biology, as population structure and fecundity studies reveal seasonal spawning synchronized with the southwest monsoon (Simon et al. 2012; Ridho et al. 2021), linking life-history traits directly to environmental cycles. Together, these studies establish the giant mudskipper as an integrative indicator of ecosystem health, responding to habitat integrity, pollution pressures, and climatic influences across its range.

The biodiversity of fish species in the Sungsang Estuary, including the giant mudskipper, is influenced by a variety of environmental factors. Numerous studies have documented the species diversity and community composition in this region, emphasizing the importance of mangrove ecosystems as critical habitats for mudskippers and other aquatic species (Fauziyah et al. 2019). However, the ongoing threat of human activities, such as deforestation and pollution, poses a significant threat to the ecosystem, thereby impacting mudskipper populations and their role. Consequently, conservation efforts are imperative to safeguard the habitat and ensure the longterm sustainability of mudskippers in South Sumatra (Septinar et al. 2023).

Several studies have been conducted on the foraging behavior of mudskippers in South Sumatra, encompassing research on their dietary habits (Ridho et al. 2019), gonad length and fecundity (Ridho et al. 2021), and range extension of P. septemradiatus (Iqbal et al. 2018). However, research on the length-weight relationship of P. schlosseri remains scarce, with most studies being based on field observations. Sungsang Coast, located in the estuary of the Musi River, Indonesia, is a well-known site for mudskippers. Despite numerous studies on the biology and ecology of mudskippers in Southeast Asia, data on lengthweight relationships and morphometric-environment interactions of P. schlosseri in the Sungsang Estuary remain scarce. This study aims to fill this gap by analyzing the length-weight relationships and morphometricenvironment interactions of P. schlosseri in the Sungsang Estuary.

### MATERIALS AND METHODS

### Study area

The research was carried out at five stations in the study area in the Sungsang Estuaries of South Sumatra, Indonesia (Figure 1 and Table 1). The Musi River is a major river with multiple uses for its resources. It flows through three provinces on Indonesia's Sumatra Island: South Sumatra, Lampung, and Bengkulu. The coast of Sungang is situated within the Musi River Estuary, where the river meets the sea (Melki et al. 2018a, b). Local fishermen depend on the rich aquatic life in the river and its estuary for their livelihoods. The Musi River Estuary is home to a variety of fish species, including freshwater stingrays, catfish, and other fish, which are not only a source of food but also contribute to the local economy and food security (Putri and Melki 2020). The mangrove ecosystem within the Musi Estuary is in a state of optimal health, providing an ideal environment for the proliferation of mudskippers (Iqbal et al. 2018; Ridho et al. 2019, et al. 2021).

Table 1. Description of sampling locations in the Sungsang Estuaries, South Sumatra, Indonesia

| Sampling sites   | Position       |               | Description   |  |
|------------------|----------------|---------------|---|--|
| and names        | Longitudes (E) | Latitudes (S) | Description   |  |
| 1-Sungsang IV    | 104°53'22.65"  | 2°22'00.07"   | Fisherman's village, but the population is not as large as in sites 2, 3 and 4.                                 |  |
|                  |                |               | There is a healthy mangrove ecosystem, and this site is the mouth of the estuary.                               |  |
| 2-Sungsang III   | 104°53'50.17"  | 2°21'56.30"   | A fisherman village area with a moderate population, known for its active                                       |  |
|                  |                |               | fishing community.  |  |
| 3-Sungsang II    | 104°54'01.76"  | 2°21'54.56"   | Similar to Sungsang III, it's a fisherman village with a high population density and active fishing activities. |  |
| 4-Sungsang I     | 104°54'14.22"  | 2°21'47.61"   | A fisherman village with a relatively larger population, also known for its significant fishing activities.     |  |
| 5-Marga Sungsang | 104°54'21.17"  | 2°21'33.41"   | Fisherman's village, but the population is not as large as in sites 2, 3 and 4.                                 |  |
|                  |                |               | There is a good mangrove ecosystem, and this site is closer to the river  |  |



Figure 1. The study area of Periophthalmodon schlosseri in Sungsang Coast, South Sumatra, Indonesia

### Sampling and preservation

A total of eleven individuals of *P. schlosseri* were collected at each site (n: 55 total) during a single sampling event in July 2024 to account for variation. Fish sampling was conducted using a  $1\times3$  m seine net with a 1 mm mesh size suitable for capturing small estuarine species. After collection, the samples were immediately placed in labeled plastic bottles containing 8-10% formalin solution for initial preservation, and in the laboratory, the samples were transferred to 75% ethanol for long-term storage and further morphometric and meristic analyses (Sotola et al. 2019; Jawad et al. 2020; Tran and Nguyen 2023). The samples were collected at the Bioecology Marine Laboratory, Universitas Sriwijaya (UNSRI), South Sumatra (voucher code specimen: UNSRI, *P. schlosseri*, collected by Melki on 15 July 2024 at Sungsang Estuary, Indonesia).

### **Morphometric measurements**

A total of seventeen morphometric measurements were recorded (Figure 2), including total length (TL), standard length (SL), eye diameter (ED), head diameter (HD), head length (HL), length of the dorsal fin 1 (LD1), the gap between D1 and D2 (GD1D2), second dorsal fin length (LD2), and distance between anal and caudal fin (DAC), length of anal fin (LA), least height of the pectoral fin (LPc), length of pectoral fin (PcF), the distance between pectoral and pelvic fin (DPI), length of pelvic fin (LPF), the width of pelvic fin (WPF), and length of caudal fin (LCF), and width of caudal fin (WCF) (Gangan et al. 2016; Rahman et al. 2022). Each measurement was measured to the nearest 0.1 cm, and body weight was measured on a digital scale with 0.1 g accuracy.



Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Rahman et al. 2022; Sokefun et al. 2022)

An allometric method (Rahman et al. 2022) was used to remove size-dependent variation from morphometric data. To do so, all of them were standardized using the formula:  $M_{adj} = M(L_s/L_o)^b$ , where M is the original measurement,  $M_{adj}$  is the adjusted measurement,  $L_o$  is the fish's standard length,  $L_s$  is the mean standard length for all samples, and b is the slope of the regression of logM on logL<sub>o</sub> for all samples. The correlation between the transformed variables and the standard length of the samples was used to evaluate the results of the allometric method.

### **Environmental parameter measurements**

Environmental parameters were measured in situ at each sampling site where fish samples were collected to assess the physicochemical characteristics of the habitat. Water temperature, pH and dissolved oxygen were measured using a portable multiparameter instrument (Hanna Instruments Inc., USA) to ensure accurate and simultaneous measurements. Salinity was measured using a hand refractometer (ATAGO Co. Ltd, Tokyo, Japan). All measurements were performed in triplicate to ensure the accuracy and reliability of the data.

### Data analysis

The following equation was used to approximate the length-weight relationships using the formula  $W = a \times TLb$  (Tran et al. 2021; Vilchez et al. 2024), where W is the body weight (g), TL is the total length (cm), and a and b were estimated by the least-squares method based on logarithms using the formula Log (W) = log (a)+b log (TL) (Raeisi et al. 2011). Fish may exhibit isometric growth, characterized by equal growth in all three dimensions (b=3), or positive allometric growth, where width and height receive priority (b>3), or negative allometric growth, where length is prioritized (b<3) (Froese 2006). The effectiveness of linear regression can be quantified by the coefficient of determination (r2) (Tran et al. 2021).

The K of the fish was estimated using the equation  $K = (W) / (a \times TLb)$ , where W is the body weight (g), TL is the total length (cm), and a and b are the regression coefficients. A non-parametric Kruskal-Walli's test with a 5% threshold of significance was employed to determine whether there were any significant variations in mean Wrm between species because the assumptions of parametric statistics could not be met. For each statistical test, the significance level was set at p<0.05.

Principal Component Analysis (PCA) was performed using XLSTAT version 2021.4.1 (Addinsoft, New York, USA) integrated with Microsoft Excel. Prior to analysis, all morphometric and environmental data were standardized to eliminate unit bias and ensure comparability between variables. PCA was used to identify patterns and correlations between environmental parameters and morphometric traits of P. schlosseri across sampling sites. PCA reduces multidimensional data into principal components that explain the maximum variance in the data set. A biplot of the first two principal components was generated to visualize the distribution of active variables (environmental and morphometric parameters) and active observations (sampling sites). Variables with similar directions and vector lengths were interpreted as having a stronger influence or association within the same dimension.

### **RESULTS DAN DISCUSSION**

### **Environmental parameters**

The environmental parameters of samples in all experiments conducted in the Sungsang Coast area exhibited minimal fluctuation (Table 2). The environmental parameters that exert a substantial influence on the survival of mudskippers include temperature, salinity, acidity (pH), and Dissolved Oxygen (DO) content (Ansari et al. 2014; Ridho et al. 2021; Dewiyanti et al. 2022).

The temperature of the water varied from  $29.8\pm0.1^{\circ}$ C to  $31.9\pm0.2^{\circ}$ C. According to previous studies, the optimal water temperature range for mudskippers is between  $23.5^{\circ}$ C and  $35.5^{\circ}$ C (Ridho et al. 2021; Dewiyanti et al. 2022; Arevalo et al. 2023). However, mudskippers demonstrated a preference for milder water temperatures, with a mean of  $26.7\pm2.1^{\circ}$ C (Nay et al. 2018). The pH levels of the water ranged from  $7.1\pm0.1$  to  $7.2\pm0.2$ , and the pH levels of the soil ranged from  $6.8\pm0.3$  to  $7.0\pm0.2$ . According to several studies, the mudskipper exhibits optimal growth and reproductive capacity in aquatic environments with pH values ranging from 6 to 8 (Ridho et al. 2021; Dewiyanti et al. 2022; Darojat et al. 2023).

The present study examined the Dissolved Oxygen (DO) levels in the aquatic environment, with a range of  $6.3\pm0.3$  to  $7.9\pm0.4$  mg L<sup>-1</sup>. This finding is notable when compared to the results reported by Ridho et al. (2021), that the mudskipper could survive at DO levels ranging from 4.2 to 6.2 mg L<sup>-1</sup>. In accordance with the findings of Dewiyanti et al. (2022), the range of DO levels in this study was from 4.9 to 7 mg L<sup>-1</sup>, indicating that mudskippers possess a considerable degree of tolerance to variations in DO levels. The salinity levels in the study areas ranged from 15.0±0.0 to 20.0±0.0 ppt. In contrast, Darojat et al. (2023) reported that mudskippers can survive in mangrove ecosystems with a salinity range of 1.7 to 2.58 ppt. Ridho et al. (2021) also reported a salinity range of 0 to 0.1 ppt. However, Dewiyanti et al. (2022) identified a higher salinity range, spanning from 18 to 25 ppt, and a more pronounced range of 24.4 to 34.4 ppt (Taniwel et al. 2020). The significance of these salinity levels is underscored by the observation that mudskippers are euryhaline, indicating their capacity to withstand a broad spectrum of salinities (Looi et al. 2021). However, pronounced fluctuations in salinity can exert an influence on their physiological processes and selection of habitat (Looi et al. 2021).

Table 2. The environmental parameters in the sampling sites

| Sampling site | Temperature (°C) | pH (water)    | pH (soil)     | DO (mg L <sup>-1</sup> ) | Salinity (ppt) |
|---------------|------------------|---------------|---------------|--------------------------|----------------|
| 1             | 31.7±0.1         | 7.2±0.2       | $7.0{\pm}0.1$ | 6.9±0.5                  | 20.0±0.0       |
| 2             | 31.7±0.2         | $7.1 \pm 0.1$ | 6.8±0.3       | 6.3±0.3                  | 16.7±1.5       |
| 3             | 31.3±0.1         | $7.1{\pm}0.1$ | $6.9{\pm}0.1$ | 6.3±0.6                  | $16.0\pm0.0$   |
| 4             | $31.9{\pm}0.2$   | $7.1 \pm 0.1$ | $7.0{\pm}0.2$ | $7.8\pm0.5$              | 15.3±0.6       |
| 5             | 29.8±0.1         | $7.2{\pm}0.1$ | $6.8 \pm 0.3$ | 7.9±0.4                  | 15.0±0.0       |

Temperature, salinity, and Dissolved Oxygen (DO) levels represent critical physical parameters that significantly influence the viability and growth potential of giant mudskippers. These fish exhibit a remarkable capacity for adaptability in response to fluctuating environmental conditions, as evidenced by their increased oxygen uptake rates in response to elevated temperatures (Pattaratumrong and Pompha 2024). Furthermore, they employ behavioral strategies to mitigate exposure to extreme conditions.

### Morphometric characteristic

Periophthalmodon schlosseri observed in this study had a mean total length (TL) of 20.08 cm, ranging from 15.00 cm to 22.60 cm, while the mean standard length (SL) was 17.34 cm, with a range of 13.00 cm to 20.00 cm (Figure 3 and Table 3). The body size recorded at the sampling sites in the Sungsang Estuary is comparable to previous findings in the Musi River Estuary, South Sumatra, Indonesia (Ridho et al. 2019, et al. 2021). However, it is significantly larger than individuals reported from Cu Lao Dung Island, Soc Trang Province, Vietnam, which ranged from 12.10-18.65 cm (Tran et al. 2022), and slightly larger than those from Tanjung Piai, Pontian, Johor, Malaysia, which ranged from approximately 20 cm (Hui et al. 2019). This difference may be due to several ecological factors, including higher habitat productivity, greater availability of prey organisms, or potentially lower levels of anthropogenic disturbance in the Sungsang Estuary. In support of this, Dinh et al. (2020) suggested that food abundance plays an important role in shaping the growth of mudskippers. Furthermore, Tran et al. (2021) reported that the diet composition of mudskippers varied with fish size, season, and habitat, suggesting that local environmental conditions may significantly influence growth performance in different populations.



Figure 3. Sample of mudskipper. A. *Periophthalmodon* schlosseri; B. Morphometric measurement

Giant mudskippers display a distinctive body shape that is adapted for both swimming and terrestrial locomotion. Their bodies are generally elongated and laterally compressed, a trait that facilitates movement in both water and on land (Pattaratumrong and Pompha 2024). The total length of these creatures can exhibit significant variation based on environmental factors and habitat conditions. For instance, studies have documented lengths of up to 25 cm in certain specimens attributed to variations in habitat type and food availability (Zhou et al. 2023). In addition to morphometric measurements, giant mudskippers exhibit specific meristic traits that can be used to differentiate them from other mudskipper species. For instance, the dorsal fin composition, including the number of spines and soft rays, exhibits variation among populations, suggesting adaptations to local environmental conditions (Nor et al. 2023).

### Length-weight relationship

The length-weight relationship of *P. schlosseri* was determined through the analysis of 55 specimens collected from five sampling sites along the Sungsang Coast. The total length (TL) ranged from 15.00 to 22.60 cm, and the body weight varied from 28.3 to 119.2 g (Table 4).

The findings of the regression analysis and the lengthweight relationship graph (Figure 4) yielded the following equation: y: 0.0026x3.45. The b value of 3.45 indicates that the fish growth pattern is positive allometric (b>3), signifying that weight growth outpaces length increase. Positive allometric growth is indicated by a length-weight relationship (LWR) where the exponent (B) is greater than 3. Studies have demonstrated that P. schlosseri exhibits such a relationship, with documented values of b indicating positive allometry (Ridho et al. 2019; Abiaobo et al. 2021; Looi et al. 2021; Mussa et al. 2024). For instance, a study conducted in the Musi River Estuary found that the correlation coefficient for the length-weight relationship (LWR) of P. schlosseri was 98.2%, with an exponent value of 3.189, confirming its positive allometric growth (Ridho et al. 2019). This suggests that as the fish grows, it becomes relatively heavier compared to its length, which may be advantageous for buoyancy and mobility in its habitat. This positive allometric growth pattern of P. schlosseri is consistent with findings from related species within the same family. For example, P. barbarus also exhibited positive allometric growth in similar ecological contexts, reinforcing the notion that this growth strategy may be a common adaptive trait among mudskippers (Indarjo et al. 2020; Abiaobo et al. 2021). The implications of such growth patterns are critical, as they can influence the species' reproductive strategies, survival rates, and overall fitness in fluctuating environmental conditions typical of mangrove ecosystems (Dinh 2016).

In comparison with other species found in mangrove ecosystems, the allometric growth of *P. schlosseri* reflects typical trends in estuarine and intertidal species, where growth patterns are often influenced by environmental conditions such as temperature, food availability, and habitat structure (Chew et al. 2014; Looi et al. 2021). The positive allometry observed in the Sungsang population

could be attributed to the productivity of the mangrove ecosystem, which provides abundant resources for these mudskippers. The Musi River Estuary is home to a diverse array of mudskipper species, which exhibit various adaptations to their mangrove habitat. For instance, studies have documented the reproductive biology and feeding habits of mudskippers in this region, emphasizing their role in the local food web (Ridho et al. 2019, et al. 2021).

### **Condition factor**

The K value exhibited a maximum at sampling site 1 (K: 1.04) and a minimum at sampling site 5 (K: 0.94) (Figure 5). The variation in K values across the sampling sites was not statistically significant, suggesting that the fish samples were healthy and well-nourished at the time of the study. The K values in the Sungsang Coastal area are comparable to those found in the Tran De District, Soc Trang Province, Mekong Delta, Vietnam mangrove habitat, which range from 1.01 to 1.03 (Dinh 2016), and the West Coast of Peninsular Malaysia, which range from 0.41 to 1.29 (Looi et al. 2021).

Table3.MorphometricmeasurementresultsofPeriophthalmodon schlosserionSungsangCoast,SouthSumatra,Indonesia

| Morphometric    | Dangad (am) | Maan±sd (am)    |
|-----------------|-------------|-----------------|
| measurements    | Kangeu (cm) | wiean±su (cm)   |
| TL              | 15.00-22.60 | $20.08 \pm 2.0$ |
| SL              | 13.00-20.00 | $17.34{\pm}1.7$ |
| ED              | 0.40-1.70   | $0.83{\pm}0.4$  |
| HD              | 2.40-4.80   | $3.44{\pm}0.6$  |
| HL              | 3.40-6.40   | $4.81 \pm 0.8$  |
| LD <sub>1</sub> | 1.50-3.00   | $2.67 \pm 0.4$  |
| $GD_1D_2$       | 0.90-2.60   | $1.47{\pm}0.4$  |
| $LD_2$          | 3.00-4.20   | $3.73 \pm 0.4$  |
| DAC             | 2.00-3.90   | $3.06 \pm 0.5$  |
| LA              | 2.60-4.30   | $3.49{\pm}0.4$  |
| LPc right       | 1.30-2.80   | $1.89{\pm}0.4$  |
| LPc left        | 1.40-2.80   | $2.05 \pm 0.4$  |
| PcF right       | 1.10-2.50   | $1.66{\pm}0.3$  |
| PcF left        | 1.50-3.00   | $1.91{\pm}0.5$  |
| DPI right       | 0.20-1.70   | $0.78{\pm}0.4$  |
| DPI left        | 0.50-1.80   | $0.96{\pm}0.4$  |
| LPF             | 0.80-2.80   | $1.63 \pm 0.7$  |
| WPF             | 1.50-3.00   | $2.36{\pm}0.5$  |
| LCF             | 2.00-4.70   | $3.40{\pm}0.8$  |
| WCF             | 1.30-3.00   | $2.32{\pm}0.5$  |

 Table 4. Range of total length (TL) and body weight (W) of

 Periophthalmodon schlosseri in Sungsang Coast, South Sumatra,

 Indonesia

| Sampling site | TL (cm)   | W (g)      |
|---------------|-----------|------------|
| 1             | 19.5-21.5 | 67.8-102.5 |
| 2             | 15.0-21.0 | 28.3-103.7 |
| 3             | 19.0-20.5 | 61.8-92.8  |
| 4             | 20.0-22.5 | 87.7-108.3 |
| 5             | 19.5-22.6 | 82.1-119.2 |
| Average       | 20.1      | 85.4       |



Figure 4. Relationship between total length and body weight of *Periophthalmodon schlosseri* in Sungsang Coast, South Sumatra, Indonesia



Figure 5. Condition factor of *Periophthalmodon schlosseri* in Sungsang Coast, South Sumatra, Indonesia

Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the length-weight relationship. The condition factor values indicated a range of nutritional status among the mudskippers, with most individuals displaying average to good health (Froese 2006). However, some specimens with lower condition factors were found to be lean, suggesting potential seasonal fluctuations in food availability that might influence the body mass-to-length ratio (Abdullah and Zain 2019; Tran et al. 2021; Nguyễn et al. 2022). Condition factors, which are used as an indicator of fish health, have been shown to vary with environmental conditions. This indicates that abiotic factors, such as temperature and salinity, as well as biotic factors, such as prey availability, significantly affect the growth patterns of these fishes (Dewiyanti et al. 2022; Dinh et al. 2022).

### Principal Component Analysis (PCA)

Principal component analysis was employed to ascertain the correlation between seventeen *P. schlosseri* morphometric characteristics and environmental factors, including water pH and soil pH, Dissolved Oxygen (DO), temperature, and salinity. The analysis yielded significant findings concentrated on two primary axes: F1 by 55.47% and F2 by 24.70%, with 80.17% representing the maximum amount of information (Figure 6).

The environmental parameter on the positive F1 axis is characterized by DO, which for sampling site 5 is high at 7.9 mg L<sup>-1</sup>. According to Kumar et al. (2021) and Mulyasari et al. (2023), a very strong correlation relationship can mean that as the value of the comparison character increases, the length of a morphometric character in fish will also increase. Consequently, elevated levels of dissolved oxygen at the Sungsang Coast could potentially influence the growth of morphometric characteristics in P. schlosseri. A study by Khater et al. (2021) and Heriyati et al. (2022) indicated that low DO levels can lead to a reduction in fish appetite and growth. The findings indicate that salinity exerts minimal influence on the morphometric growth of P. schlosseri. The classification of mudskippers as euryhaline organisms is attributed to their capacity to respond to variations in salt concentration (Taniwel et al. 2020; Kim et al. 2021; Hamidah et al. 2024).

The positive F2 axis is characterized by sampling site 1, which is associated with the environmental parameter component of soil pH and the morphometric characteristics of WPF, defined as the width of the pelvic fins utilized during locomotion by mudskippers. This parameter is believed to be closely related to their biological functions (Hidayat et al. 2022; Quigley et al. 2022). The pH value of the soil at sampling site 1 is 7, indicating a high value within the threshold of the giant mudskipper life. The measurement of soil pH is crucial as the mudskipper habitat is located in the sediment. A low pH value in the mudskipper habitat prompts the fish to allocate their energy toward environmental adjustments rather than growth and foraging (Smith and Nobriga 2023).



Figure 6. PCA was examined to determine morphometric characteristics related to environmental factors of *Periophthalmodon schlosseri* on Sungsang Coast, South Sumatra, Indonesia

This study analyzed the giant mudskipper on Sungsang Coast, revealing positive allometric growth (b>3) and healthy condition factors. Dissolved oxygen and pH exhibited а strong influence on morphometric characteristics, while temperature and salinity supported optimal habitats. The findings emphasize the critical role of mangroves in sustaining giant mudskipper populations and offer insights into mangrove ecosystem management. This study highlights that dissolved oxygen and pH are the most influential environmental variables affecting the morphometric variation of P. schlosseri, suggesting their potential as key indicators in mangrove ecosystem monitoring.

### ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to Abah Badrun for his assistance in collecting mudskippers, which was very important for this research. We would also like to thank Gusti Ayu for her patience and help in setting up the research site.

### REFERENCES

- Abdullah MIC, Zain KM. 2019. Length-weight relationships, condition factor and growth parameters of *Periophthalmus chrysospilos* (Bleeker, 1852) (Gobiiformes: Gobiidae), in Bayan Bay, Penang, Malaysia. Sains Malays 48 (2): 271-279. DOI: 10.17576/jsm-2019-4802-02.
- Abiaobo N, Asuquo IE, Ejiogu IN, James EJ. 2021. Aspects of the biology of *Periophthalmus barbarus* (mudskipper), from Jaja Creek, Niger Delta, Nigeria. Ecol Evol Biol 6 (1): 15. DOI: 10.11648/j.eeb.20210601.14.
- Ansari AA, Trivedi S, Saggu S, Rehman H. 2014. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. J Entomol Zool Stud 2 (6): 22-33.
- Arevalo E, Cabral HN, Villeneuve B, Possémé C, Lepage M. 2023. Fish larvae dynamics in temperate estuaries: A review on processes, patterns and factors that determine recruitment. Fish Fish 24 (3): 466-487. DOI: 10.1111/faf.12740.
- Arulnayagam A, Khim JS, Park J. 2021. Floral and faunal diversity in Sri Lankan mangrove forests: A systematic review. Sustainability 13 (17): 9487. DOI: 10.3390/su13179487.
- Chew SF, Hiong KC, Lam SP, Ong SW, Wee WL, Wong WP, Ip YK. 2014. Functional roles of Na+/K+-ATPase in active ammonia excretion and seawater acclimation in the giant mudskipper, *Periophthalmodon schlosseri*. Front Physiol 5: 158. DOI: 10.3389/fphys.2014.00158.
- Corush JB, Zhang J. 2022. One size does not fit all: Variation in anatomical traits associated with emersion behavior in mudskippers (Gobiidae: Oxudercinae). Front Ecol Evol 10: 0108. DOI: 10.3389/fevo.2022.967067.
- Darojat AZ, Marhendra APW, Kurniawan N. 2023. Identification of mudskipper species in mangrove area of Luwu Timur, Luwu Utara, and Wajo South Sulawesi Indonesia. Biotropika 11 (2): 74-83. DOI: 10.21776/ub.biotropika.2023.011.02.02.
- Dewiyanti I, Melanie K, Almuniro S, Damora A, Nufadillah N, Batubara AS. 2022. Growth patterns and condition factor of the mudskipper (*Periophthalmus gracilis*) in mangrove ecosystem rehabilitation areas in Banda Aceh and Aceh Besar, Indonesia. Fish Aquat Life 30 (2): 85-94. DOI: 10.2478/aopf-2022-0008.
- Dinh QM, Nguyen THD, Truong NT, Doan DX, Nguyen TTK. 2022. Monthly variations in growth pattern and condition factor of *Periophthalmodon septemradiatus* (Gobiiformes: Periophthalminae) living along the Bassac River in Viet Nam. PeerJ 10: e13880. DOI: 10.7717/peerj.13880.

- Dinh QM, Tran LT, Tran TTM, To DK, Nguyen TTK, Tran DD. 2020. Variation in diet composition of the mudskipper, *Periophthalmodon septemradiatus*, from Hau River, Vietnam. Bull Mar Sci 96 (3): 487-500. DOI: 10.5343/bms.2018.0067.
- Dinh QM. 2016. Growth and body condition variation of the giant mudskipper *Periophthalmodon schlosseri* in dry and wet seasons. Tap Chi Sinh Hoc 38 (3): 7425. DOI: 10.15625/0866-7160/v38n3.7425.
- Fauziyah F, Nurhayati N, Bernas SM, Putera A, Suteja Y, Agustiani F. 2019. Biodiversity of fish resources in Sungsang Estuaries of South Sumatra; IOP Conference Series: Earth and Environmental Science 278 (1): 012025. DOI: 10.1088/1755-1315/278/1/012025.
- Froese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis, and recommendations. J Appl Ichthyol 22 (4): 241-253. DOI: 10.1111/j.1439-0426.2006.00805.x.
- Gangan SS, Kumar R, Ramteke KK, Kumar AP, Jaiswar AK. 2016. Study of morphological variation discernible by multivariate analysis between the species of genus *Setipinna* (Teleostei: Clupeiformes). Ecol Environ Conserv 22: S11-S16.
- Hamidah A, Murni P, Said M. 2024. The diversity of mudskipper fish family Gobiidae in mangrove area, Seberang District, Tanjung Jabung Regency, West Jambi. J Surv Fish Sci 11 (1): 2045. DOI: 10.53555/sfs.v11i01.2045.
- Hasan V, South J, Katz A, Ottoni FP. 2022. First record of the Small-eyed loter *Prionobutis microps* (Weber, 1907) (Teleostei: Eleotridae: Butinae) in Java, Indonesia. Cybium 46 (1): 49-51. DOI: 10.26028/CYBIUM/2022-461-008.
- Heriyati E, Rustadi R, Isnansetyo A, Triyatmo B, Istiqomah I, Deendarlianto D, Budhijanto W. 2022. Microbubble aeration in a Recirculating Aquaculture System (RAS) increased dissolved oxygen, fish culture performance, and stress resistance of Red Tilapia (*Oreochromis* sp.). Trends Sci 19 (20): 6251. DOI: 10.48048/tis.2022.6251.
- Hidayat S, Wicaksono A, Raharjeng ARP, Jin DSM, Alam P, Retnoaji B. 2022. The morphologies of mudskipper pelvic fins in relation to terrestrial and climbing behaviour. Proceedings of the Zoological Society. The University of Edinburgh, Edinburgh, 8 February 2022. DOI: 10.1007/s12595-021-00422-1.
- Hui NY, Mohamed M, Othman MNA, Tokiman L. 2019. Diversity and behaviour of mudskippers of Tanjung Piai, Pontian, Johor. IOP Conf Ser Earth Environ Sci 269 (1): 012037. DOI: 10.1088/1755-1315/269/1/012037.
- Indarjo A, Salim G, Zein M, Susiyanti S, Soejarwo PA, Nugraeni CD, Bija S, Pham YTH. 2020. Characteristics of Von Bertalanfy growth, allometric, condition index and mortality of *Periophthalmus barbarus* in mangrove and probiotics conservation area (KKMB), Tarakan, North Kalimantan. Ilmu Kelautan 25 (1): 31-38. DOI: 10.14710/ik.ijms.25.1.31-38.
- Iqbal M, Halim A, Adriani D, Pormansyah, Saputra RF. 2018. Range extension of *Periophthalmodon septemradiatus* (Gobiidae) in southern Sumatra, Indonesia. Cybium 42 (4): 376-378. DOI: 10.26028/cybium/2018-424-009.
- IUCN. 2023. Periophthalmodon schlosseri. The IUCN Red List of Threatened Species 2023: e.T196314A153206425. www.iucnredlist.org/species/196314/153206425.
- Jawad LA, Koya A, Gnohossou P. 2020. Fixation, preservation and freezing effects on morphometrics of two fish species collected from Lake Ganvie, Benin, West Africa. Thalass Sal 42: 75-82. DOI: 10.1285/i15910725v42p75.
- Jordan P, Fröhle P. 2022. Bridging the gap between coastal engineering and nature conservation? A review of coastal ecosystems as naturebased solutions for coastal protection. J Coast Conserv 26 (2): 4. DOI: 10.1007/s11852-021-00848-x.
- Khater ES, Bahnasawy AH, Elghobashy H, Shaban Y, El-Sheikh FM, El-Reheem SA, Aboegela M. 2021. Mathematical model for predicting oxygen concentration in Tilapia fish farms. Sci Rep 11: 24130. DOI: 10.1038/s41598-021-03604-1.
- Kim J, Lee C, Yoo D, Kim H. 2021. Genetic adaptations in mudskipper and tetrapod give insights into their convergent water-to-land transition. Animals 11 (2): 584. DOI: 10.3390/ani11020584.
- Kumar GR, Bano F, Serajuddin M. 2021. Effect of formalin preservation on studies on morphology and condition factor of the freshwater Shark *Wallago attu* (Bloch and Schneider, 1801) using truss network system. Indian J Fish 68: 3. DOI: 10.21077/ijf.2021.68.3.98695-16.
- Looi LJ, Aris AZ, Isa NM, Yusoff, FM, Haris H. 2021. Elemental composition and health risk assessment of giant mudskipper (*Periophthalmodon schlosseri*) from the intertidal zone of the west

coast of Peninsular Malaysia. Front Mar Sci 7: 618284. DOI: 10.3389/fmars.2020.618284.

- Mai HV, Tran LX, Dinh QM, Tran DD, Murata M, Sagara H, Yamada A, Shirai K, Ishimatsu A. 2019. Land invasion by the mudskipper, *Periophthalmodon septemradiatus*, in fresh and saline waters of the Mekong River. Sci Rep 9: 14227. DOI: 10.1038/s41598-019-50799-5.
- Melki, Isnansetyo A, Widada J, Murwantoko M. 2018a. The significance of water quality parameters on the diversity of ammonia-oxidizing bacteria in the water surface of Musi River, Indonesia. AACL Bioflux 11 (6): 1908-1918.
- Melki, İsnansetyo A, Widada J, Murwantoko M. 2018b. Distribution of ammonium-oxidizing bacteria in sediment with relation to water quality at the Musi River, Indonesia. Hayati 25 (4): 198-205. DOI: 10.4308/hjb.25.4.198.
- Mulyasari N, Subaryono N, Utomo BSB, Taufik I, Kusmini II, Yosmaniar N. 2023. Morphometric and genetic characterization of dominant fish species in Progo River, Yogyakarta, Indonesia. Sci World J 38 (2): 111-120. DOI: 10.1155/2023/7197251.
- Mussa ZJ, Aziz BAAA, Saleh SM, Abbas AH, Al-Asadi MK, Jumah AAK. 2024. Mudskippers a good bioindicator for polluted soils in the mudflat region of Southern Iraq. Mesop J Mar Sci 38 (2): 111-119. DOI: 10.58629/mjms.v38i2.354.
- Nathaniel AM, Gbobo BMFO, Raimi MO. 2024. Food and feeding of Atlantic mudskipper *Periophthalmus barbarus* in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria. Qeios ID: QNW7VZ. DOI: 10.32388/QNW7VZ.
- Nay TJ, Gervais CR, Hoey AS, Johansen JL, Steffensen JF, Rummer JL. 2018. The emergence emergency: A mudskipper's response to temperatures. J Therm Biol 78: 65-72. DOI: 10.1016/j.jtherbio.2018.09.005.
- Nguyễn NT, Ha LM, Nguyen ATN, Chu NH, Tran HD, Hưng NP, Ta TT. 2022. Variation in the allometry of morphometric characteristics, growth, and condition factors of wild *Bostrychus sinensis* (Butidae) in Northern Vietnam. Pak J Zool 55 (2): 1-10. DOI: 10.17582/journal.pjz/20200917140936.
- Nor NM, Saifuzzaman S, Azmir IA, Hussin N. 2023. Morphological characteristics and reproductive organs assessment of blue-spotted mudskipper *Boleophthalmus boddarti* in Peninsular Malaysia. Biotropia 30 (1): 21-36. DOI: 10.11598/btb.2023.30.1.1561.
- Pace CM, Gibb AC. 2009. Mudskipper pectoral fin kinematics in aquatic and terrestrial environments. J Exp Biol 212 (14): 2279-2286. DOI: 10.1242/jeb.029041.
- Parenti LR, Jaafar Z. 2017. The natural distribution of mudskippers. In: Jaafar Z, Murdy EO (eds). Fishes Out of Water. CRC Press, Florida. DOI: 10.1201/9781315119861.
- Pattaratumrong MS, Pompha T. 2024. Habitat of the amphibious mudskipper *Periophtalmodon schlosseri* in Songkhla Lake, Thailand. Biodiversitas 25 (5): 1875-1881. DOI: 10.13057/biodiv/d250503.
- Putri WAE, Melki. 2020. Study of the water quality of the Musi River Estuary, South Sumatra. J Mar Aquat Sci 6 (1): 36. DOI: 10.24843/jmas.2020.v06.i01.p05. [Indonesian]
- Quigley ZMG, Blob RW, Kawano S. 2022. Kinematic comparisons between mudskipper fins and Salamander limbs during terrestrial locomotion. J Exp Zool A Ecol Integr Physiol 337 (6): 612-625. DOI: 10.1002/jez.2594.
- Raeisi H, Daliri M, Paighambari SY, Shabani MJ, Bibak M, Davoodi R. 2011. Length-weight relationships, condition factors and relative weight of five fish species of Bushehr waters, Northern Persian Gulf. Afr J Biotechnol 10 (82): 19181-19186. DOI: 10.5897/AJB11.2650.
- Rahman MAF, Azmir IA, Hussin NJ. 2022. Morphological study of selected mudskipper species (Family: Oxudercidae) and development of key pictorial. Iran J Ichthyol 9 (4): 180-194. DOI: 10.22034/iji.v9i4.808.
- Ridho MR, Patriono E, Rahmawati D, Pratama R, Avesena M. 2021. Short communication: Investigating gonad length and fecundity in mudskippers (Gobiidae) at the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 22 (10): 4413-4420. DOI: 10.13057/biodiv/d221034.
- Ridho MR, Patriono E, Solikha M. 2019. Food habits of three species of mudskippers in the Musi River Estuary, South Sumatra, Indonesia. Biodiversitas 20 (8): 2368-2374. DOI: 10.13057/biodiv/d200835.
- Santoso HB, Krisdianto K, Yunita R. 2024. Iron bioaccumulation and ecological implications in the coastal swamp wetlands ecosystem of South Kalimantan: Insights from giant mudskipper fish as

bioindicators. J Degrad Min Lands Manag 11 (3): 5539-5550. DOI: 10.15243/jdmlm.2024.113.5539.

- Santoso HB, Suhartono E, Yunita R, Biyatmoko D. 2020. Mudskipper fish as a bio-indicator for heavy metals pollution in a coastal wetland. Egypt J Aquat Biol Fish 24 (7): 1073-1095. DOI: 10.21608/ejabf.2020.144402.
- Septinar H, Putri YP, Midia KR, Bianto B. 2023. Mangrove forest conservation efforts through nurseries in Sungsang IV village, Banyuasin Regency. Jurnal Ilmu Lingkungan 1 (2): 77-88. DOI: 10.31851/esjo.v1i2.11920. [Indonesian]
- Setyawan AD, Winarno K. 2006. The direct exploitation in the mangrove ecosystem in Central Java and the land use in its surrounding: Degradation and its restoration effort. Biodiversitas 7 (3): 282-291. DOI: 10.13057/biodiv/d070318.
- Simon KD, Bakar Y, Mazlan AG, Zaidi CC, Samat A, Arshad A, Temple SE, Brown-Peterson NJ. 2012. Aspects of the reproductive biology of two archer fishes *Toxotes chatareus*, (Hamilton 1822) and *Toxotes jaculatrix* (Pallas 1767). Environ Biol Fishes 93 (4): 491-503. DOI: 10.1007/s10641-011-9944-6.
- Smith WE, Nobriga MK. 2023. A bioenergetics-based index of habitat suitability: Spatial dynamics of foraging constraints and food limitation for a rare estuarine fish. Trans Am Fish Soc 152 (5): 650-671. DOI: 10.1002/tafs.10427.
- Sokefun O, Gan HM, Tan MP. 2022. Morphometrical characterization of the Atlantic mudskipper species (*Periophthalmus barbarus*) (Linnaeus, 1766) (Perciformes; Gobiiae) from Abonema in Port Harcourt, Rivers State, Nigeria. Intl J Fish Aquac 10 (3): 72-76. DOI: 10.22271/fish.2022.v10.i3a.2719.
- Sotola VA, Craig CA, Pfaff PJ, Maikoetter JD, Martin NH, Bonner TH. 2019. Effect of preservation on fish morphology over time: Implications for morphological studies. Plos One 14 (3): e0213915. DOI: 10.1371/journal. pone.0213915.
- Steppan SJ, Meyer AA, Barrow LN, Alhajeri BH, Al-Zaidan ASY, Gignac PM, Erickson GM. 2022. Phylogenetics and the evolution of terrestriality in mudskippers (Gobiidae: Oxudercinae). Mol Phylogenet Evol 169: 107416. DOI: 10.1016/j.ympev.2022.107416.
- Su J, Friess DA, Gasparatos A. 2021. A meta-analysis of the ecological and economic outcomes of mangrove restoration. Nat Commun 12: 5050. DOI: 10.1038/s41467-021-25349-1.
- Taniwel D, Leiwakabessy F, Rumahlatu D. 2020. Short communication: Density and length-weight relationship of mudskipper (*Periophthalmus* spp.) in the mangrove area of Kairatu Beach, Maluku, Indonesia. Biodiversitas 21 (11): 5465-5473. DOI: 10.13057/biodiv/d211155.
- Tran HD, Nguyen HH, Ha LM. 2021. Length-weight relationship and condition factor of the mudskipper (*Periophthalmus modestus*) in the

Red River Delta. Reg Stud Mar Sci 46: 101903. DOI: 10.1016/j.rsma.2021.101903.

- Tran LX, Maekawa Y, Soyano K, Ishimatsu A. 2020. Morphology of the feeding apparatus in the herbivorous mudskipper, *Boleophthalmus pectinirostris* (Linnaeus, 1758). Zoomorphology 139 (2): 231-243. DOI: 10.1007/s00435-020-00476-3.
- Tran LX, Nguyen TTK, Vo TT. 2022. Morphological comparison of the cranial movement apparatus in mudskippers (Gobiidae: Oxudercinae). Zoology 154: 126042. DOI: 10.1016/j.zool.2022.126042.
- Tran LX, Nguyen TTK. 2023. Morfology of the buccal and opercular sealing apparatus in mudskippers (Gobiidae: Oxudercinae). J Ichthyol 63 (4): 605-615. DOI: 10.1134/S0032945223040197.
- Valen FS, Hasan V, Ottoni FP, Nafisyah AL, Erwinda M, Annisa AN, Adis MA. 2022. First country record of the bearded gudgeon *Pogoneleotris heterolepis* (Günther, 1869) (Teleostei: Eleotridae) from Indonesia. IOP Conf Ser Earth Environ Sci 1036: 012074. DOI: 10.1088/1755-1315/1036/1/012074.
- Vilchez M, Dattilo J, Brewer SK. 2024. Length-weight relationships of native and non-native fishes in the lower Red River Cathment, USA. J Appl Ichthyol 2024: 5578825. DOI: 10.1155/2024/5578825.
- Waleed TA, Abdel-Maksoud YK, Kanwar RS, Sewilam H. 2024. Mangroves in Egypt and the Middle East: Current status, threats, and opportunities. Intl J Environ Sci Technol 22: 1225-1262. DOI: 10.1007/s13762-024-05788-1.
- Wirabuana PYAP, Baskorowati L, Pamungkas B, Mulyana B, South J, Purnobasuki H, Andriyono S, Hasan V. 2025. Mangroves, fauna compositions and carbon sequestration after ten years restoration on Flores Island, Indonesia. Sci Rep 15: 4866. DOI: 10.1038/s41598-025-87307-x.
- You X, Sun M, Li J, Bian C, Chen J, Yi Y, Yu H, Shi Q. 2018. Mudskippers and their genetic adaptations to an amphibious lifestyle. Animals 8 (2): 24. DOI: 10.3390/ani8020024.
- Zhou H, Donatelli CM, Laneuville O, Standen EM. 2023. Skeletal anatomy of the pectoral fin in mudskipper species from terrestrial and aquatic habitats. J Morphol 284 (8): e21612. DOI: 10.1002/jmor.21612.
- Ziadi-Künzli F, Maeda K, Puchenkov P, Bandi M. 2024. Anatomical insights into fish terrestrial locomotion: A study of barred mudskipper (*Periophthalmus argentilineatus*) fins based on µct 3d reconstructions. J Anat 245 (4): 593-624. DOI: 10.1111/joa.14071.
- Zulkifli SZ, Mohamat-Yusuff F, Ismail A, Miyazaki N. 2012. Food preference of the giant mudskipper *Periophthalmodon schlosseri* (Teleostei: Gobiidae). Knowl Manag Aquat Ecosyst 405: 7. DOI: 10.1051/kmae/2012013.