Species richness and longitudinal distribution of crustaceans in the Logawa River, Banyumas, Indonesia

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Abstract. Sastranegara MH, Kusbianto, Pulungsari AE. 2020. Species richness and longitudinal distribution of crustaceans in the Logawa River, Banyumas, Indonesia. Biodiversitas 21: 5322-5330. The Logawa River originates in a forest on Slamet Mountain and empties into the Serayu River. In this river, crustaceans play an important role as river macrobenthos. This research aimed to evaluate the species richness and longitudinal distribution of crustaceans. The research method was a stratified random sampling technique at eight stations with five replicates. Crustacean samples were collected using a Surber net, and water samples were taken with a water sampler. The results showed that there were six species of Decapoda in the river. Of these six species, three were shrimps and three were crabs. In longitudinal distribution, the shrimp Macrobrachium idae could be categorized as a cosmopolitan species that inhabited all stations, although there were several river branches before Stations IV (Cangkriing Stream), V (Mengaji Stream), and VI (Banjaran Stream). The crab Varuna littorata was found only at Station VI. In general, the species richness decreased after Station IV due to COD from the riverside. This was caused by human activities such as stone and sand excavation and overfishing in the habitat. The upstream habitat with its bedrock substrate was not suitable for decapods, except for cosmopolitan species.

Keywords: Decapoda, river branching, riverside, substrate, water quality

INTRODUCTION

Lotic waters can be fresh or brackish. Freshwater flows from upstream to downstream and through areas of differing topography, and streams and tributaries can be merged along with the flow (Duya 2008). Such waterways have a function in storing and draining water from rainfall and other water sources. Water storage and drainage areas are arranged according to the natural conditions around them (Lazo et al. 2019).

Natural and anthropogenic disturbances can affect the species richness of organisms such as crustaceans that inhabit rivers. Environmentally detrimental methods of catching river species, such as the use of poisons and other chemicals, can threaten the presence of crustaceans and affect catches. Therefore, the understanding of biological and environmental parameters needs to be optimized to maintain the availability of wild products (Deekae and Abowe 2010). By collecting species richness data, researchers can gain insight into longitudinal distributions to map species distributions (Altermatt et al. 2014).

The Logawa River traverses various topographies, originating in a forest on the south slope of Slamet Mountain in Baturraden Sub-district, Banyumas District, Central Java Province, Indonesia, and emptying into the Serayu River. The Logawa River is about 25 km long from upstream to downstream. In some locations, human activities such as sand and stone excavation are destroying crustacean habitats. From the upstream to the downstream areas of the river, riversides are bounded by forest and garden areas, followed by rain-filled rice fields, irrigated rice fields, inorganic waste pollution in the form of mofur disposal, and organic waste pollution from settlements. Along the river, there is fishing activity using both fishing equipment and chemicals, which are disposed of in the river waters and cause decreases in some water quality parameters.

Studies have reported on crustacean species richness in various regions (Howard et al. 2015; Ng 2004; Sastranegara et al. 2020). Research on macrobenthic organisms, including insects, gastropods, and annelids, has also been carried out in the Logawa River (Wibowo et al. 2017). The altitudinal, latitudinal, and longitudinal distribution of freshwater amphipod species has been reported from Switzerland (Crustacea: Amphipoda) (Altermatt et al. 2014). However, the species richness and longitudinal distribution of freshwater decapod shrimp and crab species (Crustacea: Decapoda) have never been studied in this river. Therefore, research into the species richness and longitudinal distribution of crustaceans is important. Information from this research provides a necessary scientific foundation for the formulation of river management policies.

The purpose of this study was to evaluate the species richness and longitudinal distribution of crustaceans in the Logawa River in Banyumas, Indonesia. The findings of this study offer a scientific foundation for policies concerning the management of the Logawa River and the conservation of crustaceans.
MATERIALS AND METHODS

Study area

This research was conducted at eight stations (Stations I-VIII) along the Logawa River in Banyumas District, Central Java Province, Indonesia (Figure 1). Fieldwork was conducted for 3 months with five sampling replicates every 2 weeks, i.e., 16th June 2019, 30th June 2019, 14th July 2019, 28th July 2019, and 12th August 2019. Crustacean identification was carried out at the Aquatic Biology Laboratory, Faculty of Biology, Universitas Jenderal Soedirman, Purwokerto, Indonesia, and water quality analyses were conducted at the Environmental Laboratory of the faculty.

The characteristics of each station varied based on their coordinates, altitude, riverside, substrate types, human activities, width, depth, and location (Table 1). There were some branches in the river system before Stations IV, V, and VI (Figure 1).

Crustacean and water quality sampling

Crustacean and water quality samples were taken from the same study area. Shrimp and crab samples were preserved in alcohol. This study used a survey method employing a stratified random sampling technique with locations determined from upstream to downstream. Some stations were located after branches in the river system. From these streams and tributaries, the origin of species richness could be predicted.

Figure 1. Location of the Logawa River, Banyumas District, Indonesia indicating the crustacean sampling sites: Station I (07°19’36.20"S, 109°10’51.08"E), Station II (07°20’10.91"S, 109°11’00.05"E), Station III (07°21’51.07"S, 109°10’44.69"E), Station IV (07°24’05.09"S, 109°11’39.09"E), Station V (07°25’27.83"S, 109°11’47.70"E), Station VI (07°27’32.70"S, 109°12’50.92"E), Station VII (07°28’47.22"S, 109°13’00.84"E), and Station VIII (07°29’45.79"S, 109°13’02.58"E).
Table 1. Environmental conditions along the Logawa River, Banyumas District, Indonesia

| Characteristics | Station I          | Station II         | Station III         | Station IV         | Station V          | Station VI         | Station VII        | Station VIII        |
|-----------------|--------------------|--------------------|---------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Coordinate      | 7°19′36.20″ S 109°10′51.08″ E | 7°20′10.91″ S 109°11′00.05″ E | 7°21′51.07″ S 109°11′39.09″ E | 7°24′05.09″ S 109°11′47.70″ E | 7°27′32.70″ S 109°12′50.92″ E | 7°28′28.47″ S 109°13′00.84″ E | 7°29′45.79″ S 109°13′02.58″ E |
| Altitude        | 622 m asl.         | 486 m asl.         | 289 m asl.          | 115 m asl.         | 69 m asl.          | 43 m asl.          | 32 m asl.          | 31 m asl.          |
| Riverside       | - Forest           | - Garden           | - Rained rice field | - Settlement       | - Irrigated rice field | - Settlement       | - Irrigated rice field | - Garden           |
|                 | - Garden (agricultural areas) | - Settlement       | - Rained rice field | - Setlement        | - Irrigated rice field | - Settlement       | - Irrigated rice field | - Moor             |
|                 |                    |                    |                     |                    |                    |                    |                    | - Garden           |
|                 |                    |                    |                     |                    |                    |                    |                    | - Moor             |
|                 |                    |                    |                     |                    |                    |                    |                    | - Garden           |
|                 |                    |                    |                     |                    |                    |                    |                    | - Moor             |
| Substrate types | - Bedrock (40%)    | - Boulder (50%)    | - Boulder (40%)     | - Boulder (25%)    | - Boulder (10%)    | - Cobble (20%)     | - Cobble (10%)     | - Cobble (10%)     |
|                 | - Boulder (35%)    | - Cobble (30%)     | - Cobble (25%)     | - Cobble (25%)    | - Cobble (25%)    | - Cobble (5%)      | - Cobble (40%)     | - Cobble (10%)     |
|                 | - Cobble (15%)     | - Gravel (20%)     | - Gravel (25%)     | - Gravel (35%)    | - Gravel (35%)    | - Gravel (40%)     | - Gravel (40%)     | - Gravel (40%)     |
|                 |                    |                    | - Sand (15%)       | - Sand (30%)      | - Sand (30%)      | - Sand (45%)       | - Sand (30%)       | - Sand (30%)       |
|                 |                    |                    | - Gravel (15%)     | - Silt (10%)      | - Silt (10%)      | - Silt (10%)       | - Silt (10%)       | - Silt (10%)       |
|                 |                    |                    |                     |                    |                    |                    |                    |                    |
| Human activities| - Garden fertilization | - Garden fertilization | - Stone excavation | - Stone excavation | - Stone excavation | - Stone excavation | - Stone excavation | - Stone excavation |
|                 | - Fishing          | - Fishing          | - Sand excavation  | - Sand excavation  | - Sand excavation  | - Sand excavation  | - Sand excavation  | - Sand excavation  |
|                 |                    |                    | - Fishing          | - Fishing         | - Fishing         | - Fishing         | - Fishing         | - Fishing         |
| Width           | 12.0±1.22 m        | 10.8±1.10 m        | 15.3±2.22 m        | 15.3±2.22 m       | 15.3±2.22 m       | 15.3±2.22 m       | 15.3±2.22 m       | 15.3±2.22 m       |
| Depth           | 0.3±0.06 m         | 0.3±0.04 m         | 0.2±0.06 m         | 0.2±0.06 m        | 0.2±0.06 m        | 0.2±0.05 m        | 0.2±0.05 m        | 0.2±0.05 m        |
| Location        | Baseh              | Baseh              | Sunyalangu         | Jipang            | Karanglewas Kidul | Sidadoba           | Kedungrandu        | Notog             |
| Sub-district    | Kedungbanteng      | Kedungbanteng      | Karanglewas        | Karanglewas       | Karanglewas       | Patikraja          | Patikraja          | Patikraja         |
Crustacean and water quality sampling was carried out from upstream to downstream in longitudinal order. Crustacean sampling was carried out at eight stations (Figure 1). Crustacean samples were collected using a Surber net and water samples were collected using a water sampler with three replicates collected by switching location at each station at 20-minute intervals. In total, 120 samples were collected (8 stations × 3 plots × 5 replicates).

In the field, crustacean specimens were washed using clean running water, soaked immediately in plastic bags containing aqua dest, and then placed in plastic bags containing 96% alcohol solution for preservation. Bags were labeled with the location of the sampling station. In the laboratory, crustacean specimens were placed in specimen bottles containing 96% alcohol solution for preservation. These bottles were again labeled with the location of the sampling station.

For water quality samples, jerry cans were cleaned and filled with water in the field. These were labeled with the location of the sampling station. Samples were put inside a cool box at 4°C and transported to the laboratory within 8 hours.

Crustacean identification

Observations of shrimp and crab samples included the rostrum, post antennular shape, teeth on the anterolateral edge, spines and setae on the first pereiopods, number of pereiopods, carpus size, merus size, chela size, location of pubescence on the second pereiopods, chela gap in the second pereiopods, tubercles in the chela, preanal carina, abdomen, uropod, and telson. Measurements made of shrimp and crab samples included the rostrum, length, peduncle antennular length, carapace thickness and width, first and second pereiopods (length of the carpus, merus, and chela). These data were needed for the crustacean identification process. Shrimp and crab samples were identified based on Chia and Ng (2006), Devi and Joseph (2017), Ng (2004), Yule and Sen (2004).

Water quality analysis

Thirteen physical and chemical water quality parameters were tested. Physical variables included transparency, current velocity, flow velocity, temperature, and total suspended solids (TSS), and chemical parameters were pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), sulfide (H₂S), nitrate (NO₃), phosphate (PO₄), and ammonia (NH₃). These were analyzed using the Winkler and spectrophotometric methods based on APHA, AWWA, and WEF (2012).

Data analysis

Species richness was evaluated by Paleontological Statistics ver. 4.01, 1999-2020, for observed and estimated species, including Chao 1, Chao 2, Jackknife 1, Jackknife 2, and Bootstrap analyses (Hammer 2020). Environmental condition data by species were analyzed by Spearman rank correlation using IBM SPSS Statistics ver. 25, 2017 (IBM Corp., Armonk, NY, USA), for relationships between physical, chemical, and biological parameters. Dendrograms were obtained based on the similarity (%) matrix among the species assemblage from each sampling site and species distribution along the longitudinal gradient (IBM 2017). Longitudinal distribution was also analyzed descriptively and presented in the form of distribution patterns (Iglikowska and Namiotko 2012; Suryaningsih et al. 2018).

RESULTS AND DISCUSSION

Species richness

This research A total of six species of Decapoda were identified in this study (Table 2). The decapods were in three families: the Palaeomonidae (Macrobrachium cowlesi, M. idae, and M. oenone), Gecarcinidae (Parathelphusa bogoriensis and P. convexa), and Varuniidae (Varuna litterata) (Table 3). The observed species richness was an overestimate compared to the high means and standard deviations of the Chao 2 and Bootstrap analyses. Cumberlidge et al. (2014) noted that the use of the latest version of the software has corrected the previous former version. Jackknife 1 and 2 estimates were more reliable for correcting the bias of these decapods in Logawa River (the mean and standard deviation values of observed species richness were close to the estimates of 6; Table 2). By station, Chao 1 fit Station VII (lower and upper values were detected at 3; Table 2) better than other stations, especially Station IV (lower and upper values were detected at 2 and 10, respectively).

The number of individuals of M. idae was the highest, followed by M. cowlesi, M. oenone, P. convexa, P. bogoriensis, and V. litterata. M. idae was a cosmopolitan species that inhabited all stations (Table 3).

All water quality parameters fluctuated, except temperature, NH₃, COD, and pH. The temperature, NH₃, and COD tended to increase, whereas the pH tended to decrease from Station I to Station VIII (Table 4).

Among the world’s lobsters, freshwater crabs, freshwater crayfish, and freshwater shrimp, 2,878 species were assessed in the International Union for Conservation of Nature’s (IUCN) Red List of Threatened Species Version 2019-2. Those species assessed included M. cowlesi, M. idae, M. oenone, P. bogoriensis, and P. convexa.

Macrobrachium cowlesi was not present at Station I. The dominant substrate type at Station I was bedrock (40%; Table 1) which was not a preferred habitat for this species. Therefore, bedrock was evaluated as a threat to this species. Starting from Station II, boulders began to dominate the substrate (50%) and M. cowlesi began to appear.
Table 2. Observed and estimated species richness along the Logawa River, Banyumas, Indonesia

| Species richness                  | Total | I     | II    | III   | IV    | V     | VI    | VII   | VIII   |
|-----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| Observed species richness         | 6     | 2 (1-2) | 5 (2-3) | 5 (1-5) | 5 (2-5) | 4 (3-4) | 5 (4-5) | 3 (3-3) | 4 (3-4) |
| Estimated species richness        | Chao 1| 2 (1-3) | 5 (2-6) | 5 (1-5) | 5 (2-10) | 4 (3-5) | 5 (4-8) | 3 (3-3) | 4 (3-7) |
| Estimated total species richness  | Chao 2| 5.65±0.54 | 6.04±0.86 | 6.11±1.32 | 5.34±0.63 |       |       |       |        |

Table 3. Crustacean along the Logawa River, Banyumas, Indonesia

| Species            | Parameter | Unit | I     | II    | III   | IV    | V     | VI    | VII   | VIII   |
|--------------------|-----------|------|-------|-------|-------|-------|-------|-------|-------|--------|
| M. cowlesi         | individual |       | 0.2±0.45 | 0.4±0.89 | 0.8±1.30 | 2.8±2.59 | 4.6±5.55 | 2.6±3.4 | 0.8±1.79 |       |
| M. idae            | individual |       | 1.2±2.68 | 1.8±2.49 | 0.4±0.89 | 0.8±1.71 | 2.8±2.05 | 4.6±3.03 | 2.6±3.6 | 1.0±1.46|
| M. oenone          | individual |       | 1.0±1.22 | 2.8±3.83 | 1.0±1.00 | 0.2±0.45 | 1.0±1.22 | 9.0±3.94 | 1.0±0.55 |       |
| P. bogoriensis     | individual |       | 0.2±0.45 | 0.2±0.45 | 0.2±0.45 | 0.2±0.45 |       |       |       |        |
| P. convexa         | individual |       | 0.8±1.79 | 0.6±0.89 | 2.6±3.21 | 4.0±3.67 | 5.2±1.64 | 3.8±1.48 | 3.6±1.82 |       |
| V. litterata       | individual |       | 0.2±0.45 | 0.2±0.45 | 0.2±0.45 | 0.2±0.45 |       |       |       |        |

Table 4. Water quality along the Logawa River, Banyumas, Indonesia

| Parameter       | Unit | I     | II    | III   | IV    | V     | VI    | VII   | VIII   |
|-----------------|------|-------|-------|-------|-------|-------|-------|-------|--------|
| Transparency    | m    | 0.3±0.06 | 0.3±0.04 | 0.2±0.06 | 0.1±0.02 | 0.2±0.05 | 0.2±0.05 | 0.5±0.01 | 0.5±0.01 |
| Current velocity| ms⁻¹ | 0.9±0.22 | 0.9±0.12 | 0.8±0.13 | 0.8±0.08 | 0.8±0.15 | 0.9±0.22 | 0.1±0.03 | 0.2±0.2 |
| Flow velocity   | m³s⁻¹ | 3.2±1.39 | 2.4±0.88 | 2.7±0.84 | 1.9±0.40 | 3.1±0.70 | 4.8±1.44 | 2.1±0.47 | 51.7±2.76 |
| Temperature     | °C   | 18.2±0.45 | 18.5±0.87 | 19.8±0.84 | 22.8±1.59 | 24.2±2.49 | 25.8±0.45 | 26.6±0.55 | 26.8±0.84 |
| TSS             | mgL⁻¹ | 1.6±0.49 | 0.7±0.23 | 14.0±6.92 | 138.6±2 | 19.1±3.94 | 13.3±1.75 | 17.2±5.67 | 62.4±8.77 |
| pH              | mgL⁻¹ | 7.0±0.00 | 7.0±0.00 | 7.0±0.00 | 6.8±0.00 | 6.0±0.00 | 6.0±0.00 | 6.0±0.00 | 6.0±0.00 |
| DO              | mgL⁻¹ | 8.6±0.92 | 8.6±0.93 | 8.9±0.77 | 9.6±1.45 | 9.4±0.93 | 6.9±1.50 | 7.5±2.6 | 5.9±1.89 |
| BOD             | mgL⁻¹ | 1.29±0.24 | 2.02±0.52 | 1.58±0.36 | 1.43±0.39 | 1.97±0.28 | 1.96±0.16 | 2.06±0.96 | 2.82±1.64 |
| COD             | mgL⁻¹ | 34.8±2.28 | 42.8±1.64 | 31.8±7.64 | 76.0±8.55 | 54.2±9.85 | 51.4±9.03 | 76.6±3.35 | 131.2±6.3 |
| H₂S             | mgL⁻¹ | nd       | nd     | nd     | nd     | nd     | nd     | nd     | <0.002 |
| NO₃             | mgL⁻¹ | 0.127±0.1 | 0.084±0.1 | 0.144±0.1 | 0.272±0.1 | 0.584±0.2 | 0.869±0.1 | 0.811±0.1 | 0.845±0.2 |
| PO₄             | mgL⁻¹ | 0.027±0.1 | 0.016±0.1 | 0.018±0.1 | 0.015±0.1 | 0.024±0.1 | 0.044±0 | 0.044±0.1 | 0.030±0.1 |
| NH₃             | mgL⁻¹ | 1.103±0.1 | 1.288±0.2 | 1.404±0.2 | 1.227±0.1 | 1.179±0.2 | 1.458±0.4 | 1.524±0.6 | 1.494±0.7 |

Note: nd: not detected, Std: standard

NH₃ concentrations in the river were relatively high, exceeding the permissible surface water quality standard at all stations (Table 4). High concentrations of NH₃ originate from agricultural, municipal, and industrial runoff discharged into rivers (Zheng et al. 2012; Warner et al. 2016; Nuruzzaman et al. 2017; Melki et al. 2018; Van Zelm 2020). Along the Logawa River, agricultural and municipal areas were dominant. Inorganic material entering the Logawa River came mainly from garden and rice field activities in agricultural areas, whereas organic material entering the Logawa River originated mainly from settlement activities in municipal areas. Both activities discharged waste into the river, leading to elevated NH₃ concentrations (Figure 2). Garden fertilization activities such as nitrogen, phosphorus, and potassium fertilizers began from Station I. This resulted in an increase of NH₃ with the increase of temperature (p < 0.05; r = 0.762) at Station VIII. NH₃ increased with temperature (Table 4) from upstream (18.2°C) to downstream (26.8°C) following the topography from high altitude at Station I to low altitude at Station VIII, before decreasing when the river was wide and deep at Station VIII (Table 1). Increases were also found in NO₃ and PO₄ (p < 0.05; r = 0.719). The increase in NO₃ resulted in a decrease in pH (p < 0.05; r = −0.913) while the increase in PO₄ resulted in a decrease in DO (p < 0.05; r = −0.795) because oxygen is needed in the nitrification process.

COD concentrations were relatively high, exceeding the permissible surface water quality standards between Stations IV and VIII, and tended to increase towards downstream areas (Table 4 and Figure 3). According to Iloms (2020), high concentrations of COD are sourced from waste oil that enters the river. Oil entering the waters of the Logawa River comes from areas near settlements starting from Station IV (Figure 1). Increased COD impacts water quality and adaptation strategies for macrobenthic
organisms (Mahazar et al. 2013; Woke et al. 2014; Yusop et al. 2017). Similar to NH₃, COD increased concurrently with temperature (p < 0.01; r = 0.905). The increase in COD resulted in a decrease in pH (p < 0.05; r = −0.782) between Stations IV and VIII as waters became acidic due to NH₃ pollution (Table 4).

According to De Grave and Wowor (2013), *M. cowlesi* (Holthuis, 1950 in Animalia: Arthropoda: Malacostraca: Decapoda: Palaemonidae) is classified as Data Deficient (DD) for factors such as occurrence, ecological requirements, population size, population trends, and long-term threats to freshwater habitat, especially in rivers. The threats to this species are unknown.

*Macrobrachium idae* was present at all stations and tended to be able to live on the existing substrate (Table 1) and under the observed water quality conditions (Table 3). According to De Grave et al. (2013a), *M. idae* (Heller, 1862 in Animalia: Arthropoda: Malacostraca: Decapoda: Palaemonidae) is categorized as of Least Concern (LC), occupying stagnant freshwater and estuarine habitats, especially in lowland areas. The specific threats to this species are unidentified.

**Figure 2.** NH₃ concentration along the Logawa River, Banyumas, Indonesia, where the red line indicates the water quality standard of 0 mgL⁻¹ based on Government Regulation of the Republic of Indonesia Number 82 Year 2001

**Figure 3.** COD concentration along the Logawa River, Banyumas, Indonesia, where the red line indicates the water quality standard of < 50 mgL⁻¹ based on Government Regulation of the Republic of Indonesia Number 82 Year 2001
As a cosmopolitan species, *M. idae* was able to use all stations as habitat. A specific threat was evaluated at Station III, which had the lowest abundance of individuals (0.4 individual) compared to the other stations, because locals had instigated activities such as stone and sand excavations, especially at Station III. These activities were also found at Stations IV, VIII, and VIII. This resulted in decreasing boulder dominance and increases in gravel ($p < 0.05; r = -0.900$), sand ($p < 0.01; r = -0.919$), and silt ($p < 0.01; r = -0.869$) at Station VIII.

*Macrobrachium oenone* was present at all stations except Station VII. According to De Grave et al. (2013b), *M. oenone* (De Man, 1902 in Animalia: Arthropoda: Malacostraca: Decapoda: Palaemonidae) is categorized as DD for parameters such as occurrence, ecological requirements, population size, population trends, and long-term threats in freshwater habitat. The specific habitat requirements are unknown. The threats to the species are unknown. The absence of *M. oenone* was thought to be due to the increase of NH$_3$ at Station VII. NH$_3$ was predicted to be a threat to this species.

*Parathelphusa bogoriensis* was present only between Stations II and IV. According to Esser and Cumberlidge (2008a), *P. bogoriensis* (Bott, 1970 in Animalia: Arthropoda: Malacostraca: Decapoda: Gecarcinidae) is categorized as LC in freshwater habitats. The specific habitat requirements are unknown. The threats to the species are habitat loss and pollution.

The dominant substrate type of bedrock at Station I caused the absence of *P. bogoriensis*. The high COD concentrations that began at Station IV were tolerated by *P. bogoriensis* but the accumulated COD concentrations between Stations V and VIII caused the absence of *P. bogoriensis*. Therefore, bedrock and COD were predicted as threats to this species.

The presence of *P. convexus* followed the same pattern as that of *M. cowlesi*. According to Esser and Cumberlidge (2008b), *P. convexus* (De Man, 1879 in Animalia: Arthropoda: Malacostraca: Decapoda: Gecarcinidae) is categorized as DD due to the paucity of data from freshwater habitats. The threats to the species are habitat loss and pollution.

Based on our research data, the presence of boulders was a factor in the decrease of *P. convexus* at Station II ($p < 0.05; r = -0.778$). However, the presence of gravel was connected to an increase of this species at Station VI ($p < 0.05; r = 0.815$). These findings are shown in Figure 4. Therefore, the availability of boulders and COD were predicted to be threats to this species, while gravel seemed to facilitate their presence.

*Varuna litterata* was found only at Station VI after the branching of the Banjaran Stream. According to Ng and Davie (2019), *V. litterata* (Fabricius, 1798 in Animalia: Arthropoda: Malacostraca: Decapoda: Varunidae) is not on the Red List for freshwater, brackish, or marine habitats.

**Longitudinal distribution**

Of the six species collected, *M. idae* could be categorized as a cosmopolitan species. Based on Kılıçölüoğlu et al. (2016), cosmopolitan species tend to adapt to all elevations and altitudinal conditions. Conversely, *V. litterata* was a rare species along the Logawa River. *V. litterata* can live in freshwater, brackish, and marine ecosystems. In this river, there was decreasing species richness after Station IV due to COD pollution from the riverside and human activities in the habitat, and at Station I due to the bedrock substrate conditions. Conversely, there was increasing species richness in the middle of the stream along the longitudinal gradient (Figure 5). Hazeri et al. (2019) reported that crustacean species depend on the availability of habitat structure. In detail, Silva-Junior et al. (2017) reported that decapods were more abundant in leaf litter substrates than in sandy areas. In the Logawa River, leaf litter substrate was predicted to have originated from the tributary before Station II and the stream before Stations IV, V, and VI (Figure 1).
In conclusion, the species richness of the six observed species fluctuated from upstream to downstream. In longitudinal distribution pattern, the cosmopolitan species *M. idae* lived at all stations, even in the presence of human disturbances such as water highly polluted by NH3 and COD, while the rare species *V. litterata* could not survive under these conditions. Unfortunately, stone and sand excavations and overfishing accelerated the process of crustacean habitat removal; naturally, crustaceans, except cosmopolitan species, do not prefer habitat with bedrock substrate.

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