Melki melki <melki@unsri.ac.id>

[biodiv] Submission Acknowledgement

1 pesan

Ahmad Dwi Setyawan via SMUJO <support@smujo.com> 16 Februari 2025 pukul 14.11
Balas Ke: Ahmad Dwi Setyawan <editors@smujo.id>
Kepada: Melki Melki <melki@unsri.ac.id>

Melki Melki:

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

Melki melki <melki@unsri.ac.id>

[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

- 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> 27 Februari 2025 pukul 15.50
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:

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

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COVERING LETTER

Dear **Editor-in-Chief,**

I herewith enclosed a research article,

- [x] 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).
- [x] The submission file is in OpenOffice, Microsoft Word (DOC, not DOCX), or RTF document file format.
- [x] 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.
- [x] The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines.
- [x] Most of the references come from current scientific journals (c. 80% published in the last 10 years), except for taxonomic papers.
- [x] Where available, DOIs for the references have been provided.
- [x] 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:

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

All necessary files have been uploaded, and contain:

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

Further considerations

- [x] Manuscript has been "spell & grammar-checked" Better, if it is revised by a professional science editor or a native English speaker
- [x] References are in the correct format for this journal
- [x] All references mentioned in the Reference list are cited in the text, and vice versa
- [x] Colored figures are only used if the information in the text may be losing without those images
- [x] Charts (graphs and diagrams) are drawn in black and white images; use shading to differentiate

Title:

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

Author(s) name:

MELKI[1♥], FADHILAH DZAKIYYAH ANANTA[1], ISNAINI[1], FITRI AGUSTRIANI, REZI APRI[1], HARTONI[1], ELLIS NURJUALISTI NINGSIH[1], JENI MEIYERANI[1]

Address

(Fill in your ~~institution's~~ institution's name and address, your personal cellular phone and email)

[1]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.

For possibility publication on the journal:

(fill in *Biodiversitas* or *Nusantara Bioscience* or *mention the others*)

- [x] Biodiversitas Journal of Biological Diversity
- [ ] Nusantara Bioscience
- [ ] Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia
- [ ] Asian Journal of Agriculture
- [ ] Asian Journal of Ethnobiology
- [ ] Asian Journal of Forestry
- [ ] Asian Journal of Natural Product Biochemistry
- [ ] Asian Journal of Tropical Biotechnology
- [ ] International Journal of Bonorowo Wetlands
- [ ] Cell Biology and Development
- [ ] Indo Pacific Journal of Ocean Life
- [ ] International Journal of Tropical Drylands

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.Sc~~M. 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[1♥], FADHILAH DZAKIYYAH ANANTA[1], ISNAINI[1], FITRI AGUSTRIANI, REZI APRI[1], HARTONI[1], ELLIS NURJUALISTI NINGSIH[1], JENI MEIYERANI[1]

[1]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: 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 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. 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 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~~3.92~~ 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. 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.

~~**Key words**~~**Keywords:** 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,

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for example, is correlated with the southwest monsoon, which affects resource availability and habitat conditions (Simon et al. 2012).

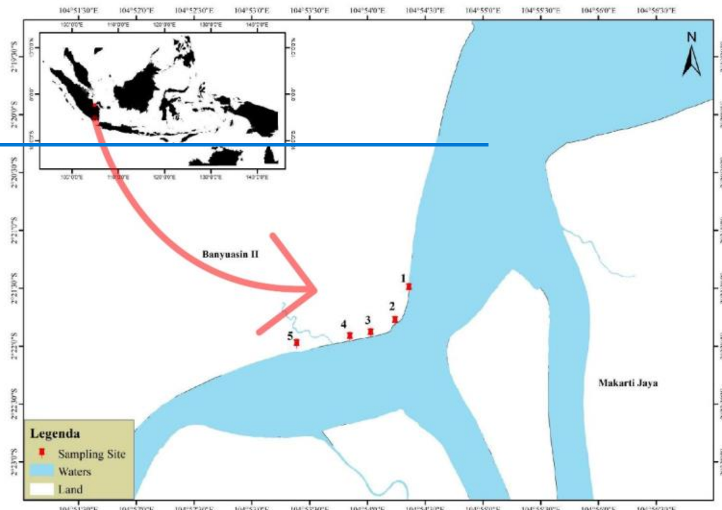
The biodiversity of fish species in the Sungsang estuary, including the giant mudskipper, is influenced by a variety of environmental factors. Numerous studies have documented the species diversity and community composition in this region, emphasizing the importance of mangrove ecosystems as critical 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 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 well-known site for mudskippers. Nevertheless, research data on mudskippers in this area is limited.

MATERIALS AND METHODS

Study area

The research was carried out at five stations in the study area, which extends from latitudes ~~2º21’48~~2º21'48~~”~~ " S and longitudes ~~104º53’57~~104º53'57~~”~~ " E in the Sungsang coast of South Sumatra, Indonesia (Figure 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).



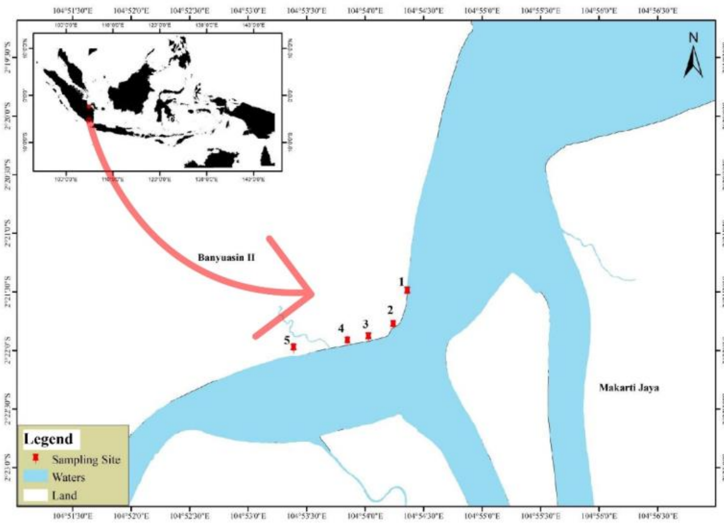


Figure 1. The study area of *P. schlosseri* in Sungsang coast

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.

A total of seventeen morphometric measurements were recorded, 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

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 ~~centimeter~~centimeters, and body weight was measured on a digital scale with 0.1 gram accuracy.

Data analysis

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).

The K of the fish was estimated using the equation K= (W) / (a x 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

Environmental ~~parameters~~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

Sampling site	Temperature (°C)	pH (water)	pH (soil)	DO (mg L^{-1})	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

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±0.3 to 7.9±0.4 mg 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^{-1}. 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).

Temperature, salinity, and dissolved oxygen (DO) levels represent critical physical parameters that ~~exert a significant influence on~~significantly 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.

Morphometric ~~charateristic~~characteristic

The *P. schlosseri* found had an average total length (TL) of 20.08 cm, with a minimum length of 15 cm and a maximum 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 maximum length of 20 cm (Table 2). The body length of *P. schlosseri* at the sampling sites was found to be equivalent to the body length measured (Ridho et al. 2019, 2021) in the Musi River estuary, South Sumatra, Indonesia. However, the size 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 of 12.10-18.65 cm, and that found at the Tanjung Piai, Pontian, Johor, Malaysia (Hui et al. 2019), sized approximately 20 cm. The length of these fish is likely influenced by the abundance of fish food sources in their habitat, as evidenced by the findings of Dinh et al. (2020). Tran et al. (2021) also reported that the food composition of mudskippers was similar between sexes~~,~~ but varied depending on fish size, season, and habitat.

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* ~~in~~ on Sungsang coast

No.	Morphometric Measurements	Ranged (cm)	Mean ± sd (cm)
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±0.4
	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

Length-weight relationship

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

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~~3.9~~

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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), 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).

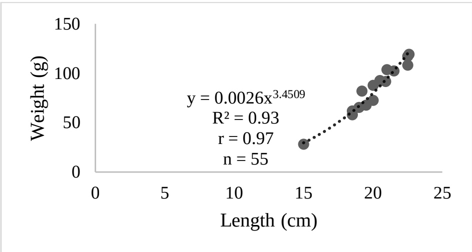

Figure 2. Relationship between total length and body weight of *P. schlosseri* in Sungsang coast

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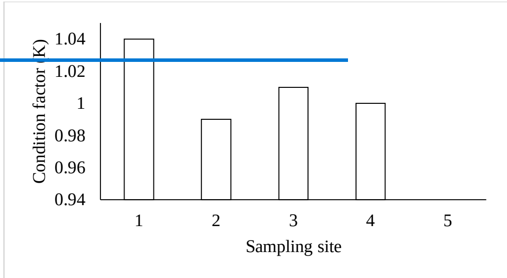
In comparison with other species found in mangrove ecosystems, the allometric growth of *P. schlosseri* reflects typical trends in estuarine and intertidal species, where growth patterns are often influenced by environmental conditions such as temperature, food availability, and habitat structure (Chew 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).

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).



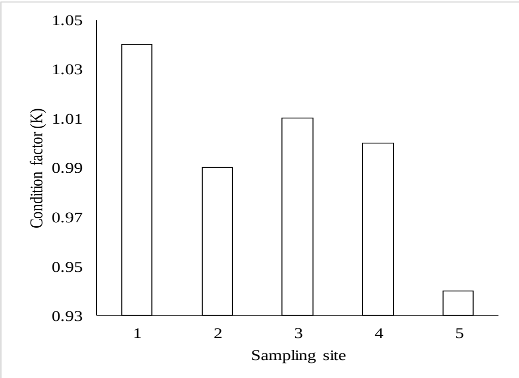


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Figure 3. Condition factor of *P. schlosseri* in Sungsang coast

Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the 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).

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).

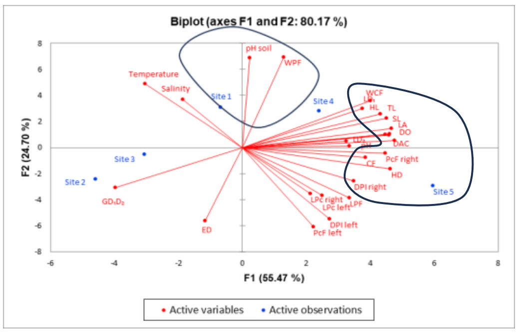

Figure 4. PCA was examined to determine morphometric characteristics related to environmental factors of *P. schlosseri* ~~in~~ on Sungsang coast

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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 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 *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~~s~~ environmental adjustments rather than growth and foraging (Smith and Nobriga 2023).

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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.

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Analysis of morphology and population dynamics of giant mudskipper *Periophthalmodon schlosseri* (Pallas, 1770) (Gobiiformes: Oxudercidae) *Periophtalmodon 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 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. Th~~e objective of this study was~~is 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 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 ~~at a faster rate~~faster 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

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 (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).

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. 2024). Mudskippers exhibit physiological, 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 ~~(~~*Periopthalmodon*~~.~~ *schlosseri*~~)~~ *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

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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 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

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)

Table 1. Description of sampling locations in the Sungsang estuaries

Sampling sites and names	Position		Description
	Longitudes (E)	Latitudes (S)	
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"	Fisherman's village area
3 – Sungsang II	104° 54' 01.76"	2° 21' 54.56"	Fisherman's village area
4 – Sungsang I	104° 54' 14.22"	2° 21' 47.61"	Fisherman's village area
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

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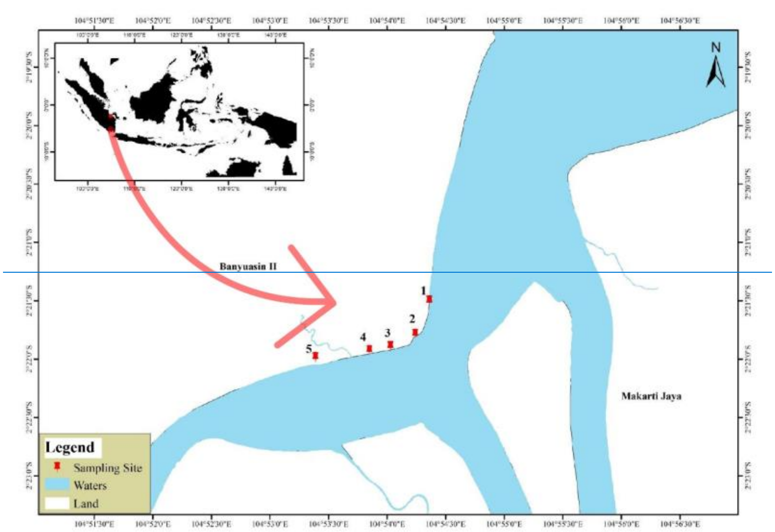

Figure 1. The study area of *P. schlosseri* in Sungsang coast

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. Upon completion of ongoing genetic analyses, voucher specimens will be deposited at Universitas Sriwijaya. Fish sampling was conducted using a 1 × 3 m seine net with a 1 mm mesh size suitable for capturing small estuarine species. After collection, samples were immediately placed in labeled plastic bottles containing 8-10% formalin solution for initial preservation. In the laboratory, samples were transferred to 75% ethanol for long-term storage and further morphometric and meristic analyses. The use of 8-10% formalin for initial fixation followed by 75% ethanol for long-term storage 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).

Morphometric measurements

A total of seventeen morphometric measurements were recorded, 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) (Figure 2) (Gangan et al. 2016; Rahman et al. 2022). All morphometric data were standardized by dividing each measurement by the standard length (SL) and then multiplying by 100% to eliminate the effect of size variation between individuals. Each measurement -was measured to the nearest 0.1 centimeters, and body weight was measured on a digital scale with 0.1 gram accuracy.

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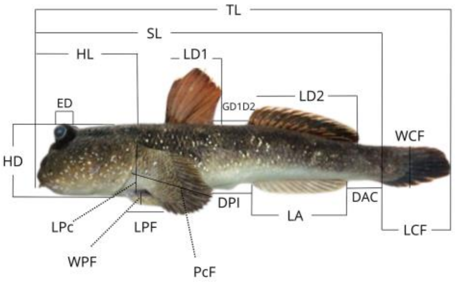

Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Sokefun et al. 2022; Rahman et al. 2022)

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 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).

The K of the fish was estimated using the equation K= (W) / (a x 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) 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 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

Sampling site	Temperature (°C)	pH (water)	pH (soil)	DO (mg L^{-1})	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

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±0.3 to 7.9±0.4 mg 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^{-1}. 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).

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

P. schlosseri *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 (Table 2). 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.

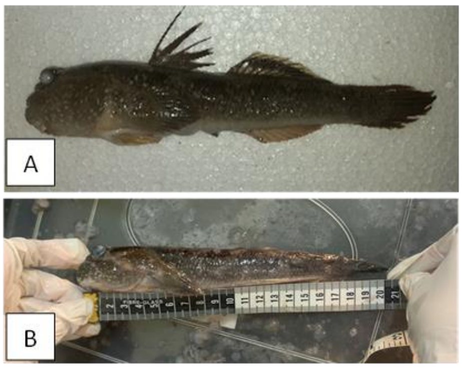

Figure 3. Sample of mudskipper (A. *Periophthalmodon schlosseri*, B. Morphometric measurement)

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

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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

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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
LD_1	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

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).

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

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 ($b > 3$), 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).

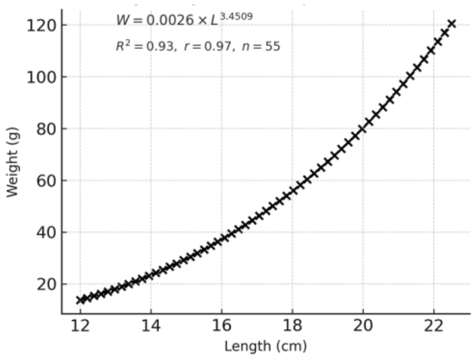

Figure 2. Relationship between total length and body weight of *P. schlosseri* in Sungsang coast

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).

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).

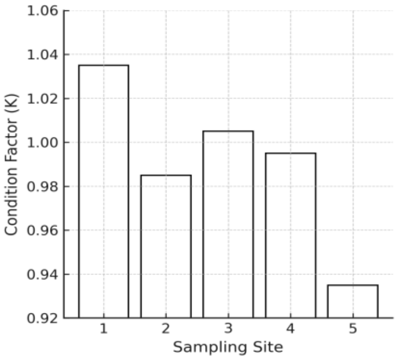

Figure 3. Condition factor of *P. schlosseri* in Sungsang coast

Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the 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 4).

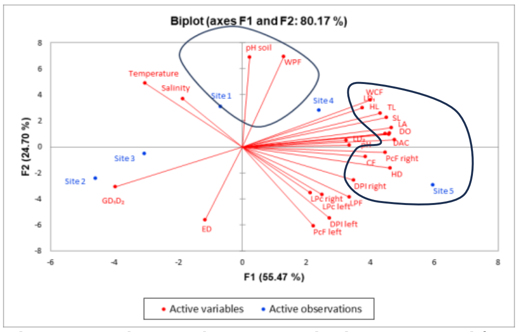

Figure 4. PCA was examined to determine morphometric characteristics related to environmental factors of *P. schlosseri* on Sungsang coast

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 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 *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 growth and foraging (Smith and Nobriga 2023).

This study analyzed the giant mudskipper (*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 morphometric characteristics, while temperature and salinity supported optimal habitats. The findings emphasize the 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 affecting the morphometric variation of *P. schlosseri*, suggesting their potential as key indicators in mangrove ecosystem 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.

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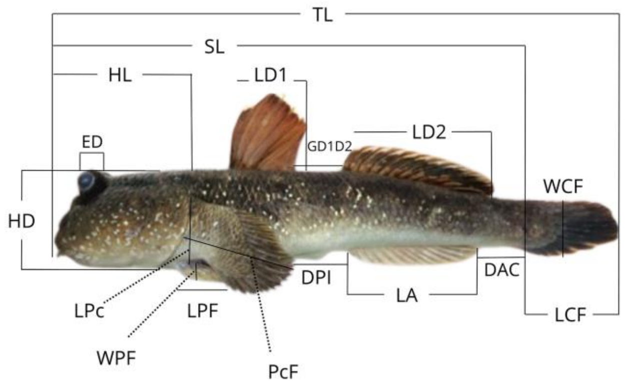
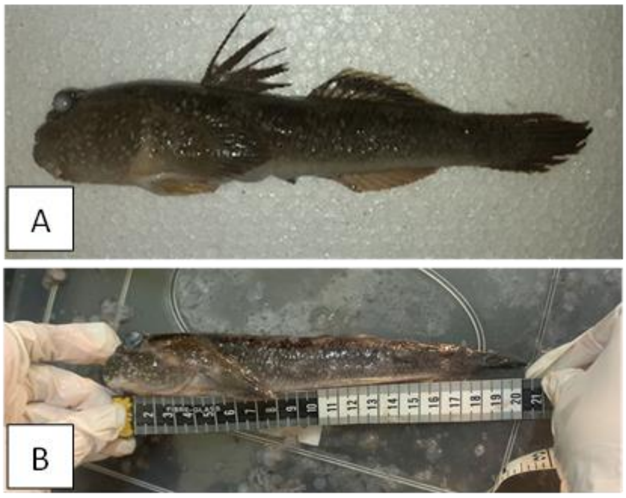
Table of Responses

Lines	Reviewer Comments/Suggest	Answer
2-3	Font: italic Periophthalmodon schlosseri (Pallas, 1770) (Gobiiformes: Oxudercidae)	Repaired as recommended *Periophthalmodon schlosseri* (Pallas, 1770) (Gobiiformes: Oxudercidae)
8-16	**Abstract.** The Giant Mudskipper (*Periophthalmodon schlosseri* (Pallas, 1770)) 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. 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 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 at a faster rate than their length.	**Abstract.** The Giant Mudskipper *Periophthalmodon schlosseri* (Pallas, 1770) 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.
26-27	Add references: "The mangrove ecosystem is a significant area due to its role in providing a habitat for a wide variety of aquatic and terrestrial biota."	added as recommended: "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) added to reference: 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. (in lines 330-331) 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. (in lines 425-427)
27-28	"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."	added as recommended: "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) added to reference: 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. (in lines 401-402) 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. (in lines 432-433)
37-38	"A notable example is the giant mudskipper (*P. schlosseri*), which contributes significantly to the biomass value of the mangrove ecosystem." add an explanation of the conservation status of this species based on the IUCN Red List, and also add the global distribution information	A notable example is the giant mudskipper *Periophthalmodon schlosseri*, which contributes significantly to the biomass value of the mangrove ecosystem. 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). (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 species, which means that its presence or absence can indicate the ecological health of its habitat	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).
77-78	provide all detailed location and general description of each site in the Table "The research was carried out at five stations in the study area, which extends from latitudes 2º21'48" S and longitudes 104º53'57" E in the Sungsang estuaries of the Sungsang IV Village, South Sumatra, Indonesia (Figure 1)."	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. Table 1. Description of sampling locations in the Sungsang estuaries (in line 88)
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. "8-10% formalin" "75% ethanol"	The use of 8-10% formalin for initial fixation followed by 75% ethanol for long-term storage 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)

		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. (in lines 347-348)
106	Measurement data cannot be presented directly before being equalized by dividing by SL and then multiplying by 100%	All morphometric data were standardized by dividing each measurement by the standard length (SL) and then multiplying by 100% to eliminate the effect of size variation between individuals. Each measurement was measured to the nearest 0.1 centimeters, and body weight was measured on a digital scale with 0.1 gram accuracy. (in lines 112-113)
107	Provide a figure of measurements "morphometric measurement"	 Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Sokefun et al. 2022; Rahman et al. 2022) (in lines 117-118) added to reference: 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. (in lines 408-410)

181	Provide the figure of specimen	 Figure 3. Sample of mudskipper (A. *Periophthalmodon schlosseri*, 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** 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. (in lines 292-295)

Melki melki <melki@unsri.ac.id>

[biodiv] Editor Decision

1 pesan

Smujo Editors via SMUJO <support@smujo.com> 15 April 2025 pukul 21.52
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:

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

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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 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 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 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

Running title: Morphology and Population Dynamics of Mudskipper

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 et al. 2024). Mudskippers exhibit physiological, 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 *Periophthalmodon schlosseri* 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 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 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

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).

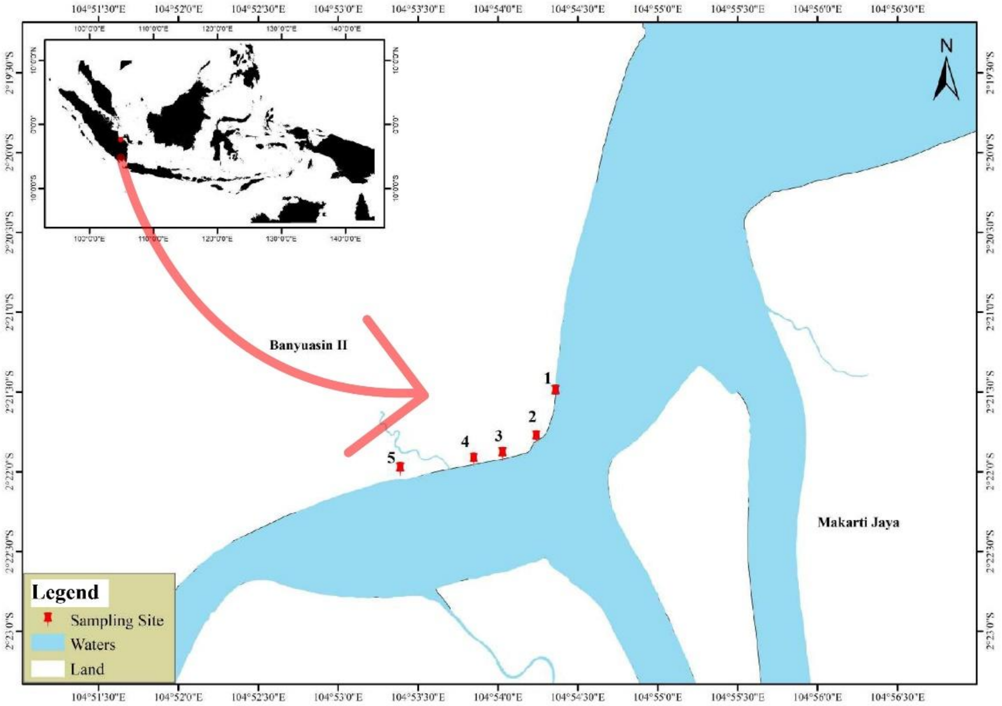

Figure 1. The study area of *P. schlosseri* in Sungsang coast

Table 1. Description of sampling locations in the Sungsang estuaries

Sampling sites and names	Position		Description
	Longitudes (E)	Latitudes (S)	
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 activitie
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

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 × 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).

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 centimeters, and body weight was measured on a digital scale with 0.1 gram accuracy.

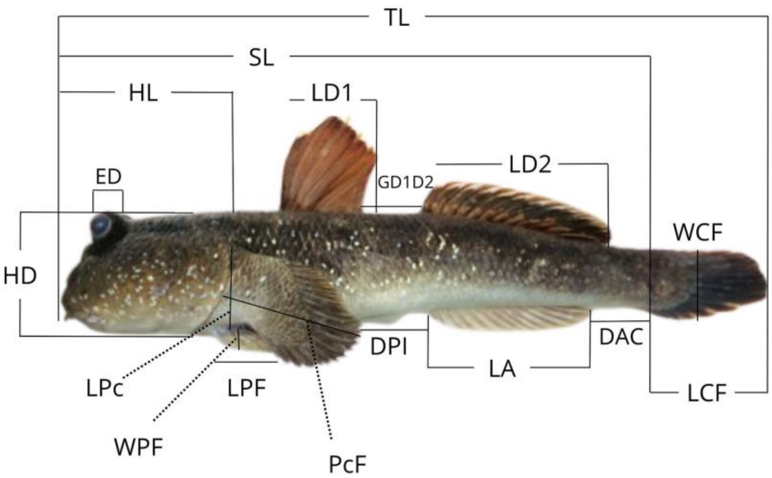

Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Sokefun et al. 2022; Rahman et al. 2022)

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_o 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 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).

The K of the fish was estimated using the equation K= (W) / (a x 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) 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 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

Sampling site	Temperature (°C)	pH (water)	pH (soil)	DO (mg L^{-1})	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

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±0.3 to 7.9±0.4 mg 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^{-1}. 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).

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

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 cm (Table 2). 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.

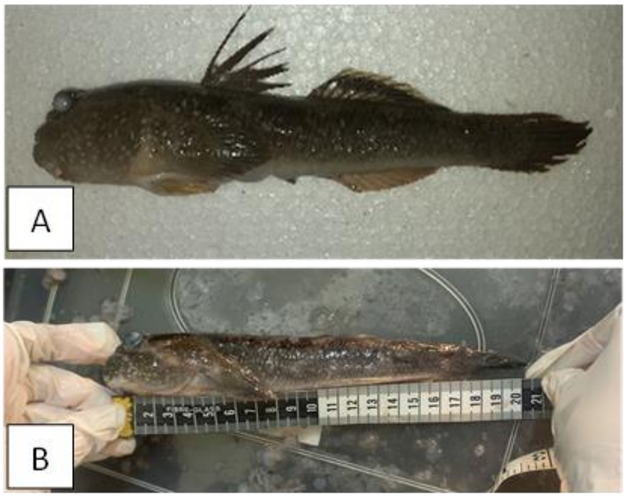

Figure 3. Sample of mudskipper (A. *Periophthalmodon schlosseri,* B. Morphometric measurement)

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).

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
LD_1	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

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).

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

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), 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).

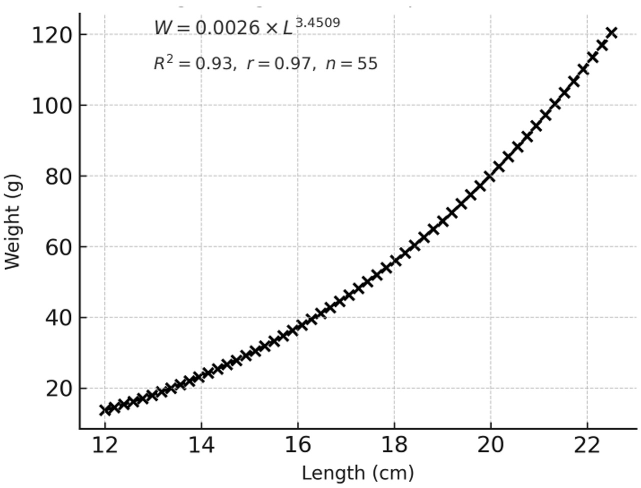

Figure 2. Relationship between total length and body weight of *P. schlosseri* in Sungsang coast

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).

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).

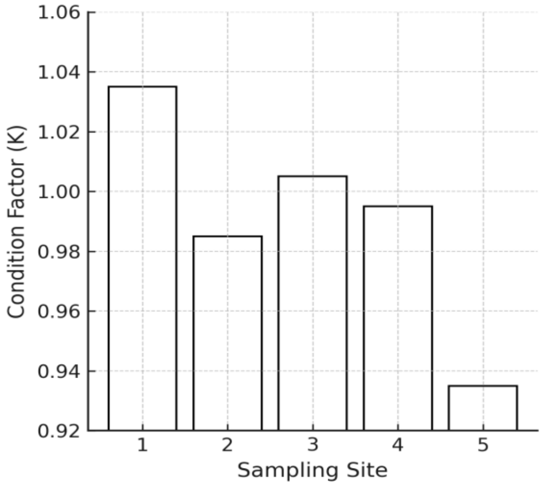

Figure 3. Condition factor of *P. schlosseri* in Sungsang coast

Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the 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 4).

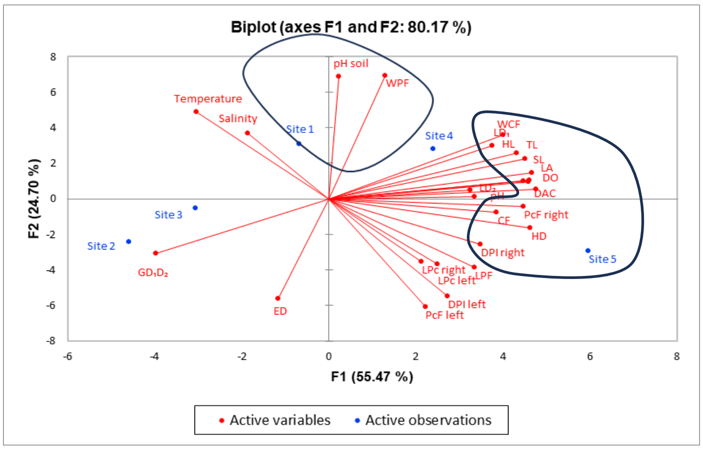

Figure 4. PCA was examined to determine morphometric characteristics related to environmental factors of *P. schlosseri* on Sungsang coast

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 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 *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 growth and foraging (Smith and Nobriga 2023).

This study analyzed the giant mudskipper *P. schlosseri* 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 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.

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Table of Responses

Lines	Reviewer Comments/Suggest	Answer
24-25	Add references. Ex: https://sfi-cybium.fr/fr/first-record-small-eyed-loter-prionobutis-microps-weber-1907-teleostei-eleotridae-butinae-java https://iopscience.iop.org/article/10.1088/1755-1315/1036/1/012074	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. (in lines 24-28)
25-27	add references. Ex: https://www.nature.com/articles/s41598-025-87307-x https://smujo.id/biodiv/article/view/521	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. (in lines 28-32)
35-37	add an explanation of the conservation status of this species based on the IUCN Red List, and also add the global distribution information	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). (in lines 41-45)
48-49	add reference. Ex: https://smujo.id/biodiv/article/view/17613	The giant mudskipper *Periophthalmodon schlosseri* 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.

<table>
<tr><td></td><td></td><td>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.

(in lines 53-62)</td></tr>
<tr><td>74</td><td>provide all detailed location and general description of each site in the Table</td><td>The description of these sampling locations is shown in Table 1.

(in line 84)

Table 1. Description of sampling locations in the Sungsang estuaries

<table>
<tr><th rowspan="2">Sampling sites and names</th><th colspan="2">Position</th><th rowspan="2">Description</th></tr>
<tr><th>Longitudes (E)</th><th>Latitudes (S)</th></tr>
<tr><td>1 – Sungsang IV</td><td>104° 53' 22.65"</td><td>2° 22' 00.07"</td><td>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</td></tr>
<tr><td>2 – Sungsang III</td><td>104° 53' 50.17"</td><td>2° 21' 56.30"</td><td>A fisherman village area with a moderate population, known for its active fishing community</td></tr>
<tr><td>3 – Sungsang II</td><td>104° 54' 01.76"</td><td>2° 21' 54.56"</td><td>Similar to Sungsang III, it’s a fisherman village with a high population density and active fishing activitie</td></tr>
<tr><td>4 – Sungsang I</td><td>104° 54' 14.22"</td><td>2° 21' 47.61"</td><td>A fisherman village with a relatively larger population, also known for its significant fishing activities</td></tr>
<tr><td>5 – Marga Sungsang</td><td>104° 54' 21.17"</td><td>2° 21' 33.41"</td><td>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</td></tr>
</table>

(in line 96)</td></tr>
<tr><td>91, 92</td><td>is there voucher specimen code?
Please mention the catalog no</td><td>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).

(in lines 104-105)</td></tr>
<tr><td>95</td><td>Add references.</td><td>After collection, the samples were immediately placed in labeled plastic bottles containing 8-10% formalin solution for initial preservation, and in the laboratory, the</td></tr>
</table>

		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). (in lines 101-104) added to reference: 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. (in lines 428-429)
103	Measurement data cannot be presented directly before being equalized by dividing by SL and then multiplying by 100%	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 $\log L_o$ 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. (in lines 119-123)
104	Provide a figure of measurements	A total of seventeen morphometric measurements were recorded (Figure 2) (in line 108)
178	Provide the figure of specimen	 Figure 3. Sample of mudskipper (A. *Periophthalmodon schlosseri*, B. Morphometric measurement) (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, 299	see guideline	has been revised (in lines 301, 305, 334, 351, 379, 380, 382, 384, 400, 403, 405, 407, 412, 446)

Unsri Google Apps

Melki melki <melki@unsri.ac.id>

[biodiv] Editor Decision

1 pesan

Smujo Editors via SMUJO <support@smujo.com> 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

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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 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 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 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

Running title: Morphology and Population Dynamics of Mudskipper

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 floodin-, 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 et al. 2024). Mudskippers exhibit physiological, 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

Commented [VH1]: Delete

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 *P. schlosseri* 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.

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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 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

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).

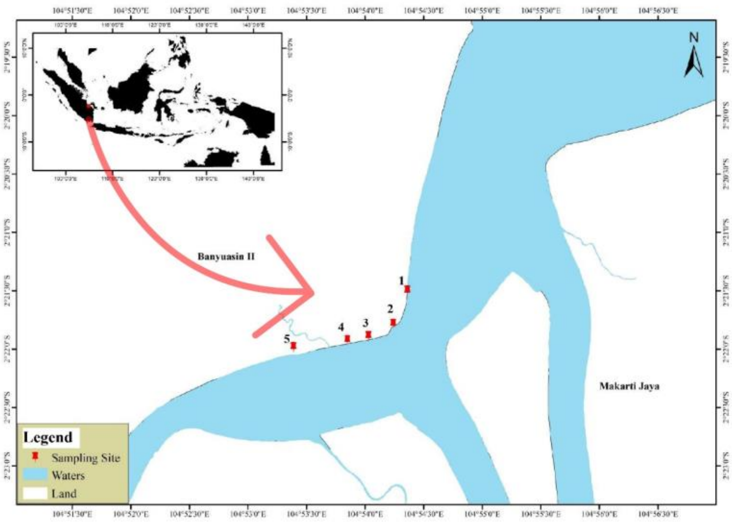

Figure 1. The study area of *P. schlosseri* in Sungsang coast

Table 1. Description of sampling locations in the Sungsang estuaries

Sampling sites and names	Position		Description
	Longitudes (E)	Latitudes (S)	
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 activitie
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

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 × 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).

Commented [VH3]: *P. schlosseri*

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 centimeters, and body weight was measured on a digital scale with 0.1 gram accuracy.

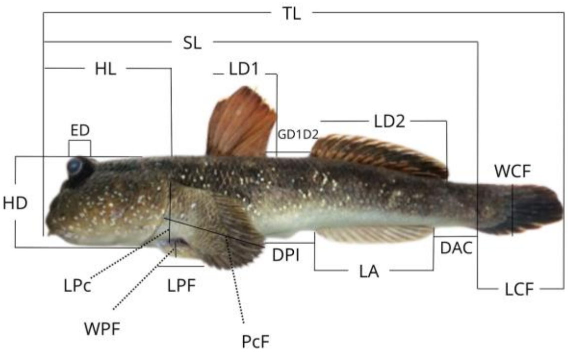

Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Sokefun et al. 2022; Rahman et al. 2022)

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 $\log L_o$ 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 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).

The K of the fish was estimated using the equation K= (W) / (a x 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) 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 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

Sampling site	Temperature (°C)	pH (water)	pH (soil)	DO (mg L^{-1})	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

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±0.3 to 7.9±0.4 mg 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^{-1}. 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).

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

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 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 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.

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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
LD_1	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

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).

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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

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), 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).

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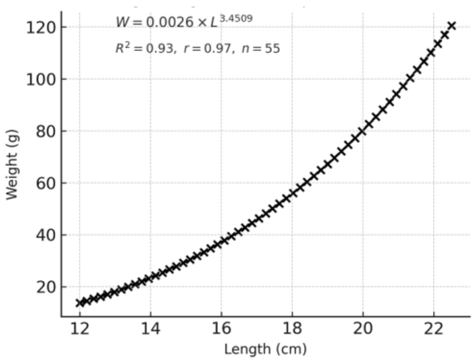

Figure 2. Relationship between total length and body weight of *P. schlosseri* in Sungsang coast

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).

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).

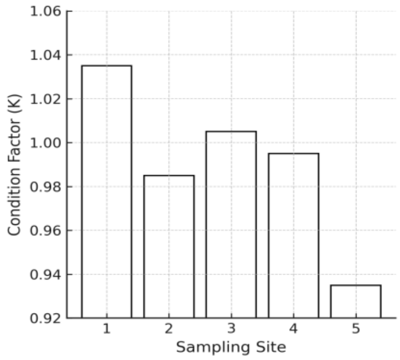

Figure 3. Condition factor of *P. schlosseri* in Sungsang coast

Furthermore, the condition factor (K), a metric of health and well-being, was evaluated and correlated with the 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 4).

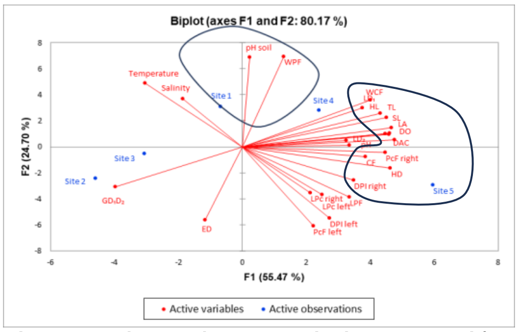

Figure 4. PCA was examined to determine morphometric characteristics related to environmental factors of *P. schlosseri* on Sungsang coast

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 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).

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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 *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).

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This study analyzed the giant mudskipper ~~*P. schlosseri*~~ 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*~~ *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.

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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.

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Table of Responses

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

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Biodiversitas Journal of Biological Diversity

BIODIVERSITAS
Volume 26, Number 5, May 2025
Pages: xxxx

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d2605xx

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

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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 *(Gobiiformes: 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 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 (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 et al. 2024). Mudskippers exhibit physiological, 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, 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 long-term 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 length-weight 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 and names	Position		Description
	Longitudes (E)	Latitudes (S)	
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

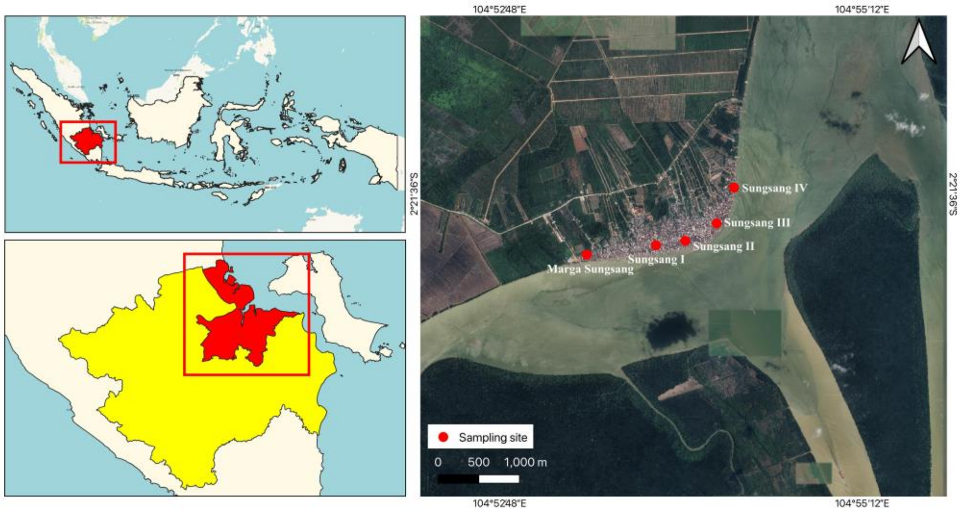

Figure 1. The study area of *Periophthalmodon schlosseri* in Sungsang coast, South Sumatra, Indonesia

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 1×3 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.

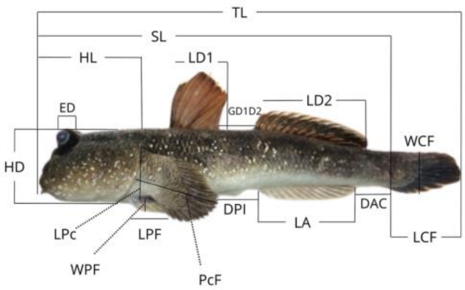

Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Rahman et al. 2022; Sokefun et al. 2022)

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 $\log M$ on $\log L_o$ 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 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).

The K of the fish was estimated using the equation K = (W) / (a x 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±0.1°C to 31.9±0.2°C. According to previous studies, the optimal water temperature range for mudskippers is between 23.5°C 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 7.0±0.2. 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±0.4 mg 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^{-1}. 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).

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Table 2. The environmental parameters in the sampling sites

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Sampling site	Temperature (°C)	pH (water)	pH (soil)	DO (mg L^{-1})	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

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).

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 length-weight 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

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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).

Table 3. Morphometric measurement results of *Periophthalmodon schlosseri* on Sungsang coast, South Sumatra, Indonesia

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
LD_1	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

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

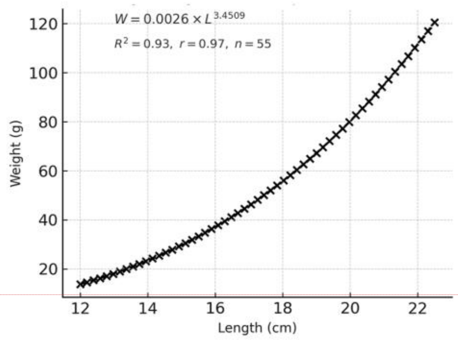

Figure 4. Relationship between total length and body weight of *Periophthalmodon schlosseri* in Sungsang coast, South Sumatra, Indonesia

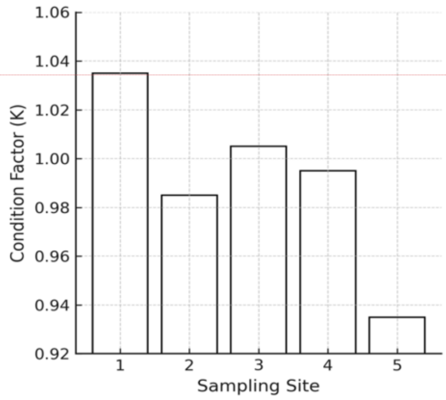

Figure 5. Condition factor of *Periophthalmodon schlosseri* in Sungsang coast, South Sumatra, Indonesia

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).

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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^{-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 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).

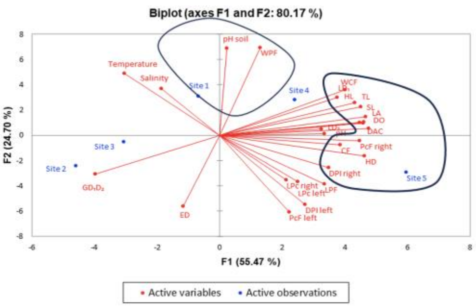

Figure 6. PCA was examined to determine morphometric characteristics related to environmental factors of *Periophthalmodon schlosseri* on Sungsang coast, South Sumatra, Indonesia

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.

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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.

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

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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:
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Biodiversitas Journal of Biological Diversity

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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.

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BIODIVERSITAS
Volume 26, Number 5, May 2025
Pages: 2269-2277

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d260524

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
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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 et al. 2024). Mudskippers exhibit physiological, 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, making them effective biomarkers 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 long-term 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 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

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 and names	Position		Description
	Longitudes (E)	Latitudes (S)	
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

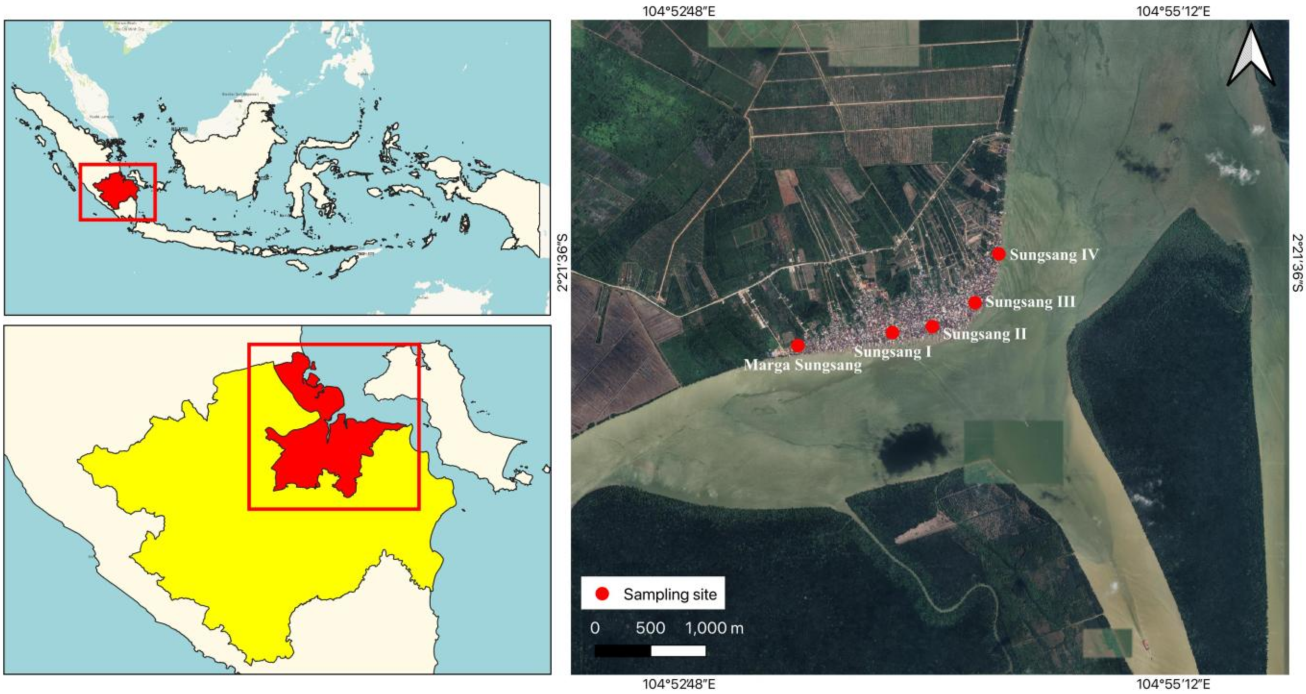

Figure 1. The study area of *Periophthalmodon schlosseri* in Sungsang Coast, South Sumatra, Indonesia

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 1×3 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 (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.

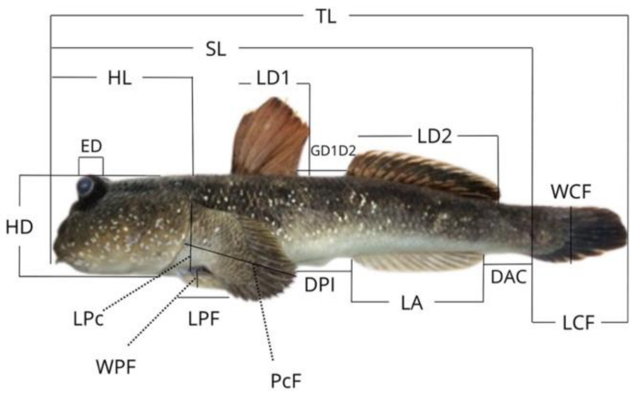

Figure 2. Morphometric measurements of mudskippers (Gangan et al. 2016; Rahman et al. 2022; Sokefun et al. 2022)

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_o 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 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).

The K of the fish was estimated using the equation K = (W) / (a x 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±0.1°C to 31.9±0.2°C. According to previous studies, the optimal water temperature range for mudskippers is between 23.5°C 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 7.0±0.2. 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±0.4 mg 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^{-1}. 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).

Table 2. The environmental parameters in the sampling sites

Sampling site	Temperature (°C)	pH (water)	pH (soil)	DO (mg L^{-1})	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

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 length-weight 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).

Table 3. Morphometric measurement results of *Periophthalmodon schlosseri* on Sungsang Coast, South Sumatra, Indonesia

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
LD_1	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

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

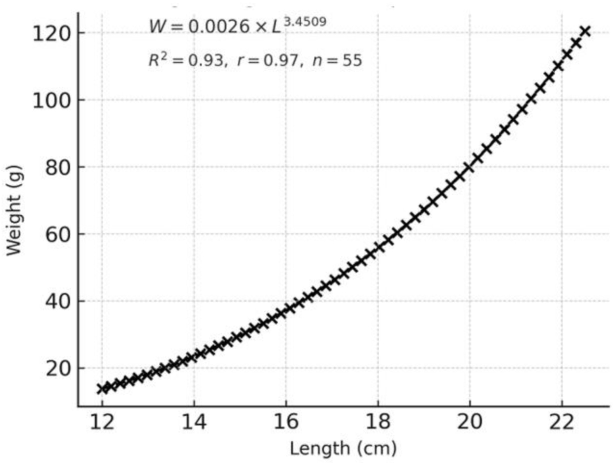

Figure 4. Relationship between total length and body weight of *Periophthalmodon schlosseri* in Sungsang Coast, South Sumatra, Indonesia

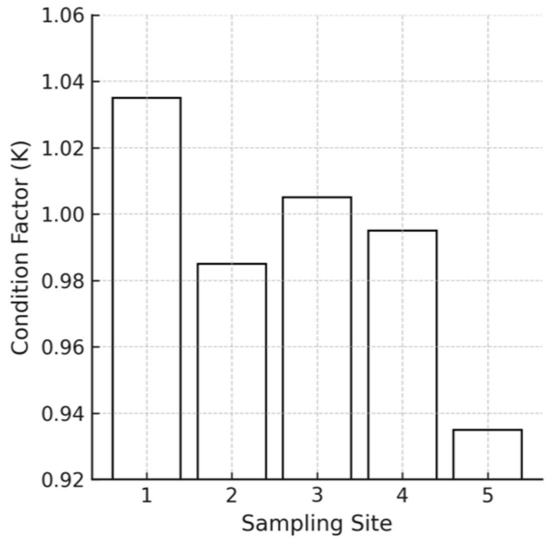

Figure 5. Condition factor of *Periophthalmodon schlosseri* in Sungsang Coast, South Sumatra, Indonesia

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^{-1}. 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).

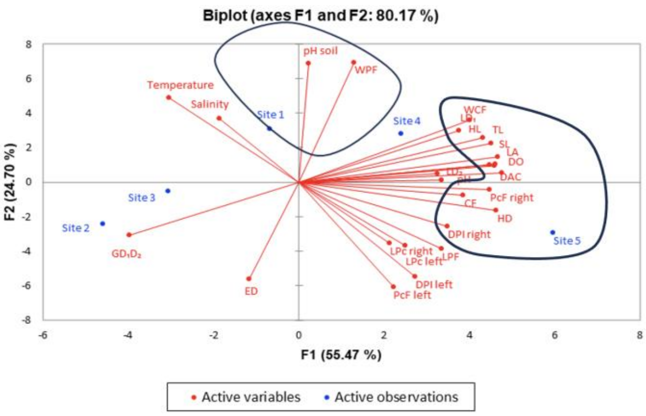

Figure 6. PCA was examined to determine morphometric characteristics related to environmental factors of *Periophthalmodon schlosseri* on Sungsang Coast, South Sumatra, Indonesia

This study analyzed the giant mudskipper on Sungsang Coast, revealing positive allometric growth (b>3) and healthy condition factors. Dissolved oxygen and pH exhibited 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.

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