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Research Article

Assessment of Riparian Ecosystem Health in the Tamiang River, Aceh, Indonesia as Remains Habitat of *Batagur borneoensis* (Schlegel & Muller, 1844)

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ABSTRACT

The riparian zone along the Tamiang River, Aceh Province, is an important habitat for the survival of the tuntong laut (*Batagur borneoensis*) which is already threatened with extinction. This study aims to evaluate the quality and role of the riparian zone as a habitat for *B. borneoensis* along the Tamiang River, which can then be used as a reference in conservation. Riparian habitat quality was assessed by calculating the Qualitat del Bosc de Ribera (QBR) index, which was determined based on the total riparian cover, cover structure, cover quality, and channel alteration. In addition, observations of water quality (salinity, turbidity, and dissolved oxygen (DO)) and the number of riparian vegetation species were also carried out. Monitoring was carried out at five stations: Iyu River, Kampung Baru, Batang Lawang, Pusong Kapal Dermaga, and Pusong Kapal. The results showed variations in water quality between locations with DO and turbidity levels exceeding the quality standards set by the government. The richness of the types of riparian vegetation found ranged from 0-8 species (seedlings), 2-7 species (saplings), and 1-4 species (poles). The quality of riparian habitats in all study locations experienced significant degradation, including the euhemerobic and polyhemerobic (Hemeroby) categories, Cultural assisted system and Semi-transformed system (Naturalness), and Extreme degradation to poor-fair quality (QBR). The presence of *B. borneoensis* in the research location can adapt to the poor quality of riparian habitat. However, the density decreases significantly at higher salinity.

Keywords: Batagur borneoensis, Hemeroby, Naturalness, QBR

Introduction

Tuntong laut (*B. borneoensis*) is a freshwater turtle commonly found in Sumatra and Kalimantan [1]. It is a terrapin species categorized as Critically Endangered in CITES Appendix II [2]. One of their natural habitats is located on the Tamiang River, Aceh Province [3]. *B. borneoensis* has seasonal behaviour to breed by migrating from freshwater rivers to the coast [4]. Some factors influence the *B. borneoensis* choice of where to lay eggs, including nuisance organisms, sand and soil conditions, and riparian vegetation [5]. At the same time, people's daily activities on the river can degrade the quality of the river and riparian habitats, affecting the presence of the *B. borneoensis*. The results of previous studies indicate that the riparian vegetation along the Tamiang River is dominated by one species of mangrove, Berembang (*Sonneratia caseolaris*), which is suitable for supporting the *B. borneoensis* habitat [6].

The existence of vegetation can positively impact the ecosystem balance [7]. The riparian zone is a semi-territorial transitional area regularly influenced by freshwater that extends from the water body's edge to the plateau's edge [8]. The riparian zone is a place to grow a variety of vegetation, from shrubs to poles, which function as food providers and animal habitats, maintaining

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biodiversity and ecological balance [9, 10]. The riparian zone is an essential habitat for the survival of adult and juvenile *B. borneoensis* because most of its activities, such as foraging, mating, and other activities, are not far from this zone [11]. However, within a decade, the riparian area of the Tamiang watershed experienced degradation, one of which resulted in flash floods [12].

Riparian degradation in the *B. borneoensis* habitat along the Tamiang river occurs due to increased human activities, such as land clearing for oil palm plantations, settlements, and expansion of rice fields. The intervention of community activities can disrupt the survival of animals in an ecosystem [13, 14] and cause species shifts and loss of habitat connectivity [6], especially the loss of the *B. borneoensis* population, even towards extinction. Mangrove vegetation, part of the riparian vegetation for the *B. borneoensis* habitat, needs attention and consistency in its management [6, 15] because it can affect the habitat of organisms with vulnerable life stages. In addition, another impact of riparian degradation is a decrease in water quality. The changed water quality parameters such as turbidity, salinity, and organic matter cause *B. borneoensis* to look for new habitats [4, 11, 16].

Approaches that are often used for monitoring the river riparian areas are the Qualitat del Bosc de Ribera (QBR), Naturalness and Hemeroby indices [17-19]. The QBR index helps to represent and manage the river's main channel and riparian areas. QBR index analysis was carried out based on four indicators: total vegetation cover, vegetation cover structure, cover quality, and river channel alterations [18]. The naturalness index analysis is carried out based on the naturalness of the habitat, while the hemeroby index analysis is carried out based on disturbances caused by human activities. By correlating the three indices, it can be used to assess an ecosystem's quality or health [17, 19]. Prevention efforts to limit damage to the riparian zone are carried out by using an ecological approach by maintaining the water quality parameters, riparian vegetation and environmental quality so that it can be a reference for better management of the *B. borneoensis* habitat [15, 20]. In this regard, it is necessary to protect and preserve riparian vegetation. So this study aimed to evaluate the quality and role of the riparian zone as a habitat for *B. borneoensis* along the Tamiang river, Aceh. This information is critical as a reference in the conservation of *B. borneoensis* because riparian vegetation is one of the essential components of an aquatic ecosystem.

Material and Methods

Study area

This research was conducted in August 2019. The research location was along the Tamiang River, Aceh Tamiang District, Aceh Province, Indonesia, with coordinates 4°23'19.31" North Latitude and 98°14'15.66" East Longitudes. Observations were conducted at five predetermined stations: Iyu River, Kampung Baru, Batang Lawang, Pusong Dermaga, and Pusong Kapal (Figure 1 and Table 1). The selection of research sites was determined by purposive sampling based on community information regarding the presence of *B. borneoensis*, which was often found to forage for food or come to the surface to sunbathe on fallen branches or poles.

Measurement of water physicochemical parameters

The measurement of water physicochemical parameters was repeated three times at each location. Water samples were collected using one-litre mineral water bottles. Water physicochemical parameters measured at the study site can be seen in Table 2. The measured water quality only consists of salinity, turbidity, and dissolved oxygen because these parameters influence the survival of *B. borneoensis* [27].

Determination of density of B. borneoensis

For collecting density data of *B. borneoensis*, some traps were installed along the Tamiang river. The trap used is 120 cm × 80 cm in size. Each location has two traps with an installation time of approximately 3 hours. Trap installation sites were selected based on information from the local community and YSLI manager as an organization of *B. borneoensis* conservation in Aceh. These stakeholders helped researchers to determine the sites where *B. borneoensis* was often found or observed mostly. Besides that, information about the number of *B. borneoensis* from stakeholders was then integrated with field data from the traps. This integrated data generated qualitative information in category data form, as seen in Table 3. This data form helped researchers to describe the field condition clearly because *B. borneoensis*

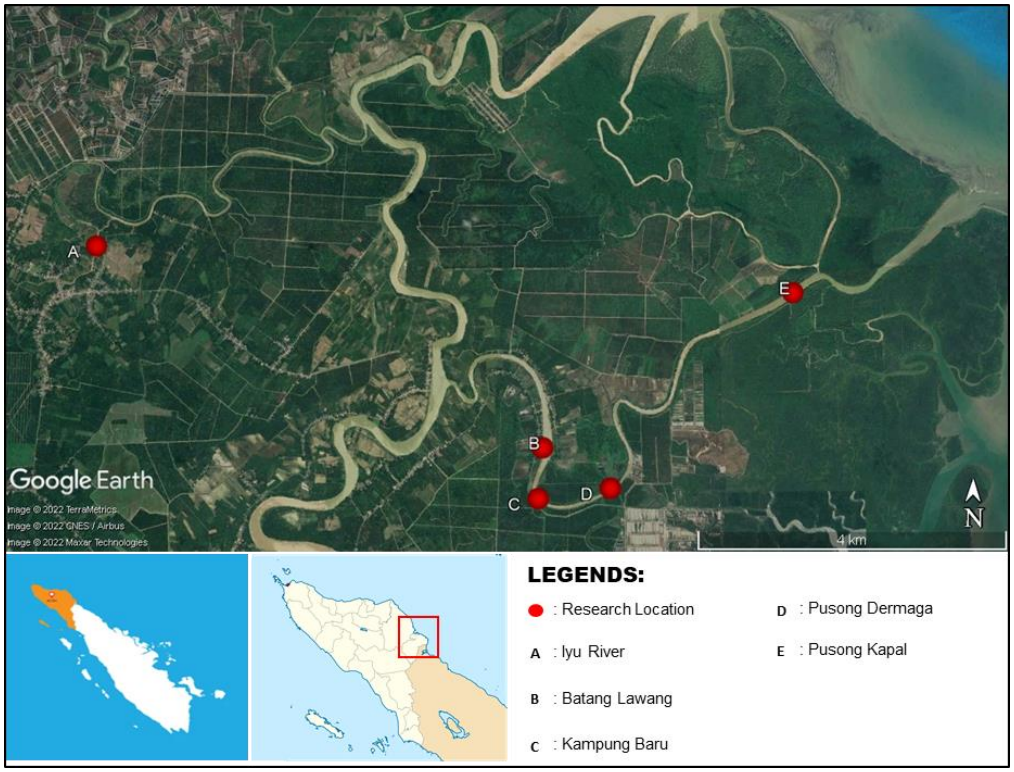


Figure 1. Sampling locations for quality analysis of riparian vegetation in the Tamiang River, Aceh Tamiang District, Aceh Province

Table 1. Detailed information on sampling stations

Stations	Surrounding Activities
Iyu River	settlements and oil palm plantations
Batang Lawang	oil palm plantations
Kampung Baru	oil palm plantations, mangrove forests, and boat transportation routes
Pusong Dermaga	settlements and oil palm plantations
Pusong Kapal	settlements and oil palm plantations

was not always trapped during trap installation.

Species richness of riparian vegetation in the Tamiang river

A vegetation analysis was carried out to determine the species richness of plant communities in each study site using quadratic plots. In each location, nested plots were established with 2 × 2 m^2, 5 × 5 m^2, and 10 × 10 m^2 to record all necessary data for seedling, sapling, and pole stages, respectively. The observed variables for each stage were as follows: (i) Seedling stage (germinated seeds to < 1.5 m in height): species, number of individuals of each species; (ii) Sapling stage (height > 1.5 m to the diameter at breast height (dbh) < 10 cm): species, number of individuals of each species; (iii) Pole stage (10 cm < dbh < 20 cm): species, number of individuals of each species. Each species found in one measurement plot was recorded to determine species richness. Species found are documented to facilitate the identification process.

Riparian ecosystem quality analysis with QBR Index

The quality of riparian along the Tamiang River as the habitat of *B. borneoensis* was determined using the QBR index. The design in determining the location of sampling using the purposive sampling method. Four indicators are considered in determining riparian habitat quality using the QBR index: total vegetation cover, vegetation cover structure, cover quality, and river channel alterations [21]. After the data is analyzed by adding up the four indicators, a value called classes of riparian quality is obtained with a value ranging from 0 to 100 and compared to Table 4 [22].

Environmental change analysis

Environmental change factors were determined by observing the area around the research location and then analyzing using the Hemeroby and Naturalness index. The Hemeroby Index is an index that describes the level of human disturbance to the ecosystem. This indicator uses vegetation classification rules to illustrate the level of human disturbance to the landscape or land use type. The Hemeroby index is determined based on the criteria for a combination of disturbance factors and has a category (Table 5) [23]. The Naturalness Index is an index that describes the level of naturalness of an ecosystem. Determination of the Naturalness index based on element value and naturalness category [24].

The measurement of the hemeroby index is based on the formula from [23], namely:

$$M = 100 \sum_{h=1}^{m} \frac{fm}{m} \times h \quad \ldots [1]$$

Description:
m : number of categories of hemeroby
fm : proportion of the area of the category *m*
h : hemeroby-factor (linear from *h*=1 for minimal und *h*=*m* for maximal hemeroby)

Data Analysis

The results of measuring water physicochemical parameters obtained from each location were then calculated by difference tests using SPSS Software. The difference test on each water physicochemical parameter at the observed location using the one-way ANOVA test, followed by the Tukey HSD test if the data distribution is normal and the data is homogeneous. If the data distribution is not normal and the data is heterogeneous, it used the Brown-Forsythe test, followed by the Games Howell test [25]. The analysis result of riparian vegetation was compilated using Microsoft Excel. The observations of the riparian vegetation profile were then used to calculate the QBR index. A PCA test was carried out to determine the parameters affecting the density of *B. borneoensis* at each location based on water quality, plant diversity, and riparian quality. Also, a Pearson correlation test was performed to determine the relationship between parameters, namely the density of *B. borneoensis* water quality, plant diversity, and riparian quality.

Results and Discussion

Water and plant diversity quality in the riparian zone of Tamiang River

The water quality in the Tamiang River ecosystem is obtained by measuring the physicochemical water parameters. The salinity values in Tamiang River ranged from 0–0.58%. The highest salinity value was found at the Pusong Kapal location (0.58%), while the lowest was at the Batang Lawang location (0%). The difference in salinity values at the study site is caused by the site

Table 2. Water physicochemical parameters measured at the study site

Parameter	Unit	Methods/Tools used
Salinity	%	Refractometer
Turbidity	NTU	Turbidity meter
Dissolved Oxygen (DO)	mg/L	Dissolved Oxygen meter

Table 3. Density categories of *B. borneoensis* found in the Tamiang River

Number of individuals	Category
0	Never found *B. borneoensis*
1	Rarely found *B. borneoensis* (Slight density)
2	Sometimes found *B. borneoensis* (medium density)
3	Often found *B. borneoensis* (many densities)

Table 4. Quality classes according to the QBR index

Riparian habitat quality class	QBR value	Colour Category
Riparian habitat in natural condition	≥ 95	Blue
Some disturbance, good quality	75–90	Green
Disturbance important, fair quality	55–70	Yellow
Strong alteration, poor quality	30–50	Orange
Extreme degradation, bad quality	≤ 25	Red

Table 5. Quality classes according to the Hemeroby index [23].

Degree of hemeroby	Degree of naturalness	Human Impact
Ahemerobe	Natural	none
Oligohemerobe	Close to natural	limited removal of wood, pastoralism, imissions through air and water
Mesohemerobe	Seminatural	clearing and occasional ploughing, clear-cut, occasional slight fertilization
Euhemerobe	Far from natural	application of fertilizers, lime and fertilizers, ditch drainage, deep ploughing, drainage, application of pesticides and intensive fertilization
Polyhemerobe	Strange to natural	single destruction of the biocenosis and covering of the biotope with external material at the same time
Metahemerobe	Artificial	biocenosis destroyed

taking from upstream to downstream, where the downstream is close to the estuary. Based on Indonesia government regulation (PP) No. 22 of 2021 concerning water quality standards for biota in mangroves [26], the range of salinity values at all locations met the standard from 0-34‰ or 0-3.4%. *B. borneoensis* prefers low salinity water in the range of 0-5‰ [27]. Most *B. borneoensis* activities include foraging in rivers with low salinity [4].

The turbidity values of each location ranged from 7.99-22.15 NTU. The highest turbidity value was found at Kampung Baru (22.15 NTU), while the lowest was at Pusong Kapal (7.99 NTU). Based on PP No. 22 of 2021 concerning water quality standards for biota in mangroves [26], all locations did not meet the standard, i.e. 5 NTU. The high turbidity value at the study site is due to the entry of sediment and pollutants around the river flow and water runoff, especially from agricultural and plantation areas [28, 29]. In addition, the high intensity of illegal logging in the riparian zone along the Tamiang River, Aceh, is also a significant factor causing water degradation because riparian functions are lost, so sediment stabilization and nutrient filtration are disturbed [11, 28].

The DO values obtained in this research ranged from 3.92-4.84 mg/L. The value of DO in all locations did not meet the Indonesian government standard, i.e.> 5 mg/L. Some human activities can increase the level of pollutants and sediment in the water, further reducing the DO concentration in the water for the degradation process [30] [31].

The profile of riparian vegetation along the Tamiang River as a habitat for *B. borneoensis* can be seen from species richness. The taxa richness of riparian vegetation found along the observation sites varied and ranged from 0-8 species (seedling), 2-7 species (sapling), and 1-4 species (poles). Pusong Kapal is the downstream location with the highest taxa richness of riparian vegetation in the form of seedlings. However, this differs from the conditions in the Iyu River, located upstream, where no seedlings are found (Figure 2).

The results of this study can indicate that in the future, it is suspected that it will impact the extinction of riparian vegetation, so revegetation activities are necessary. The riparian vegetation was more commonly found in downstream areas. The results showed that the riparian seedling vegetation ranged from 0-8 species, with *Sonneratia caseolaris* dominating except in the Iyu River, where no dominance was found. The fruit of *S. caseolaris* is food for the *B. borneoensis*. In addition, the growing poles are suitable habitats for *B. borneoensis*, including as shelters and perches for both young and adults [6].

Riparian vegetation in the form of saplings was found between 2-7 species. Similar to seedlings, more taxa richness was found downstream. The species of sapling that dominates each location is different. *Nypa fruticans* dominated the site of the Iyu River. Batang Lawang and Pusong Kapal were dominated by *S. caseolaris*. Kampung Baru was dominated by *Barringtonia racemosa*,

Table 6. The water quality of the Tamiang River

Location	Salinity (%)		Turbidity (NTU)		Dissolved oxygen (mg.L^{-1})	
Iyu River	0.10 ± 0.00	bc	15.20 ± 3.40	b	3.92 ± 0.14	a
Batang Lawang	0.00 ± 0.00	a	12.57 ± 3.11	b	4.56 ± 0.20	b
Kampung Baru	0.13 ± 0.03	c	22.15 ± 0.15	c	4.84 ± 0.07	b
Pusong Dermaga	0.09 ± 0.02	b	11.99 ± 2.64	ab	4.47 ± 0.29	ab
Pusong Kapal	0.58 ± 0.55	d	7.99 ± 0.77	a	4.58 ± 0.42	b

Note: The same letter notation at the same parameter showed no significant difference between locations based on the one-way ANOVA test followed by Tukey HSD (Turbidity and Dissolved Oxygen) and Kruskal-Wallis followed by Mann Whitney test (Salinity); α 0.05 and n= 3-8

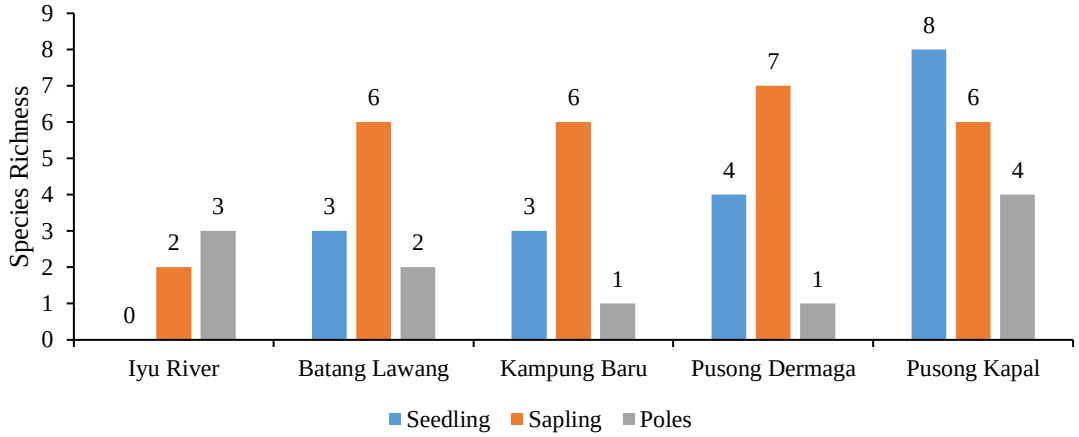


Figure 2. Species richness of riparian vegetation in the *B. borneoensis* habitat along the Tamiang River

while *N. fruticans* and *S. caseolaris* dominated Pusong Dermaga.

The number of poles taxa richness in the riparian zone of the sampling location ranged from 1-4 species. Pusong Kapal had the highest pole taxa richness, while other locations were low. The Iyu River was dominated by *N. fruticans* poles, while other locations were dominated by *S. caseolaris*. The finding of species dominance in each research location indicated that the river riparian ecosystem in the research location is still less stable. Proper conservation at the research site is always necessary to maintain the ecosystem. Types of poles dominating the riparian zone of the Tamiang River come from mangrove vegetation. This mangrove vegetation plays a role in preventing water eutrophication [32]. Besides that, mangrove vegetation also plays a role in the remediation of heavy metals and oil in the waters [33, 34].

Density of B. borneoensis along the Tamiang River

Based on the results of trapping and interviews, the number of *B. borneoensis* found by the community varied between locations (Table 7). The highest density of *B. borneoensis* was found in Batang Lawang and Kampung Baru, while the lowest was in Pusong Kapal. The locations of Batang Lawang and Kampung Baru are locations that support the survival of *B. borneoensis* because the riparian vegetation is dominated by *S. caseolaris* (as the primary food) [16] and the salinity value is low [6, 27].

Riparian ecosystem quality based on the QBR index in the Tamiang River

The results of determining the quality of riparian habitat can be seen in Table 8. The highest total riparian cover was found in the Iyu River and Pusong Kapal, with riparian cover values of 10-80%, while the lowest was found in Pusong Dermaga, with riparian cover values of 0-50%. The highest cover structures are found in Iyu River and Pusong Kapal, with tree cover values of 25-75% and Shrubs 10-25%, while the lowest is at Pusong Dermaga with Tree cover values of 0-25% and Shrubs 10-25%. The highest cover quality was found in Iyu River and Pusong Kapal with a number of endemic species 1-3, while the lowest

Table 7. Density of *B. borneoensis* along Aceh Tamiang River

Location	Density	Description
Iyu River	2	Sometimes found (medium density)
Batang Lawang	3	Often found (high density)
Kampung Baru	3	Often found (high density)
Pusong Dermaga	2	Sometimes found (medium density)
Pusong Kapal	0-1	Never-Rarely found (0-low density)

Table 8. Riparian habitat quality at five research locations on the Tamiang River

Location	Total riparian cover	Cover structure	Cover quality	Channel alteration	QBR
Iyu River	5-10	5-10	5-25	10	25-55
	Riparian cover 10-80%	Tree cover 25-75%	Number of native tree species 1-3	Fluvial terraces modified	Extreme degradation-strong alteration, bad-poor quality
Batang Lawang	5	5	5-10	10	25-30
	Riparian cover 10-50%	Tree cover 25%: Shrubs 25%	Number of native tree species 1-2	Fluvial terraces modified	Extreme degradation-strong alteration, bad-poor quality
Kampung Baru	5	5	5	10	25
	Riparian cover 10-50%	Tree cover 25%: Shrubs 25%	Number of native tree species 1	Fluvial terraces modified	Extreme degradation, bad quality
Pusong Dermaga	0-5	0-5	0-5	5	5-20
	Riparian cover 0-50%	Tree cover 0-25%: Shrubs 10-25%	Number of native tree species 0-1	Channel modified by rigid structures along the margin	Extreme degradation, bad quality
Pusong Kapal	5-10	5-10	5-25	25	40-70
	Riparian cover 10-80%	Tree cover 25-75%; Shrubs 10-25%	Number of native tree species 1-3	Unmodified river channel	Strong alteration-disturbance importance, poor-fair quality

was in Pusong Dermaga with a number of endemic species 0-1. The highest channel alteration was found at Pusong Kapal, with an unmodified river channel shape, while the lowest was at Pusong Dermaga, with a modified channel shape by building structures along the river.

The results of the QBR index analysis can be seen in Figure 3. The quality of riparian habitat along the Tamiang River is low or poor (Iyu River and Pusong Kapal) to bad quality (Batang Lawang, Kampung Baru and Pusong Dermaga). Riparian habitat changes have a very significant impact on habitat degradation. This riparian ecosystem along the Tamiang River has not been managed. According to Indonesian Government Regulation No. 38 of 2011, the river border areas must be addressed for large unbanked rivers outside urban areas at least 100 m from the left and right of the riverbed along the river channel [38]. This riverbank cannot be converted unless it is used for a bridge.

Riverbank conversion degrades riparian habitats. River riparian vegetation affects biota migration [8]. The conversion of river border land mainly causes riparian habitat degradation in the Tamiang River into oil palm plantations, rice fields, ponds, or settlements. Various community activities in riverbank areas that do not follow the regional spatial plan will have an impact on decreasing the quality of the river border ecosystem, which in turn will also affect the decline in the population of *B. borneoensis*. Riparian ecosystem damage can disrupt turtle species' health [39], and reproductive success is

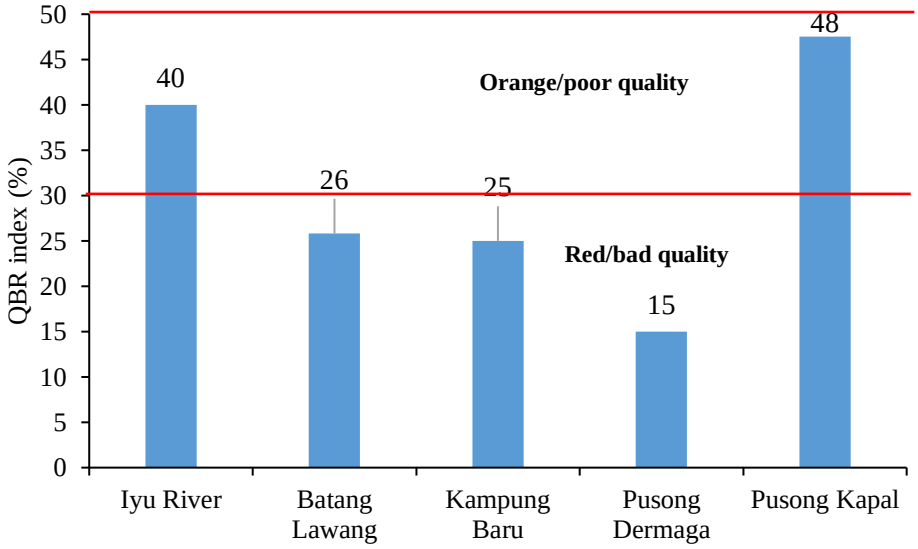
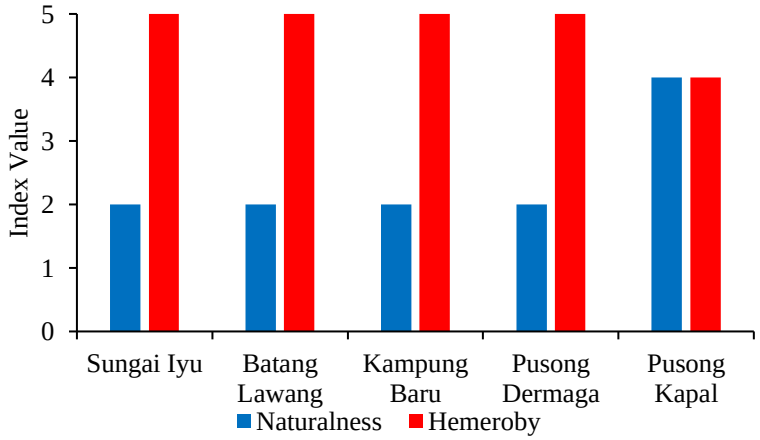


Figure 3. The quality of riparian vegetation in the Tamiang river based on the QBR Index



Naturalness:
2 = Semi-transformed system
4 = Cultural assisted system

Hemeroby:
4 = Euhemerobic
5 = Polyhemerobic

Figure 4. The quality of habitat riparian of Tamiang river based on Naturalness and Hemeroby Index

very low [40].

As seen at Pusong Dermaga site, watersheds near residential areas had a low QBR value (15), including the poor riparian habitat quality category. The Pusong Dermaga area had almost no riparian vegetation, and the residential areas also marked this area. The QBR values of Iyu River and Pusong Kapal were the highest compared to other locations. However, this value was still in the category of poor quality. This value indicated that the riparian habitat quality along the Tamiang River was already low. The low quality of riparian habitat was mainly caused by community activities such as land conversion to agriculture, plantations, and settlements [6].

Based on the research results above, improving the quality of riparian vegetation in the Tamiang River as a habitat for *B. borneoensis* is necessary. Since most *B. borneoensis* spend most of their lives in water [41], revegetation is needed along the river riparian zone and monitoring and control of human activities.

Anthropogenic factor quality in riparian zone of Tamiang River based on naturalness and hemeroby index

The level of human disturbance in the riparian zone of the Tamiang River can be seen based on

the hemeroby and naturalness indices. In general, it was found that all study sites had experienced significant disturbances (Figure 4). According to the hemeroby index, all locations belong to the category polyhemerobic (5), except Pusong Kapal, which is in the euhemerobic category or far from natural because many human activities have been found in the area (4). The low hemeroby value is in Pusong Kapal compared to other locations, indicating minimum human activity. The ecosystem with the category polyhemerobic indicated that there were soil mechanical disturbances, direct mechanical disturbances to vegetation, and high chemical disturbances [23, 35]. According to the naturalness index, all locations belong to the category Semi-transformed system (2), except for Pusong Kapal, which is included in the category Cultural assisted system (4). The landscape condition of the Semi-transformed system category is indicated by not dominant biological production, dominated by buildings in the surrounding area, and intensive water control [24, 35]. The five locations in this research included active areas such as settlements, agriculture, and plantations. In addition, it is positively correlated with the turbidity value due to the loss of riparian vegetation around the Tamiang River flow, which causes sediment entry and pollutants into the river [36]. Riparian vegetation can significantly affect water quality due to high anthropogenic activities, which can have an impact on reducing water quality [37].

Correlation between water, plant diversity, and riparian quality toward density of B. borneoensis in the Tamiang River

The grouping of riparian habitat quality along the Tamiang River and the interaction of some biotic and abiotic factors can be determined based on Principal Components Analysis (PCA) (Figure 5). From Figure 5, it is also obtained that PC1 and PC2 have been able to describe 84% of the data variance. Pusong Kapal had the best riparian habitat quality and was different from other locations. This result was characterized by the highest QBR and Naturalness index values, the lowest channel alteration, and better cover structure and quality with the lowest Hemeroby index. The lowest hemeroby index has resulted in low levels of turbidity. However, the presence of *B. borneoensis* was less, which might be due to the high salinity. Meanwhile, other locations have the opposite quality compared to Pusong Kapal, namely the level of Hemeroby and high turbidity, low salinity, and low QBR index, naturalness, and the quality of the cover structure. In addition, the channel alteration at this location was high, while the density of *B. borneoensis* was also high. Based on the PCA, it was known that *B. borneoensis* could survive in high human activities areas and environments with low naturalness levels and riparian habitat quality (QBR) as long as the salinity level is low. This result was in accordance with the research results by [6, 11, 27], who stated that the abundance of *B. borneoensis* was lower or

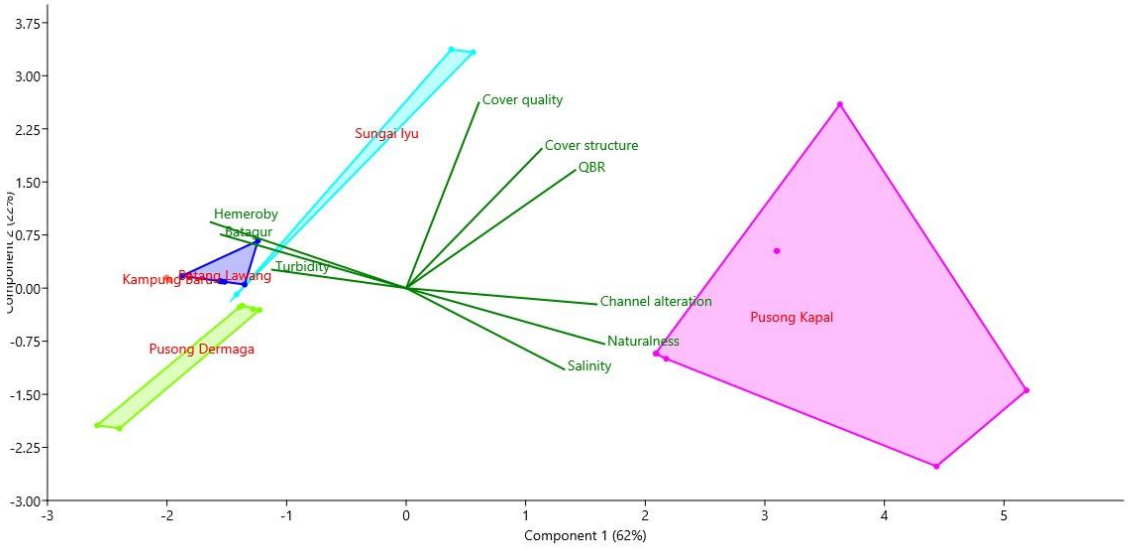


Figure 5. The profile of water and riparian habitats quality along the Tamiang River toward the density of *B. borneoensis* based on PCA

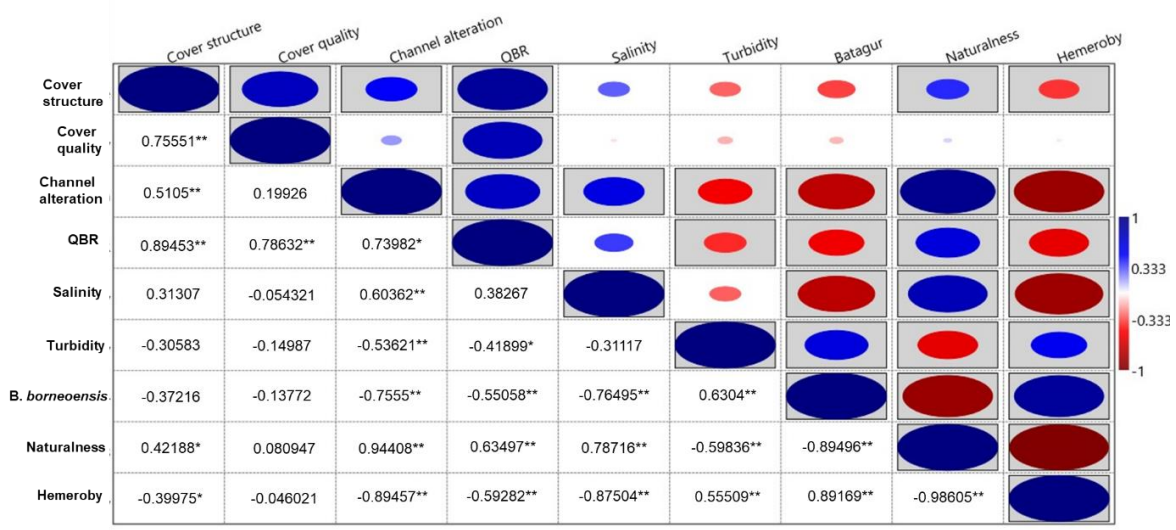


Figure 6. The correlation of water and riparian habitats quality along the Aceh Tamiang River toward the density of *B. borneoensis*

rarely found downstream of the Tamiang River with high salinity values.

The correlation between each parameter observed also be analyzed using the Pearson correlation test. The results showed that some parameters had positive or negative correlations (Figure 6). *B. borneoensis* strongly correlates positively with turbidity (0.6304**) and the hemeroby index (0.892**). Meanwhile, the presence of *B. borneoensis* has a strong negative correlation with channel alteration (-0.755**), QBR (-0.5506**), salinity (-0.765**), and naturalness (-0.895**). High salinity parameters tend to cause *B. borneoensis* to choose to look for new habitats [4, 11]. The density of *B. borneoensis* is influenced by QBR, canal alteration and naturalness. This result is shown from the density relationship of *B. borneoensis*, which is negatively correlated with QBR, canal alteration, and naturalness, shows that *B. borneoensis* has adapted to human disturbance and degradation of riparian habitat quality, including canal alteration, where canals built such as at the Pusong Dermaga location will cause *B. borneoensis* is becoming scarce [42, 43].

Conclusion

Water quality along the Tamiang River varies; all parameters observed have exceeded the quality standard values set by the Indonesian government, except for salinity. The taxa richness of riparian vegetation in Tamiang River was low and dominated by *Sonneratia caseolaris* for seedlings, saplings and poles. The quality of riparian habitat in all study sites has been significantly degraded, including in the category of euhemerobic and polyhemerobic (Hemeroby), Culturally assisted system and Semi-transformed system (Naturalness), Extreme degradation-poor-fair quality (QBR). The density of *B. borneoensis* at the study site could adapt to the riparian habitat's poor to bad quality. However, its density decreased significantly at higher salinity. Considering that *S. caseolaris* fruit is part of the diet of the *B. borneoensis*, it is necessary to revegetation this species in the degraded riparian zone.

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