

PROXIMATE COMPOSITION ANALYSIS OF THE MUDSKIPPER *Boleophthalmus boddarti* FROM COX'S BAZAR, BAY OF BENGAL, BANGLADESH

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Received: Jun. 12, 2026. Revised: Jul. 01, 2026. Accepted: Jul. 09, 2026. Published online: Jul. 22, 2026

ABSTRACT. Mudskippers are ecologically important intertidal fishes, yet their nutritional value remains poorly documented in the Bay of Bengal. This study evaluated the proximate composition of the mudskipper *Boleophthalmus boddarti* (Pallas, 1770) collected from the Cox's Bazar–Teknaf coast, Bangladesh, to assess its potential as an underutilised coastal food resource. A total of 270 specimens were collected from nine sampling sites between December 2023 and February 2024 and prepared as 27 site–month samples for proximate composition analysis. Moisture, ash, and protein content were analysed using the loss-on-drying, dry ashing, and Kjeldahl methods, respectively. The

resulting data were analysed to evaluate spatial and temporal variations among samples. Protein was the dominant proximate component, ranging from 57.75–77.00% with a mean of $65.10 \pm 4.32\%$. Monthly mean protein content showed a slight decline from December to February, while ash increased from $14.10 \pm 2.36\%$ to $16.73 \pm 3.50\%$. Moisture remained comparatively stable across months, with an overall mean of $13.02 \pm 2.36\%$. No significant spatial or temporal differences were detected for moisture, ash, or protein content ($p > 0.05$), indicating proximate composition stability across the sampled coastal habitats. The protein and ash values provide baseline proximate



Cite: Bhuyan, Md.S.; Morshed, A.J.M.; Uddin, M.R.; Farjana, S.J. Proximate composition analysis of the mudskipper *Boleophthalmus boddarti* from Cox's Bazar, Bay of Bengal, Bangladesh. *Journal of Applied Life Sciences and Environment* **2026**, 59 (2), 201-222.
<https://doi.org/10.46909/alse-592211>

composition information for *B. boddarti* from the Cox's Bazar–Teknaf coast, although these findings should not be interpreted as a complete nutritional or food-security assessment. Future studies should examine lipid quality, amino acid profiles, micronutrients, contaminants, and year-round seasonal variation to support safe consumption, value-added product development, and sustainable mudskipper fishery management.

Keywords: *Boleophthalmus boddarti*; Cox's Bazar; intertidal fish; marine-based nutrition; proximate composition.

INTRODUCTION

Mudskippers are highly specialised amphibious gobies of the subfamily Oxudercinae. They are recognised for their remarkable ability to occupy the narrow ecological boundary between land and water. Their morphological, locomotory, respiratory, and behavioural adaptations allow them to move, forage, and survive on exposed intertidal substrates as well as in aquatic habitats (Naylor and Kawano, 2022; Stepan *et al.*, 2022). These fishes are commonly distributed in tropical and subtropical mudflats, estuarine zones, sandy shores, and mangrove ecosystems, especially across Indo-Pacific coastal regions, where they contribute to sediment turnover, nutrient cycling, and coastal food-web interactions (Baderan *et al.*, 2023; Bhuyan *et al.*, 2024). Among them, *Boleophthalmus boddarti* (Pallas, 1770) is a distinctive mudskipper species characterised by an elongated body, protruding eyes, and well-developed pectoral fins that support terrestrial movement. Its amphibious life is further supported by specialised air-breathing adaptations, including cutaneous and

buccopharyngeal respiration, which enable survival in fluctuating intertidal environments (Murdy, 1989; Graham, 1997; Polgar and Crosa, 2009).

Beyond its ecological role, *B. boddarti* may also have socio-economic importance as a non-conventional fishery resource in coastal areas. In many tropical coastal communities, small and locally available fishes contribute to household food supply, income, and dietary diversity, particularly where access to larger commercial fish species may be limited. Although mudskippers are often overlooked in discussions of conventional fisheries, their abundance in mudflat and estuarine habitats suggests that they could support coastal nutrition if their food value is scientifically established. Recent studies on fish production systems have also emphasised the importance of sustainable approaches to improving fish growth, feed utilisation, and resource efficiency, highlighting the broader need to evaluate underutilised aquatic resources within food-security-oriented fisheries research (Gwaza *et al.*, 2025). This is especially relevant for the Cox's Bazar–Teknaf coast of Bangladesh, where extensive intertidal habitats, estuarine influence, and coastal livelihoods create a strong connection between aquatic biodiversity and community food security.

Fish are known to be valuable sources of high-quality protein, essential amino acids, minerals, and other nutrients important for human health (FAO, 1999; Lall and Anderson, 2005). Recent evidence also shows that fish-based composite foods can improve the protein content and nutritional potential of complementary foods, supporting the wider use of locally available fish

resources in nutrition-sensitive food systems (Kaunda *et al.*, 2025). More recent global nutrition discussions also emphasise the role of aquatic foods in improving food and nutrition security because they provide protein, minerals, vitamins, and other essential nutrients that are particularly important for nutritionally vulnerable groups such as children, women, and low-income coastal populations (FAO, 2024). Similarly, recent work on fish-enriched complementary foods has shown that the inclusion of fish can improve the protein value and nutritional potential of food products for young children, further supporting the importance of evaluating underutilised fish species as affordable nutrient sources (Kaunda *et al.*, 2025). Therefore, assessing the nutritional quality of locally available fish, such as *B. boddarti*, is important not only from a fisheries perspective but also from a public health and food-security perspective.

Proximate composition analysis is a fundamental approach for evaluating the nutritional value, quality, and potential utilisation of fish. Measurements of moisture, protein, and ash provide essential information about edible quality, protein contribution, mineral content, storage characteristics, and suitability for food-processing applications (Adeyeye *et al.*, 2010). These proximate composition parameters may vary according to species, habitat, diet, season, reproductive condition, size, and sex (Shearer, 1994; Akande and Faturoti, 2005). For intertidal fishes such as *B. boddarti*, which experience strong environmental fluctuations in salinity, temperature, tidal exposure, and food availability, proximate composition

analysis can also provide useful insight into how local habitat conditions may influence nutritional quality.

Several studies have examined the proximate composition of various mudskipper species from other regions, including *Apocryptes bato*, *Boleophthalmus dussumieri*, *Boleophthalmus* spp., *Periophthalmus barbarus*, and *Periophthalmodon schlosseri* (Chakma *et al.*, 2024; Duggal *et al.*, 2020; Karnila *et al.*, 2023; Muhartati *et al.*, 2021; Udoinyang *et al.*, 2022). However, species-specific proximate composition information on *B. boddarti* from the Bay of Bengal (BoB), particularly along the Bangladesh coast, remains very limited. Although *B. boddarti* has been reported from coastal mudflat habitats and is ecologically relevant to the Cox's Bazar region, its nutritional value has not been sufficiently evaluated in relation to local food security, coastal nutrition, or sustainable use. This lack of information limits the scientific basis for recognising the species as a potential fishery resource.

The novelty of the present study lies in providing one of the first detailed assessments of the proximate composition of *B. boddarti* from the Cox's Bazar–Teknaf coast of the BoB, Bangladesh. Unlike broader mudskipper studies that focus mainly on taxonomy, ecology, or species occurrence, this study directly evaluates the nutritional potential of *B. boddarti* by analysing moisture, ash, and protein content across multiple coastal sampling sites and months. By doing so, the study links mudskipper biodiversity with nutrition, food security, and fisheries-resource evaluation in a coastal region where such information is scarce.

The aim of this study was to evaluate the proximate composition of *B. boddarti* collected from the Cox's Bazar–Teknaf coast and to assess the mudskipper's potential as an underutilised coastal food resource. The specific objectives were: (i) to determine the moisture, ash, and protein content of *B. boddarti*; (ii) to examine spatial variation in proximate composition among selected coastal sampling sites; and (iii) to assess monthly variation in proximate composition. The findings are expected to contribute baseline nutritional information for *B. boddarti*, support the recognition of non-conventional fish species in coastal food systems, and provide evidence useful for future nutrition-focused research, value-added product development, and sustainable mudskipper fishery management.

MATERIALS AND METHODS

Study area

The study was conducted along the Cox's Bazar–Teknaf coast, southeastern Bangladesh, a biologically productive and socio-economically important coastal region connected to the Bay of Bengal (Figure 1). This coastal belt contains a mosaic of sandy beaches, intertidal mudflats, tidal creeks, estuarine channels, mangrove-influenced habitats, fishing villages, fish landing areas, and nearshore marine environments. The region is important for coastal fisheries, small-scale fishing, fish landing, dry-fish processing, and local livelihood activities. Nationally, fisheries make a major contribution to food and nutrition security in Bangladesh, with total fish production reaching about 5.018 million

metric tonnes in FY 2023–2024, including a substantial contribution from marine sources (DoF, 2024). The sector also supplies a major share of animal protein intake and provides direct or indirect livelihood support to a large proportion of the population (DoF, 2024). At the district level, Cox's Bazar is recognised as one of the country's important coastal fishing zones. Recent reports indicate that more than 63,000 registered fishers depend on fishing activities in the district, while the Bangladesh Fisheries Development Corporation (BFDC) fish landing centre in Cox's Bazar has recorded diverse marine fishery resources, including marine fishes, shellfishes, sharks, and rays (Kamal *et al.*, 2022; The Financial Express, 2025).

The Cox's Bazar–Teknaf coast was chosen because it combines three important features, i.e., confirmed availability of *B. boddarti*, high ecological diversity of intertidal and estuarine habitats, and strong dependence of coastal communities on fisheries resources. Samples of *B. boddarti* were collected from nine sites: Rezu Khal; Inani; Patuark; Imamer Dail; Monkhali; Shamlapur; Naf Jetty; Keary Ghat; and Shahporir Dwip. These sites were selected because they represent the major intertidal and estuarine habitats along the Cox's Bazar–Teknaf coastal gradient where *B. boddarti* occurs and can be collected during low tide. The sites differ in habitat characteristics and degree of coastal influence. Rezu Khal represents a tidal creek and estuarine-influenced habitat. Inani, Patuark, Imamer Dail, Monkhali, and Shamlapur represent open-coast intertidal mudflat and sandy-mudflat environments along the Marine

Drive coastal belt. Naf Jetty, Keary Ghat, and Shahporir Dwip represent lower Naf estuarine and island-adjacent coastal habitats influenced by tidal exchange, boat movement, fishing activity, and local resource use.

The selection of these sites is directly relevant to the objectives of the study because the habitat conditions can influence the proximate composition of fish. Differences in salinity, tidal exposure, sediment type, organic matter, food availability, freshwater influence, mangrove or estuarine connectivity, and anthropogenic activities may affect feeding ecology, energy allocation, mineral accumulation, and protein content in intertidal fishes. The Naf River estuary, for example, is a highly productive estuarine system supporting

diverse fishery assemblages, with salinity and turbidity influencing species occurrence and distribution (Chowdhury *et al.*, 2011).

Therefore, sampling across multiple sites allowed the present study to examine whether the proximate composition of *B. boddarti* varies among coastal habitats with different ecological and resource-use characteristics. By including sites with varying habitat conditions and human-use intensity, the study provided a stronger basis for evaluating the nutritional potential of *B. boddarti* as an underutilised coastal fishery resource and for understanding whether its proximate composition remains stable across different coastal environments.

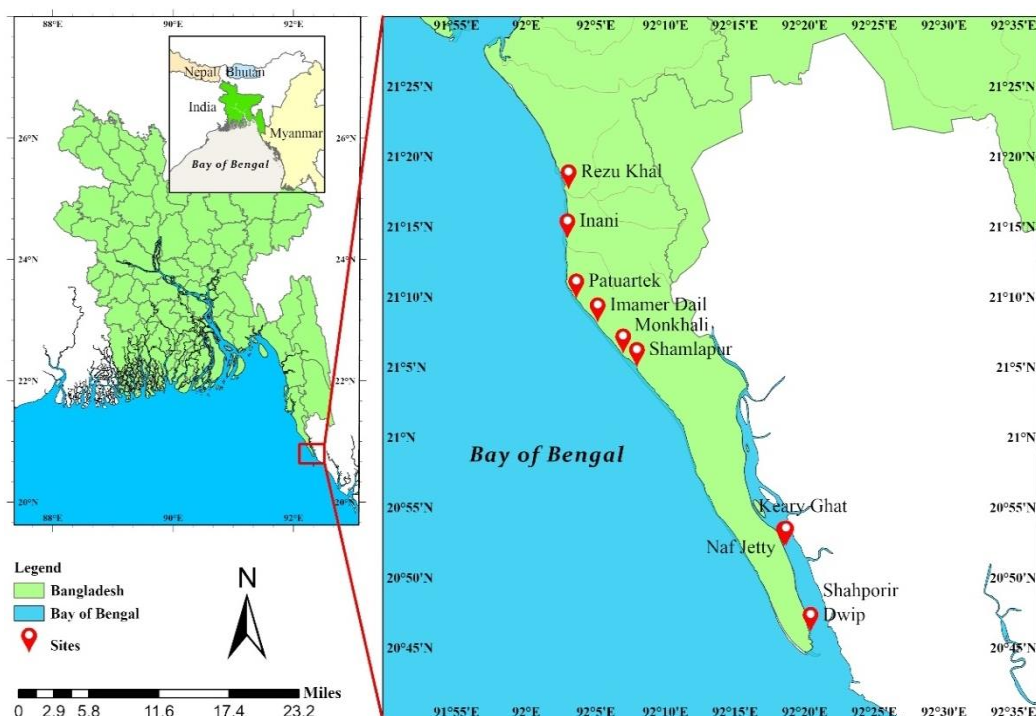


Figure 1 – Map showing the sampling sites on Cox's Bazar–Teknaf coast, Bangladesh

Sample collection and preservation

Samples of *B. boddarti* were collected from December 2023 to February 2024. In total, 270 *B. boddarti* specimens were collected, with 10 individuals collected from each sampling site during each sampling month. For proximate composition analysis, the 10 individuals collected from each site in each month were pooled to prepare one site-month composite sample, resulting in 27 composite samples from nine sites over three months. Sampling was conducted mainly during low tide, when mudflat areas and burrow openings were exposed, and the mudskippers could be collected more effectively.

Specimens were captured using locally available fishing equipment, including a cast net, thela jal, and scoop net, and hand collection. This equipment was selected because it is commonly used in shallow, intertidal mudflat habitats and suitable for collecting small, burrow-associated fishes such as mudskippers. Hand collection and digging were used where specimens retreated into burrows, as *B. boddarti* rapidly escaped into mud holes when approached.

Immediately after collection, live specimens were placed in clean plastic containers containing water from the respective sampling site to reduce handling stress and prevent desiccation during field sorting. The samples were then transferred to properly labelled polyethylene bags according to site and month. For preservation, the samples were kept in an insulated ice box with crushed ice at approximately 4°C during transport to the laboratory. In the laboratory, the specimens were rinsed with clean water to remove mud and debris, drained, and stored at -20°C until

proximate composition analysis. Prior to analysis, the samples were thawed under controlled laboratory conditions and prepared according to the requirements of moisture, ash, and protein content determination.

Mudskipper identification

Photographs were taken of each collected specimen for identification (Figure 2). The mudskippers were identified as *B. boddarti* by using external morphology, morphometric characteristics, and meristic characters, including body shape, eye position, pectoral-fin structure, dorsal-fin characters, and other diagnostic features described for oxudercine gobies. Species identification was supported by standard taxonomic and biological references on mudskippers and air-breathing fishes, including Murdy (1989), Graham (1997), Daud *et al.* (2005), Nor *et al.* (2023), and Bhuyan *et al.* (2024).

Additional regional and comparative information on mudskipper diversity, length-weight relationships, and molecular-marker studies was obtained from Vichaidist *et al.* (2014), Hui *et al.* (2019), and Azmir *et al.* (2022). Online taxonomic databases, including FishBase (2026), the World Register of Marine Species (2026), and Mudskipper.it (2026), were also used to verify the accepted scientific name and taxonomic status of the species.

Ethics declaration

No human participants were involved as study subjects, and the study did not include clinical trials, questionnaire surveys, or experimental manipulation of vertebrate animals in laboratory conditions. According to the applicable institutional and national

regulations governing the collection of wild fish for scientific research, formal ethical approval was not required. All fish samples were collected using commonly practiced field-sampling methods, and efforts were made to minimise unnecessary harm during collection and handling. The research was conducted for nutritional and scientific evaluation purposes only, in accordance with good scientific practice.

Determination of ash, moisture, and protein

Each composite sample was cleaned, drained, and homogenised before laboratory analysis. Subsamples from the homogenised composite material were used separately for moisture, ash, and crude protein determination. Therefore, the values reported in this study represent site–

month composite samples and not individual fish-level measurements. Each proximate composition variable was measured once for each site–month composite sample; therefore, analytical replicate variation could not be assessed.

Determination of ash

The ash content was determined by the dry ashing method. This method is commonly used in proximate composition analysis of fish samples, including mudskipper nutritional studies (Chakma *et al.*, 2024; Karnila *et al.*, 2023).

A clean porcelain crucible was dried, cooled in a desiccator, and weighed accurately. Then, 2 g of the dried homogenised composite sample was placed into the crucible; therefore, ash content was determined on a dried-sample basis.



Figure 2 – *Boleophthalmus boddarti*

The sample was gently heated to char the organic matter and then transferred to a muffle furnace at 550°C for 6 h until a white or light grey ash was obtained (Chakma *et al.*, 2024). The crucible containing the ash was removed from the furnace, cooled in a desiccator, and weighed again. Dry ashing by furnace ignition is also supported by standard ash determination procedures (Thiex *et al.*, 2012). The ash content was calculated using *Equation 1*:

$$A = \frac{Wa}{Ws} \times 100 \quad (1)$$

where A is the ash content (%), Wa is the weight of the ash (g), and Ws is the weight of the sample (g).

Determination of moisture

The moisture content was determined using an automated moisture analyser based on the gravimetric loss-on-drying principle in which moisture is estimated from the weight difference before and after drying. This principle is commonly used in proximate composition analysis, and moisture determination has been reported in mudskipper nutritional composition studies (AOAC International, 2023; Chakma *et al.*, 2024). Approximately 5 g of each site-month composite sample was weighed before drying, and the weight was recorded. The homogenised subsamples were placed in a moisture analyser (Model MAC 50, Radwag Wagi Electronics). The samples were dried at 105°C using infrared/halogen heating until constant weight was obtained. After drying, the final weight of each dried sample was recorded. The loss in weight after drying was considered moisture loss and expressed as percentage moisture content calculated using *Equation 2*:

$$M = \frac{Wi - Wd}{Wi} \times 100 \quad (2)$$

where M is the percentage moisture content, Wi is the initial weight of the subsample before drying, and Wd is the final weight of the subsample after drying to constant weight.

Determination of protein content

The protein content was determined using the Kjeldahl method according to AOAC Method 981.10.

A 1-g, dried, homogenised composite subsample was transferred into a Kjeldahl digestion flask; therefore, crude protein content was expressed on a dried-subsample basis. Concentrated sulfuric acid and a catalyst were added to the flask, and the subsample was digested until the organic nitrogen was converted into ammonium sulfate. After digestion, the mixture was cooled, diluted with distilled water, and made alkaline. The liberated ammonia was then distilled into a boric acid-receiving solution and titrated with standard acid. A blank sample was also analysed using the same procedure. The nitrogen content obtained from titration was converted into protein content using the protein conversion factor. This method is widely used for protein determination in food and fish samples, including mudskipper proximate composition studies (AOAC International, 1983; Chakma *et al.*, 2024; Mæhre *et al.*, 2018). The protein content was calculated using *Equation 3*:

$$P = \frac{(Vs - Vb) \times N \times 14.007 \times Cf}{W \times 10} \quad (3)$$

where P is the percentage protein content, Vs is the volume of titrant used for the subsample (mL), Vb is the volume of titrant used for the blank (mL), N is the normality of the standard acid, 14.007 is

the atomic weight of nitrogen, Cf is the protein conversion factor (5.75), and W is the weight of the subsample (g).

Statistical analysis

All proximate composition data were organised according to sampling site and month before statistical analysis. Moisture, ash, and protein content were treated as dependent variables. The two independent factors were sampling site and sampling month. The descriptive statistics, including mean and standard deviation, were calculated for each proximate composition variable. Before performing an analysis of variance, the assumptions of normality and homogeneity of variance were checked using the Shapiro–Wilk test and Levene’s test, respectively. A two-way analysis of variance without replication was used separately for moisture, ash, and protein content to evaluate whether proximate composition varied significantly among sampling sites and months. This model was selected because pooled samples were analysed for each site–month combination; therefore, only the main effects of site and month were tested, and the interaction effect was not assessed. For protein analysis, the missing value caused by insufficient sample availability was treated as missing data and excluded from the relevant analysis.

PAST software (version 3) was used to conduct the Shapiro–Wilk test, Levene’s test, and two-way analysis of variance. Microsoft Excel (version 2007) was used for data entry, data arrangement, calculation of descriptive statistics, and preparation of tables and graphs. ArcGIS (version 10.3) was used for preparing the study-area map and spatial visualisation of the sampling sites.

Statistical significance was accepted at $p < 0.05$.

RESULTS AND DISCUSSION

Proximate composition of *Boleophthalmus boddarti*

Numerous studies have demonstrated that fish meat contains 16–21% protein, <0.5% carbohydrates, 1.2–1.5% ash, 0.2–25.0% lipids, and 66–81% moisture. Fish consumption can contribute high-quality protein and essential nutrients that support normal growth and physiological functions (FAO, 1999). Protein is generally the second most abundant component of fish muscle after water (FAO, 2004). Lall and Anderson (2005) state that fish protein is a great source of the essential amino acids cysteine, methionine, and lysine. It can also greatly increase the value of energy-based diets that are deficient in these amino acids. Ash content provides an estimate of the total mineral residue present in a food sample. Numerous factors, including seasonality, biological differences, food source, and physicochemical parameters of the habitat, can affect the concentration of minerals and trace elements that contribute to the total ash content (Akande and Faturoti, 2005). Adeyeye *et al.* (2010) state that information about an organism’s moisture content can help preserve its characteristics as well as its susceptibility to fungal infection, microbial deterioration, and oxidative degradation of polyunsaturated fatty acids. Accordingly, high moisture content in a fish’s body gradually lowers the fish’s quality (Sampels, 2015). However, researchers have also noted that the fish’s sex can affect its moisture

content (Islam and Joadder, 2005; Alemu *et al.*, 2013).

The proximate composition of *B. boddarti* is shown in Table 1. Protein was the dominant proximate component, followed by ash and moisture. Although numerical variation was observed among sites and months, the differences were not statistically significant. Therefore, the results indicate that the proximate composition of *B. boddarti* remained comparatively stable across the sampled coastal habitats during the study period.

Protein content ranged from 57.75–77.00%, with the highest value at Naf Jetty in January. Mean protein content was similar in December and January and declined slightly in February, with values of $65.82 \pm 3.78\%$, $65.87 \pm 6.41\%$, and $63.69 \pm 2.17\%$, respectively (Figure 3C, D). Although this decreasing trend was not significant, it may reflect minor seasonal changes in feeding activity, maturation stage, or energy allocation. Fish protein is nutritionally important because it provides essential amino acids required for growth, tissue maintenance, and human health (FAO, 1999; Lall and Anderson, 2005). The protein values observed in this study provide baseline, dried sample-based proximate composition information for *B. boddarti* and should be compared only with studies reporting protein on a similar dry-weight or dried-sample basis. The present finding is consistent with recent evidence that incorporating fish into food formulations can enhance protein content and improve the nutritional value of foods intended for vulnerable groups, including young children (Kaunda *et al.*, 2025).

Ash content reflects the total mineral residue in fish tissue and can

provide a general indication of the mineral contribution of a fish species to the diet. In the present study, ash content varied from 4.23–21.57%, with the lowest value recorded at Keary Ghat in January and the highest value at Naf Jetty in February. Mean ash content increased slightly from December to February, with values of $14.10 \pm 2.36\%$, $14.55 \pm 4.17\%$, and $16.73 \pm 3.50\%$, respectively (Figure 3B, D). However, this pattern should be interpreted cautiously because the variation was not significant. Minor differences in ash content may be associated with site-specific sediment characteristics, food availability, physiological status, or mineral availability in the surrounding habitat. Previous studies have reported that ash content in fish may vary depending on species, season, diet, habitat condition, and mineral accumulation (Akande and Faturoti, 2005; Adeyeye *et al.*, 2010). The moderate ash content observed in the present study suggests that *B. boddarti* may contribute minerals as part of coastal diets, although detailed mineral profiling is required for stronger nutritional interpretation.

Moisture content ranged from 9.82–20.24%, with the lowest value recorded at Inani in January and the highest value at Shamlapur in February. Mean moisture values were $12.91 \pm 1.51\%$ in December, $13.21 \pm 2.45\%$ in January, and $12.93 \pm 3.13\%$ in February, indicating limited temporal fluctuation (Figure 3A, D). Moisture content is important because it influences texture, freshness, microbial spoilage, storage stability, and processing suitability of fish products. In fish, moisture may vary according to species, age, diet, season, sex, reproductive stage, and environmental condition (Alemu *et*

al., 2013; Islam and Joadder, 2005; Shearer, 1994). The comparatively low moisture values recorded in the present study are likely related to the dry-weight basis of analysis and sample-processing conditions; therefore, comparison with wet weight-based studies should be made carefully.

The spatial pattern of the proximate composition among samples showed only descriptive differences among the nine sampling sites (Figure 4). Samples from Naf Jetty had the highest individual protein value, while samples from Rezu

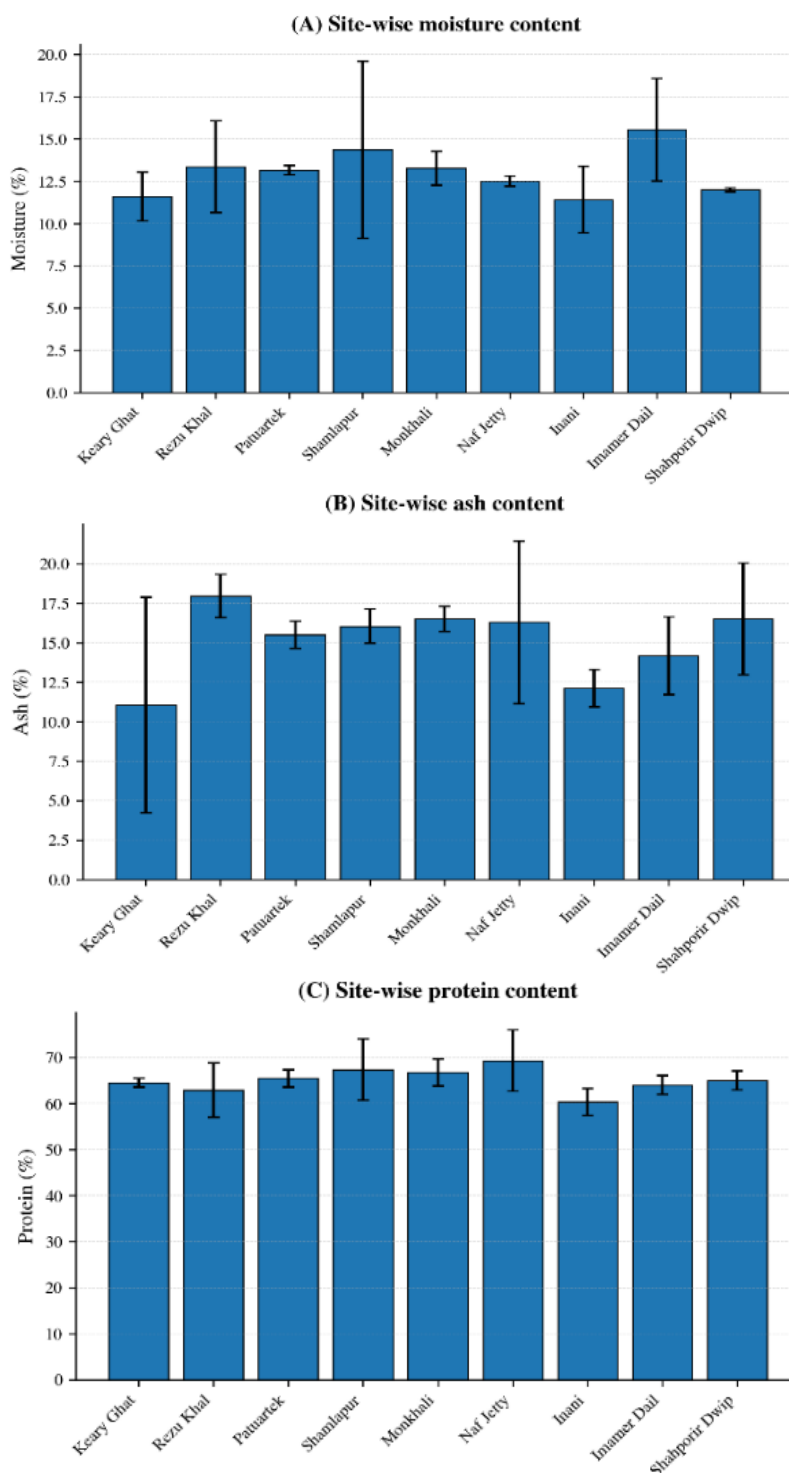
Khal, Shamlapur, and Shahporir Dwip had relatively high values for the three variables. In contrast, samples from Inani and Keary Ghat had lower values for some components. These differences may be associated with local environmental conditions such as tidal exposure, salinity influence, sediment type, organic matter availability, estuarine connectivity, food resources, and human activities. However, because site-wise variation was not significant, these patterns should not be over interpreted as strongly habitat-driven.

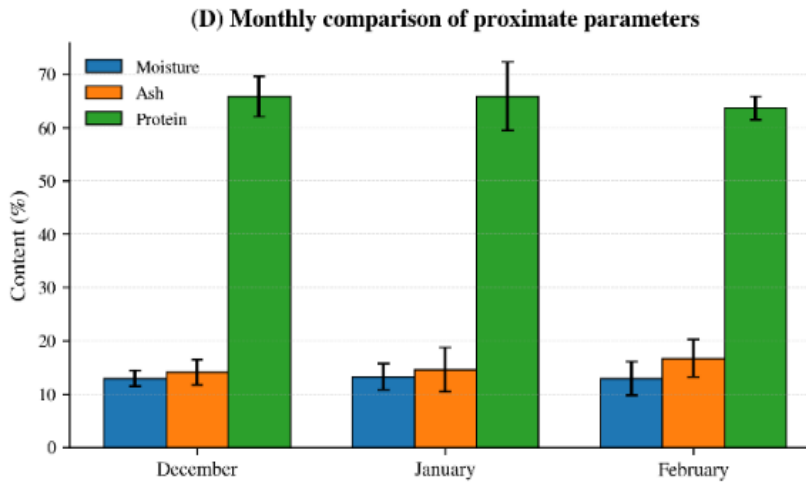
Table 1 – Proximate composition of *Boleophthalmus boddarti* based on site-month composite samples collected along the Cox's Bazar–Teknaf coast, Bangladesh

Sites	Month	Moisture (%)	Ash (%)	Protein (%)
Keary Ghat	December	11.59	11.05	64.49
	January	13.02	4.23	65.45
	February	10.16	17.87	63.52
Rezu Khal	December	15.32	16.52	69.30
	January	14.50	19.23	57.75
	February	10.27	18.13	61.60
Patuartek	December	13.47	14.77	67.37
	January	12.98	15.27	65.45
	February	13.01	16.47	63.52
Shamlapur	December	10.23	17.23	71.22
	January	12.59	15.12	71.22
	February	20.24	15.79	59.67
Monkhali	December	14.30	16.43	69.30
	January	13.16	15.74	67.37
	February	12.30	17.33	63.52
Naf Jetty	December	12.81	11.29	65.45
	January	12.20	15.98	77.00
	February	12.50	21.57	65.45
Inani	December	13.61	11.72	59.67
	January	9.82	13.43	57.75
	February	10.81	11.20	63.52
Imamer Dail	December	12.80	14.17	62.55
	January	18.81	16.65	NA
	February	15.02	11.70	65.45
Shahporir Dwip	December	12.09	13.74	63.00
	January	11.86	15.27	65.00
	February	12.03	20.50	67.00

NA = not available due to insufficient sample material

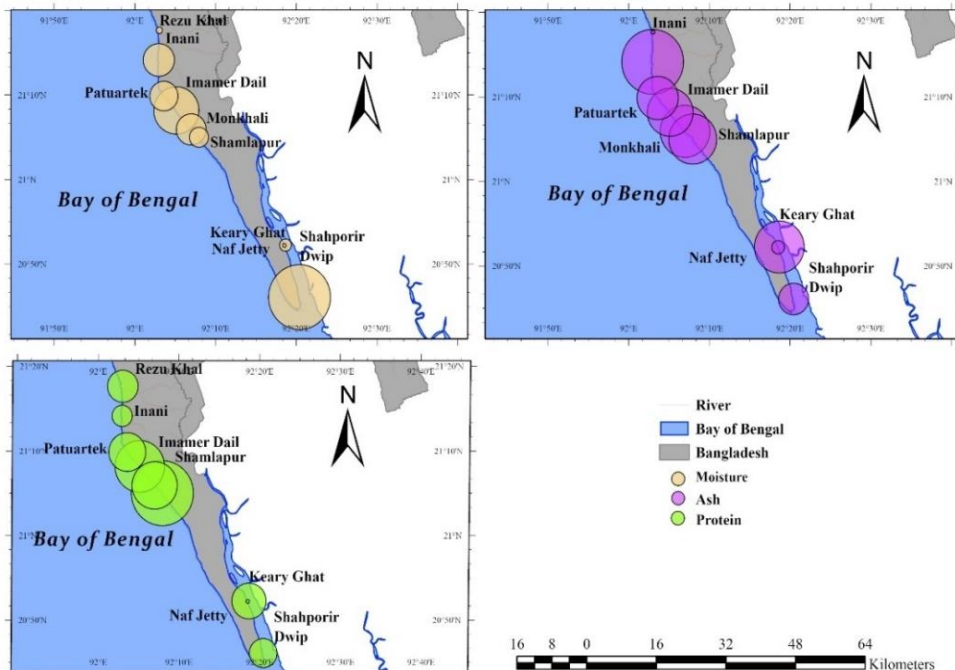
Proximate composition analysis of the mudskipper *Boleophthalmus boddarti* from Cox's Bazar, Bangladesh





(A) Moisture content across sampling sites; (B) Ash content across sampling sites; (C) Protein content across sampling sites; and (D) Moisture, ash, and protein content across three sampling months. Values are presented as mean $\pm$ standard deviation

Figure 3 – Variation in the proximate composition of *Boleophthalmus boddarti* from the Cox's Bazar–Teknaf coast, Bay of Bengal, Bangladesh among sites and months



The map shows the relative distribution of moisture, ash, and protein content across nine sampling sites. The spatial pattern indicates descriptive site-level variation, but the observed differences were not statistically significant

Figure 4 – Spatial distribution of the proximate composition parameters of *Boleophthalmus boddarti* from the Cox's Bazar–Teknaf coast, Bay of Bengal, Bangladesh

The monthly comparison showed that ash content increased slightly from December to February, protein content decreased slightly during the same period, and moisture content remained nearly stable (*Figure 3D*). This pattern suggests minor temporal shifts in proximate composition, but not enough to indicate a statistically meaningful seasonal change within the three-month sampling period.

Similar variations in fish proximate composition have been linked to feeding intensity, reproductive condition, environmental parameters, and habitat productivity (El Oudiani *et al.*, 2019; Shearer, 1994; Siva Prasad *et al.*, 2017; Varghese *et al.*, 2016). Overall, the stability of moisture, ash, and protein content suggests that *B. boddarti* maintains a relatively consistent proximate composition profile across the sampled coastal habitats during the winter. The observed patterns in proximate composition may be influenced by several biological and environmental factors. In fish, moisture, ash, and protein content can vary according to feeding intensity, food availability, reproductive stage, size, physiological condition, habitat productivity, salinity exposure, sediment characteristics, and seasonal environmental change. For an intertidal species such as *B. boddarti*, tidal exposure, estuarine influence, organic matter availability, and benthic food resources may also affect nutrient accumulation and body composition. However, these possible drivers were not measured in the present study. Therefore, the observed site- and month-wise differences should be interpreted as descriptive patterns rather than evidence

of confirmed environmental or biological control. The comparatively high protein content and moderate ash content observed in *B. boddarti* support its potential value as an underutilised coastal food resource. Previous studies on mudskipper and small indigenous fish species have shown that proximate composition varies widely among species, geographic regions, habitats, and analytical methods (Chakma *et al.*, 2024; Duggal *et al.*, 2020; Karnila *et al.*, 2023; Muhartati *et al.*, 2021).

Compared with many wet weight-based studies, the present study showed higher protein and ash values and lower moisture values, which may be explained partly by the dry-weight basis of analysis. Therefore, direct comparison with wet-weight studies should be made cautiously. Nevertheless, the results provide preliminary proximate composition data for *B. boddarti* from the Cox's Bazar–Teknaf coast and should be interpreted as baseline information rather than evidence of exceptional nutritional superiority. Indeed, they support the mudskipper's possible use in nutrition-oriented fishery development, dried fish products, fish powder preparation, and small-scale value-added food applications. Further studies on lipid content, amino acid profile, fatty acid composition, micronutrients, heavy metals, microbial safety, and year-round seasonal variation are required before recommending wider dietary or commercial utilisation.

Comparative analysis of the nutritional parameters of mudskipper species

As a result of variation among species, environments, and analytical

techniques, the comparative proximate composition of mudskipper species across national and international studies (Table 2) shows substantial variation in moisture, ash, and protein levels. *Boleophthalmus boddarti* from Cox's Bazar had relatively high protein ($65.10 \pm 4.32\%$) and ash ($15.13 \pm 3.49\%$) content in the present research, but moisture content ($13.02 \pm 2.36\%$) was comparatively low.

The majority of research from Indonesia, India, Nigeria, and South Korea reported significantly higher moisture levels (about 70–85%) and lower protein and ash content; this pattern is typical of wet weight-based analyses (Duggal *et al.*, 2020; Jung *et al.*, 2017; Karnila *et al.*, 2023; Muhartati *et al.*, 2021; Udoinyang *et al.*, 2022). The average protein and ash concentrations in *Boleophthalmus* spp. and *Apocryptes bato* (Chakma *et al.*, 2024; Wisudyanti *et al.*, 2022) were moderate. However, high levels of moisture and protein in Indonesian populations of *Periophthalmodon schlosseri* (Girsang *et al.*, 2018; Lestari *et al.*, 2022; Purwaningsih *et al.*, 2014) were observed. The different populations of mudskippers in Nigeria have high protein and low moisture content, with some populations having a high moisture content (Andem and Ekpo, 2014; Felagha *et al.*, 2022), while other populations were predominantly composed of moisture (Udoinyang *et al.*, 2022). Many of the Korean species, such as *Boleophthalmus pectinirostris*, also exhibited variable protein and moisture levels among the high-protein, low-moisture populations as well as the high-moisture populations, and this variability progressively increased throughout the

season and from one sample to another (Jung *et al.*, 2017). The increases in protein and ash concentrations in the present study are likely due to moisture loss, which increases the concentration of nutrients and minerals in the fish. The moisture levels identified in previous studies diluted the protein and ash concentrations in those studies. Additional heterogeneity among studies is likely due to environmental conditions, habitat type, food ecology, and unique physiological characteristics of each species (Bija and Rozi, 2023).

Correlation coefficient matrix

To explore the relationships between the proximate composition components of *B. boddarti* (moisture, ash, and protein), correlation coefficients were calculated to assess if changing one of the composition components would yield a predictable change in the others.

According to the results of the correlation analysis, the components of the proximate composition were positively correlated with one another. Moisture and protein had a weak positive correlation ($r = 0.23$). Ash and protein had a moderate positive correlation ($r = 0.44$), whereas moisture and ash had a weak positive correlation ($r = 0.37$). These results suggest that there is very little association among the proximate components on each other, with the most reliable association between ash and protein.

Limitations of the study

Although this study provided baseline information on the proximate composition of *B. boddarti* from the Cox's Bazar–Teknaf coast, several limitations should be considered when interpreting the findings.

Proximate composition analysis of the mudskipper *Boleophthalmus boddarti* from Cox's Bazar, Bangladesh

Table 2 – A comparison of national and international studies of the proximate composition of mudskipper species

Species	Moisture (%)	Ash (%)	Protein (%)	Location	References
<i>Boleophthalmus boddarti</i> (DW)	13.02 ± 2.36	15.13 ± 3.49	65.10 ± 4.32	Cox's Bazar, Bangladesh	Present study
<i>Periophthalmodon schlosseri</i>	79.13 ± 0.36 (WW)	4.54 ± 0.17 (DW)	91.85 ± 1.51 (DW)	Tanjung Tiram, Batubara Regency, Indonesia	Karnila <i>et al.</i> , 2023
<i>Boleophthalmus dussumieri</i>	84.70 ± 1.21 (WW)	NR	36.76 ± 13.18 (DW)	Gujarat and Maharashtra states of India	Duggal <i>et al.</i> , 2020
<i>Apocryptes bato</i> (male) (WW)	82.50 ± 0.03	2.18 ± 0.02	12.28 ± 0.06	Payra River, Bangladesh	Chakma <i>et al.</i> , 2024
<i>Apocryptes bato</i> (female) (WW)	81.78 ± 0.04	2.38 ± 0.03	12.85 ± 0.14	Payra River, Bangladesh	Chakma <i>et al.</i> , 2024
<i>Boleophthalmus</i> sp. (WW)	81.02	1.69	20.67	Mempawah mangrove area, Indonesia	Muhartati <i>et al.</i> , 2021
<i>Boleophthalmus boddarti</i>	50.87 (WW)	2.06 (DW)	17.85 (WW)	Mangrove forest area, Karangtalun Village, Cilacap, Indonesia	Wisudyanti <i>et al.</i> , 2022
<i>Periophthalmus barbarus</i> (WW)	79.95 ± 3.69	1.46 ± 0.27	18.62 ± 1.40	Ibaka mangrove ecosystem, Akwa Ibom State, Nigeria	Udoinyang <i>et al.</i> , 2022
<i>Periophthalmus koelreuteri</i> (DW)	6.00 ± 0.04	18.00 ± 1.00	52.50 ± 0.20	Okpoama-Brass, Bayelsa State, Nigeria	Felagha <i>et al.</i> , 2022
<i>Periophthalmus barbarus</i> (DW)	10.0 ± 0.25	17.9 ± 0.13	55.2 ± 0.76	Mangrove Swamp of Calabar River, Southern Nigeria	Andem and Ekpo, 2014
<i>Boleophthalmus pectinirostris</i> (WW)	58.70 - 75.80	1.30 - 3.60	16.10 - 17.60	Gangjin, Jeonnam, Korea	Jung <i>et al.</i> , 2017
<i>Mudskipper</i> sp. (WW)	79.30	3.40	9.75	Proboscis Monkey and Mangrove Conservation Area (KKMB), Tarakan City, North Kalimantan, Indonesia	Bija and Rozi, 2023
<i>Periophthalmodon schlosseri</i>	79.71 ± 0.98 (WW)	6.87 ± 0.64 (DW)	81.22 ± 2.74 (DW)	Sagara Anakan, Cilacap, Indonesia.	Purwaningsih <i>et al.</i> , 2014
<i>Periophthalmodon schlosseri</i>	79.13 (WW)	4.54 (DW)	92.83 (DW)	Lima Laras Village, Tanjung Tiram District, Batubara Regency, Indonesia	Girsang <i>et al.</i> , 2018
<i>Periophthalmodon schlosseri</i> (DW)	72.80	3.82	7.91	Mempawah mangrove ecosystem, West Kalimantan, Indonesia	Lestari <i>et al.</i> , 2022

DW = dry weight, WW = wet weight, NR = data not reported

First, the study was conducted only from December to February; therefore, the results represent a short winter-season sampling period and may not reflect year-round seasonal variation. Since fish proximate composition can be influenced by reproductive cycles, feeding intensity, temperature, salinity, and seasonal habitat conditions, future studies should include samples from all major seasons.

Second, the analysis was limited to three proximate composition variables, i.e., moisture, ash, and protein. Other important nutritional components, including lipid content, carbohydrates, and amino acid profiles, fatty acid composition, vitamins, and macro- and micro-minerals, were not analysed. As a result, the full nutritional value of *B. boddarti* was not completely assessed. In addition, food-safety variables such as heavy metals, microbial load, and other contaminants were not examined, although these are important before recommending wider dietary or commercial utilisation.

Third, pooled site-month composite samples were used for the proximate composition analysis. Although this approach provided an overall estimate for each site and month, it limited the ability to evaluate individual-level variation among fish. Therefore, possible effects of sex, size, maturity stage, age, and body condition on proximate composition were not assessed. In addition, because analytical replicates were not performed for each composite sample, laboratory repeatability and analytical variation were not evaluated; this should be considered when interpreting the variation observed among site-month values.

Fourth, although samples were collected from nine coastal sites, detailed environmental parameters such as salinity, temperature, dissolved oxygen, sediment organic matter, food availability, and pollution indicators were not measured at sample collection time. Therefore, the observed site-wise differences in proximate composition cannot be directly linked to specific environmental drivers.

Finally, because most spatial and monthly differences were not statistically significant, the findings should be interpreted primarily as baseline nutritional information rather than evidence of strong site- or month-based proximate variation. Future research with a larger sample size, individual-level analysis, year-round sampling, and combined nutritional, environmental, and food-safety assessment will provide a more complete understanding of the nutritional potential and sustainable utilisation of *B. boddarti*.

CONCLUSIONS

This study provided baseline information on the proximate composition of *B. boddarti* from the Cox's Bazar-Teknaf coast, BoB, Bangladesh. The results showed that protein was the dominant measured proximate component, followed by ash and moisture, in the analysed site-month composite samples. The observed differences among sites and months were not statistically significant, indicating that strong spatial or short-term monthly variation was not detected during the study period.

The findings should be interpreted cautiously because the study was limited

to three proximate composition variables, a short winter sampling period, and pooled site-month composite samples. In addition, environmental variables were not measured concurrently; therefore, the study cannot identify the specific biological or environmental drivers responsible for the observed numerical differences. The results should therefore be considered preliminary proximate composition data rather than a complete nutritional assessment or evidence of exceptional nutritional superiority.

Overall, the study contributes initial species- and region-specific proximate composition information for *B. boddarti* from the Bangladesh coast. Future studies should include year-round sampling, individual-level analysis, analytical replication, lipid and fatty acid profiling, amino acid analysis, mineral and vitamin assessment, contaminant screening, and simultaneous measurement of environmental parameters. Such work would provide a stronger basis for evaluating the nutritional relevance and sustainable use of this intertidal mudskipper species.

Author Contributions: Conceptualization: MSB; Methodology: MSB; Formal analysis: AJMM; Data analysis: MSB, SJF; Investigation: MSB; Supervision: MSB; Writing - original draft: MSB, SJF; Writing - review and editing: MSB, SJF, MRU. All authors declare that they have read and approved the final version of the manuscript.

Funding: This research received no external funding.

Acknowledgement: The authors are grateful to the Bangladesh Oceanographic Research Institute for providing the research facilities. The authors gratefully acknowledge the support of the volunteers who assisted with field sampling.

Data availability statement: Data are available within the manuscript.

Conflicts of interest: The authors declare no conflict of interest.

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Academic Editor: Dr. Alexandru USTUROI

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