Ecological indexes of seasonal decapod crustaceans in Tiworo Strait of Southeast Sulawesi waters, Indonesia

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Abstract. The ecological indexes of decapod crustaceans (DCs) in the Tiworo Strait have not been previously studied, despite the area being subject to exploitation. The study aimed to understand the ecological indexes of DCs in different habitats within the Tiworo Strait. Monthly samples were collected using crab pots at specific stations, with gillnets utilized where this was not possible. The collected data were then analyzed using ecological indexes, including the diversity index (H'), uniformity index (J'), dominance index (C), and distribution pattern index (Id). The results revealed the identification of 12 DC species, with the blue swimming crab (BSC) being dominant across all stations. Other dominant DCs included *Charybdis anisodon*, *Charybdis hellerii*, and *Thalamita crenata*. The diversity index (H') of DCs generally showed low values, with moderate values in certain months observed at stations 2, 3, and 4, respectively (from 4 stations which were labeled 1, 2, 3, and 4). Similarly, the uniformity index (J') generally indicated stability within the community, and only at station 1 in May had a low J' value, as it had a lower diversity. Fluctuations in the diversity and uniformity indexes at each station and month suggested moderate and low dominance (C), signifying that certain species were not dominating others, resulting in a stable (moderate C) or striving towards an unstable (low C) DCs community. These conditions indicated low productivity, with high dominance (C) only observed at station 3 in March and station 1 in April and May. Despite fluctuations in the diversity, uniformity, and dominance indexes, the distribution pattern index (Id) remained random, indicating that these species were capable of adapting to the characteristic waters of the Tiworo Strait. This data suggests a "serious early warning" for DCs management, particularly emphasizing the need to minimize bycatch and the discarding of species.
Key Words: decapod crustacean (DC), distribution pattern index, diversity index, dominance index, uniformity index.

Introduction. Biodiversity is crucial for understanding the functioning of its ecosystem's health. Ecosystem damage and over-exploitation have a positive correlation with population growth, which is a primary driver of biodiversity. Currently, there is a noticeable increase in the speed of damage pressures in terrestrial and coastal areas compared to the last 5-10 decades. These pressures lead to an unstable coastal ecosystem, subsequently affecting marine life.

Organisms inhabiting coastal waters are highly diverse, including fishes, crustaceans, mollusks, mammals, and others. Crustaceans of the decapod group constitute one of the most diverse taxonomies, and they are considered useful indicators of water quality (Kuklina et al 2013), responding rapidly to environmental changes due to pollution impact. They encompass marine species that inhabit both shallow waters and deep-sea waters exceeding 5000 m (García-Isarch & Muñoz 2015; Tyler et al 2016). Decapods support a high species diversity (Wang et al 2017). Research on the biodiversity and ecological indexes of decapods, such as shrimps and prawns, crabs, lobsters, squat lobsters, and hermit crabs is currently crucial for biodiversity monitoring (García-Isarch & Muñoz 2015). It has been shown to influence the structuring of benthic habitats, occasionally playing a keystone role by suppressing herbivores or space competitors (Alonso-Domínguez et al 2022). These organisms contribute to the maintenance of kelp forests, marsh grass, and algal turf habitats (Boudreau & Worm 2012). Changes in the abundance of their predators can strongly affect decapod population trends. Some of them contribute to maintaining coral health by removing sediment from the coral's surface and parasites (Head et al 2015).

The waters of the Indonesian archipelago have the highest biodiversity globally, attributed to its geographic position in the tropical zone and being intersected by the equator. Much of this biodiversity remains poorly understood, especially concerning economically significant, endangered, or endemic species. These species are intricately connected to social, economic, and environmental aspects, and indeed, they have implications for the politics and sovereignty of nations. Marine biodiversity, commonly utilized by people, includes reef fish (snapper, groupers, rabbit fish, giant trevally), ornamental fish, lobster, blue swimming crab, mud crab, and various small and large pelagic fish typically found in coastal ecosystems such as mangroves, seagrasses, and coral reefs. These ecosystems mutually support each other and continue to do so. The ecological functions of these ecosystems include serving as feeding, nursery, and spawning grounds for many species of fishes, gastropods, bivalves, and crustaceans. Crustaceans, particularly crab species (decapods), inhabit a broad range of habitats, from river and estuary waters to mangrove forests. In mangrove forests or seagrasses, crustacean biodiversity is high and diverse. These crustaceans engage in activities such as foraging for food, burrowing to improve substrate conditions, transporting significant amounts of sediment, altering sediment characteristics, participating in substrate oxygenation processes, and contributing to nutrient cycling and energy flow (Colpo & Negreiros-Fransozo 2004).

The Tiworo Strait is one of the blue swimming crab (BSC) (*Portunus pelagicus*) fishing grounds that is intensively exploited by fishermen. It exhibits high crustacean diversity, as indicated by the catch composition of gillnets and crab pots (Astuti et al 2022). The primary catch in this area is the BSC, with other decapod crustaceans (DCs) considered as bycatch. Commercial commodities include BSCs, mud crabs, and lobsters, while others fetch low prices. Previous data has revealed that the bycatch from crab pots and gillnets exceeds 60%. The continuous catch of BSCs and other DCs without restraint can disrupt the balance of the food web in the water ecosystem, ultimately rendering the ecosystem unstable and less productive. Therefore, the decline in DCs populations is not only a result of high catch intensity and habitat destruction, but also stems from disturbances to the water ecosystem's food web due to the use of unselective fishing gears, leading to a high bycatch.

Several decapod crustacean (DC) species have been captured using crab pots and gillnets in these waters, including *Thalamita cerasma*, *T. danae*, *Charybdis anisodon*, *Podophthalmus vigil*, *Menippe rumphi*, *Scylla* sp., *Portunus* sp., and others. The diversity of DCs and other ecological indexes has not been thoroughly studied yet. While some studies have been conducted, they mostly focus on the BSC, examining aspects of biological reproduction (La Sara et al 2016a; 2016b; 2017; Astuti et al 2020a; 2020b). Other studies fall within the domains of fisheries and biology (Laë et al 2004; Thiaw et al 2009). Only a few studies have analyzed DC ecological aspects and community structure (Muñoz et al 2012; García-Isarch & Muñoz 2015; Astuti et al 2020b). A recent study on the spatial and temporal composition and sex ratio of DCs was conducted by Astuti et al (2022), along with a study on variation in density and diversity by Lutz et al (2022). Therefore, this article is beneficial in providing preliminary information regarding DC ecological indexes captured using crab pots and gillnets.

Material and Method

Design of study location. The waters of the Tiworo Strait constitute a dynamic aquatic system influenced by hydrooceanographic factors, sedimentation, and freshwater flow from rivers and tributaries. It is renowned as a fishing ground for BSCs and other DCs in Southeast Sulawesi and Indonesia as a whole. The entire life cycle of BSCs occurs in these waters, starting from the copulation of mature DCs, spawning, and progressing through the larval zoea stage, juveniles, maturity, and adulthood. Sampling locations for DCs were deliberately chosen at the intertidal zone (station 1), river mouths (station 2), areas with seagrass growth (station 3), and water depths exceeding 30 m (station 4) (Figure 1). All these stations serve as DCs fishing grounds near the Southeast Sulawesi peninsula, specifically in South Konawe regency. Fishing gears employed for sampling included traps and bottom gillnets. These gears generally target BSCs as the primary objective, with other DC species caught incidentally. DCs sampling took place from March to September 2020.

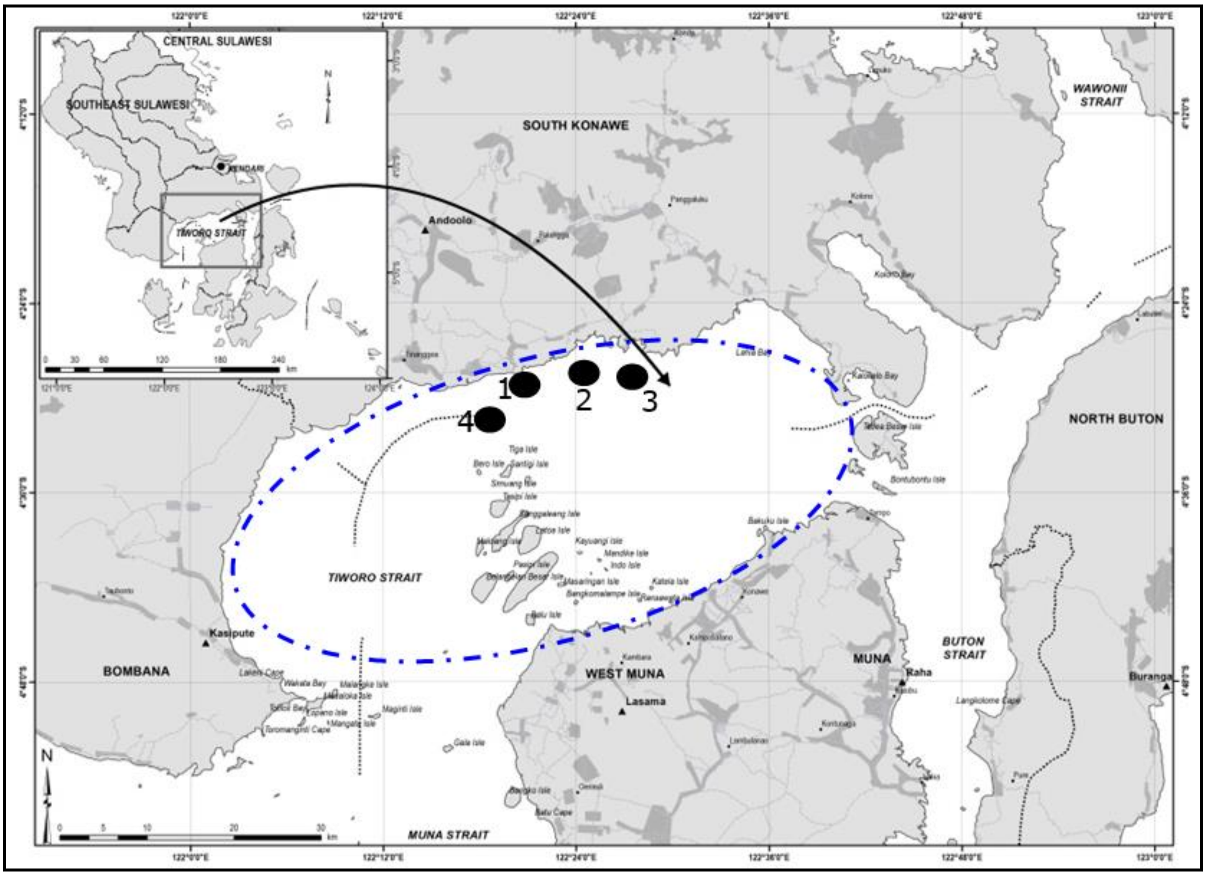

Figure 1. Map of Tiworo Strait waters of Southeast Sulawesi; blue dash line delimits the study locations and black circles are stations of decapod crustaceans sampling.

Sampling procedures. The sampling of DCs at each station was conducted monthly. The fishing gears employed at stations 1 to 3 were rectangular collapsible crab pots (length = 54 cm, width = 36 cm, and height = 19 cm) covered with nylon nets with a mesh size of approximately 0.5 cm (Figure 2). At station 4, a bottom gillnet was used. Approximately 100 units of crab pots were deployed at each station. Each crab pot was fastened to the main nylon polypropylene (θ=0.5 mm) using smaller nylon polypropylene (θ=0.25 mm). The distance between crab pots on the main nylon polypropylene was approximately 10 m. Fresh fish bait of relatively the same size was placed in each crab pot. All crab pots tied to the main nylon polypropylene were deployed during flood tide and retrieved during ebb tide. At station 4, DCs sampling involved the use of a bottom gillnet with a length of approximately 1 km, a height of 1 m, and a mesh size of 4 inches (Figure 2).

Each sample of DCs caught at each station (spatial) and in each month (temporal) was recorded and the species was identified (Carpenter & Niem 1998; Lai et al 2010). The number of members of each DC species was then counted for catch composition analysis (La Sara et al 2016a; 2017).

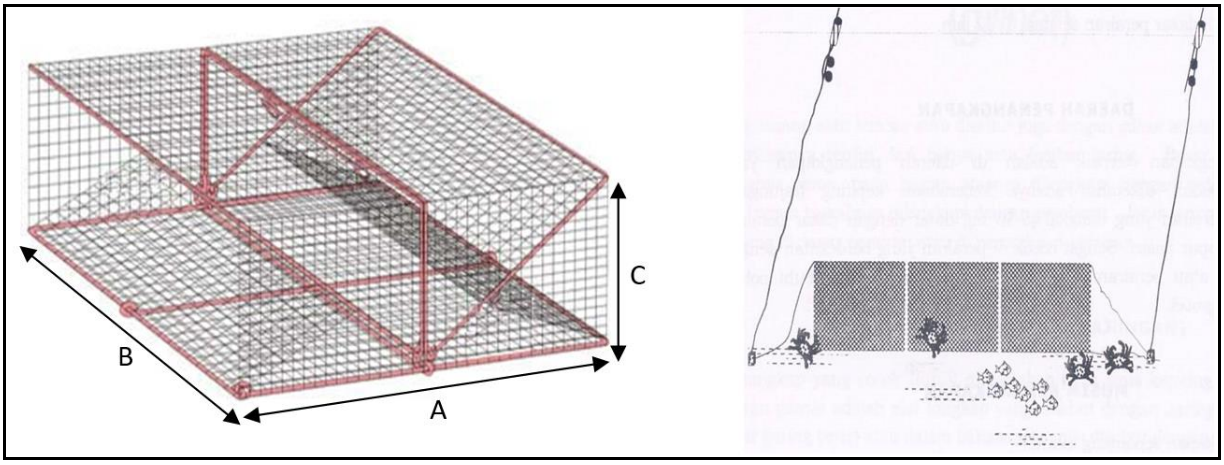

Figure 2. The rectangular collapsible crab pot on the left (length -A-=54 cm, width -B-=36 cm, and height -C-=19 cm) and the bottom gillnet on the right (length of approximately 1 km, height of 80–100 cm, and mesh size of 4.5 inches) were used for DC sampling in the waters of Tiworo Strait, Southeast Sulawesi (La Sara et al 2016c).

Species diversity of DCs. DC diversity was analyzed using the species diversity index (H'), which serves as an indicator of community structure and ecosystem stability. A higher H' value indicates a more stable ecosystem. The Shannon-Wiener index is commonly employed to measure the diversity level of species. Data on DCs in this study, collected from each station, were analyzed using the Shannon-Wiener H' index:

$$H' = -\sum_{k=0}^{n} pi \ln . pi$$

Where: H' - DC diversity index; $pi=n_i/N$; n_i - total number of individual species of i^{th}; and N - total number of DC individuals.

The characterization of H' is the following: H'<1 - low diversity, poor, very low productivity indicating an ecosystem under heavy pressure and with an unstable condition; 1<H'≤3 - moderate diversity, sufficient productivity, ecosystem in balanced condition, with moderate ecological pressure; H'>3 - high diversity, stable ecosystem, high productivity, resistant to ecological pressure.

Species uniformity of DCs. The uniformity index (J') of DCs was analyzed using the following formula:

J'=H'/logS

Where: J' - uniformity index of DCs; H' - diversity index of DCs; S - number of species ($\log S = H'_{max}$).

The J' value of species ranges between 0 and 1 with decision criteria as follows: J' close to 0 - ecosystem tends to be dominated by a single species; J' close to 1 - ecosystem is relatively even in terms of species distribution (Brower et al 1998).

Species dominance of DCs. The species dominance index (C) of the DCs community was analyzed using the following formula:

$$C = \sum_{k=0}^{n} [ni/N]^2$$

Where: C - index of DC species dominance; ni - number of individual species of the i^th^; and N - total number of inviduals.

Species distribution patterns of DCs. The distribution pattern (Id) of DCs species in the study location was analyzed using the Morisita dispersion index as follows:

$$Id = n\frac{\sum_{k=0}^{n} x^2 - N}{N(N-1)}$$

Where: Id - the Morisita distribution index; N - total number of a certain individual species (in each sampling); x^2 - total number of individuals in each sampling; and n - number of sampling units.

The significance of the indexes was tested using the Chi-square test (α=0.05), as follows:

$$X^2 = n\frac{\sum_{k=0}^{n} (x^2)}{N} - N$$

Where: if (X^2_{count}) < (X^2_{table}), there is no significant difference; and if (X^2_{count}) > (X^2_{table}), there is a significance difference.

Results

Catch composition and abundance. The catch of DCs found at all stations (spatial) during the study consisted of only 12 species. Among the DC species, BSC was found at all stations and had the highest CC, while the next highest CC was for *C. ampisodon* (Ca), *T. crenata* (Tcr), and *T. cerasma* (Tce), with the majority of them being found only at Station 4. The CC of other species was very low (Figure 3). The CC of BSC was also the highest during the study (temporal), while *C. ampisodon* (Ca) had a high CC in March, April, July, and September. The CC of other species throughout the study was found in very small amounts (Figure 4).

Species diversity of DCs. The results of ecological indexes, including H', J', C, and Id, for DCs in the spatial and temporal dimensions of Tiworo Strait waters in Southeast Sulawesi, are presented in Tables 1 to 4, respectively. The spatial and temporal H' generally indicates a low diversity of DC species in these waters. Moderate H' values were observed at station 2 in June and July, station 3 in April, May, July, and August, and station 4 in June, July, and August. However, all temporal species diversity index values (H') at all stations showed no significant differences, except for the H' value in June, which was significantly different from the H' value in May (Table 1).

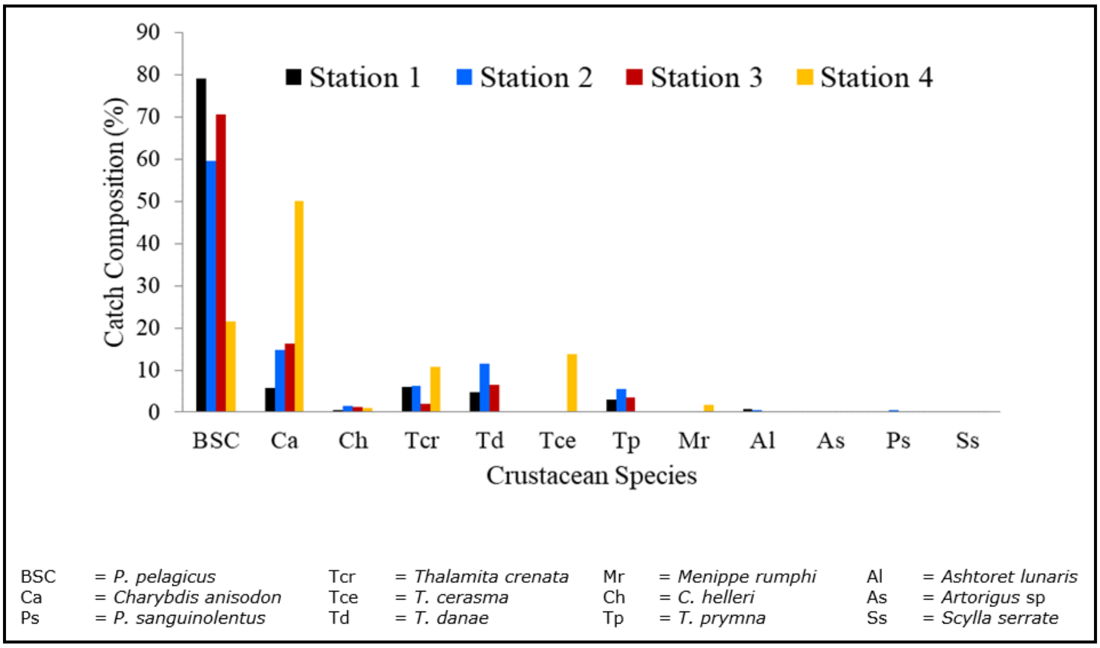

Figure 3. The Spatial DC CC Percentage in Tiworo Strait Waters of Southwest Sulawesi, Indonesia (Astuti et al 2022).

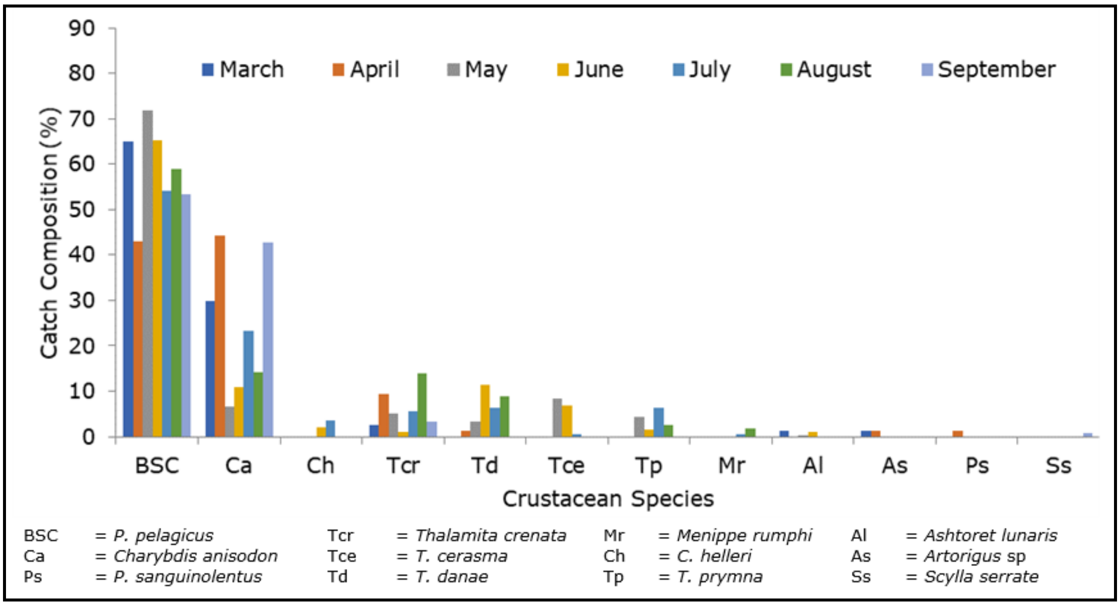

Figure 4. The Temporal DC CC Percentage in Tiworo Strait Waters of Southwest Sulawesi, Indonesia(Astuti et al 2022).

Table 1

The temporal species diversity index (H') of decapod crustaceans in Tiworo Strait waters of Southeast Sulawesi

Station	*Temporal species diversity index (H')*						
	March^{ns}	*April*^{ns}	*May*^{ns}	*June**	*July*^{ns}	*August*^{ns}	*September*^{ns}
1	0.485	0.394	0.309	0.423	0.810	0.855	0.391
2	0.721	0.902	0.920	1.058	1.384	0.587	0.925
3	0.336	1.195	1.137	0.395	1.116	1.003	0.721
4	0.536	0.839	0.936	1.051	1.006	1.230	0.299

Note: ns - no significant differences; * - significant difference.

Species uniformity of DCs. The spatial and temporal species uniformity ecological index (J') of DC species showed uniform values, close to 1. Only station 1 in May had a low J' value (J'= .51). This indicates that the temporal distribution of DC species at these stations was stable. However, all temporal J' values at all stations showed no significant differences, except for the J' value in June, which was significantly different from the J' value in May (Table 2).

Table 2
Temporal species uniformity index (J') of decapod crustaceans in Tiworo Strait waters of Southeast Sulawesi

Station	*Temporal species uniformity index (J')*						
	March^{ns}	*April*^{ns}	*May*^{ns}	*June**	*July*^{ns}	*August*^{ns}	*September*^{ns}
1	1.02	0.83	0.51	0.89	1.16	1.42	1.30
2	1.51	1.50	1.53	2.22	1.98	1.23	1.94
3	1.12	1.99	1.89	1.31	1.60	1.44	1.51
4	1.78	1.76	1.96	1.75	1.44	2.04	0.63

Note: ns - no significant differences; * - significant difference.

Species dominance of DCs. DC species found in these waters generally exhibit low to moderate dominance spatially and temporally. A relatively high C index (C > 0.75) was only observed at station 1 in April, May, June, and September and station 3 in March and June. However, all temporal species dominance index values (C) at all stations showed no significant differences (Table 3).

Table 3
Temporal species dominance index (C) of decapod crustaceans in Tiworo Strait waters of Southeast Sulawesi

Station	*Temporal species dominance index (C)*						
	March^{ns}	*April*^{ns}	*May*^{ns}	*June*^{ns}	*July*^{ns}	*August*^{ns}	*September*^{ns}
1	0.756	0.815	0.870	0.789	0.608	0.560	0.770
2	0.597	0.518	0.528	0.361	0.290	0.652	0.456
3	0.812	0.347	0.378	0.767	0.405	0.512	0.532
4	0.649	0.474	0.447	0.480	0.476	0.312	0.569

Note: ns - no significant differences.

Species distribution patterns of DCs. All spatial and temporal species distribution indexes of DCs found in these waters exhibited a random distribution. The temporal species distributions were not significantly different (X^2count = 0.443)<X^2tab = 12.592) (Table 4).

Table 4
Temporal species distribution index (Id) of decapod crustaceans in Tiworo Strait waters of Southeast Sulawesi

Station	*Temporal species distribution index (Id)*						
	March^{ns}	*April*^{ns}	*May*^{ns}	*June*^{ns}	*July*^{ns}	*August*^{ns}	*September*^{ns}
1	2.234	2.416	2.606	2.358	3.012	2.216	1.534
2	1.682	2.004	2.081	1.006	1.398	1.935	1.231
3	2.404	1.187	1.455	1.525	1.961	2.451	1.568
4	1.896	1.333	1.297	1.803	2.326	1.211	2.594

Note: ns - no significant differences.

Discussion. The diversity of abundance, sex ratio, catch composition, and other aspects of DC species, particularly in marine and coastal waters, is primarily influenced by various factors, such as the habitat characteristics specific to these DCs. These habitat features can be affected by changes in the water environment, either directly due to human activities in marine waters or indirectly from the coastal areas. Additionally, they may be influenced by natural variations caused by seasonal effects, the geographical position of the waters, and the interaction of biological-chemical-physical factors resulting from global climate change. All these factors, whether direct or indirect, impact the presence of organisms in coastal and deep-sea waters, which are generally highly sensitive to changes or pressures from the environment and human activities. Anthropogenic actions, including urbanization, industrial activities, pollution, aquaculture, tourism, and overfishing, contribute to these changes (Zaabar et al 2015). Fishing intensity and the use of unselective fishing gears are major contributors to overfishing in fisheries resources, leading to a decline in organism populations (McCauley et al 2015; Pham et al 2023). This decline may negatively affect food availability, reduce environmental quality (Moreno-Mateos et al 2017; Lampert 2019), and consequently impact water productivity.

The abundance variation of DC species in Tiworo Strait waters tended to low (Table 1). Aside from being influenced by natural changes in the waters (Külköylüoğlu et al 2023), this is primarily caused by significant and rapidly noticeable anthropogenic actions as noted by Adyasari et al (2021), who stated that Indonesia's tropical coastal waters and ecosystems are currently under threat from stresses linked to anthropogenic activities. Other reports indicate a consistent decline in the quality of Indonesian coastal waters due to excessive nutrients, organic compounds, and heavy metals originating from domestic wastewater, industry, mining, agriculture, aquaculture, and solid waste (Asian Development Bank 2016). Direct alterations to the habitat of DCs in intertidal zones, mangrove forests, river mouths, seagrass areas, and even extending to deep-sea waters are among the most impactful changes. The conversion of mangrove forests, which serve as crucial habitats for juvenile DCs as nursery grounds, feeding grounds, and shelters, has led to the loss and alteration of their ecological functions. Mangrove forests have been cut down for various purposes, including household needs, bridge development, port/jetty construction, mining activities, industrial areas, housing projects, public markets, roads, reclamation, and more. Other actions contributing to environmental changes in marine habitats, influencing the habitat of DCs, include mud sediment and pollution from the surrounding land or watershed that enters rivers and flows directly into marine habitats during heavy rain, causing run-off. This run-off can transport sediments or pollutants into mangrove areas, intertidal zones, or river mouths. The interchange of marine and freshwater from runoff appears to create brackish water characteristics, leading to seasonal spatial changes in biotic distribution and abiotic variables in the waters (Zaabar et al 2015; Muhtadi et al 2022). As a consequence, DCs and other organisms in the waters respond with adaptive changes, altering their behavior, particularly those sensitive and less adaptable to these environmental changes.

Spatial and temporal variability of DC ecological indexes may be influenced by factors such as the location of sampling stations, the dimension of equipment or fishing gears used for sampling, the number of units, the water depth of sampling locations, the number and frequency of samplings, and the timing of samplings. The importance of the sampling location scale has clear implications, namely, species richness depends on the number of species in a large landscape up to the biogeographical province level (Gaston & Blackburn 2000). A study conducted in a tropical reef lagoon showed that crustaceans, in terms of diversity, abundance, biomass, and energy flow, are one of the most abundant groups of epifauna in all marine ecosystems (Briones-Fourzán et al 2020). These organisms play an important regulatory function, particularly in seagrass ecosystems, as they prey on small fauna (Ramírez et al 2015).

García-Isarch & Muñoz (2015) explained that the high diversity of DCs in a certain area is due to the presence of special temperate species, special temperate-subtropics species, and special tropic species. Other factors influencing these diversities may be explained through the species condition of biogeography and oceanography. The location of the study, situated between river and seawater, may exhibit fluctuations in terms of spatial and seasonal variability in its conditions due to the influences of both continental riverine input and coastal waters (Lutz et al 2022). Wang et al (2017) elucidated that some coastal areas rich in biodiversity in the Indo-West Pacific regions (e.g., Japan, Taiwan, Indonesia, the Philippines, and South India) have a steep continental slope with depths reaching several km from the coastline. The presence of fishermen in these areas may lead to intensive DC exploitation, causing a decrease in diversity. The intensive exploitation of DCs using collapsible crab pots and gillnets in Tiworo Strait over the last two decades has resulted in decreased diversity may show that their population had been experiencing heavy pressure (Astuti et at 2022). In this strait, fishermen mainly target shrimp using bottom trawls. However, DCs are unintentionally caught as bycatch. This has resulted in a decline in DC diversity both spatially and temporally, as evidenced by the low diversity observed at most of the stations and months. An observable phenomenon occurred with low DCs diversity and moderate diversity at station 2 in June and July, station 3 in April, May, July, and August, and station 4 in June, July, and August, even though it has been known that all temporal H' values at all stations showed no significant differences, except for the H' in June and May (Table 1). The reason for this phenomenon is not yet known, but it is noted that from mid-2019 to 2021, between June and September, Indonesia experienced highly irregular seasonal changes known as El Niño. During this period, a drier dry season with higher temperatures caused widespread drought. During the study, the water temperature in coastal areas measured between 39-42°C. At that time, almost all cultivated biota, such as seaweed (*Eucheuma cottonii* and *E. spinosum*) and grouper fish raised in floating cages, experienced mass mortality. DCs sampling during this period was low. In September, there is a transition from summer to the rainy season, and the number of DC samples taken is infrequent.

Factors like ebb and flood tides influence the distribution and abundance of the blue swimming crab in the intertidal zone close to mangrove forests (La Sara et al 2017). These factors may explain why DCs in September at all stations exhibited low to moderate H' values, despite a low and moderate diversity variation. Both spatially (across stations) and temporally (across times), there was high diversity in DCs. This high H' is much better than the H' found by Muñoz et al (2012) in different locations, with H' values of 3.22 in Mauritania and 3.30 in Guinea-Bissau. García-Isarch & Muñoz (2015) clarified that intensive shrimp exploitation had several negative impacts, including certain stocks being overexploited and physical changes to the habitat of benthic communities.

The species diversity of DCs found in this study (Table 1) demonstrated a clear and strong correlation with its species uniformity distribution (Table 2). Spatial and temporal species J' values of DCs were generally high, except at stations 1 in May, where there was instance of low species J' values. The low species uniformity indicated that the DCs community in this month (temporal) and at this station (spatial) experienced significant pressure on the DCs population and its habitat. Generally, fluctuating species uniformity distribution in these waters, influenced by spatial and temporal factors such as at station 1 in May, is thought to be partly due to the impact of elevated sea temperatures caused by El Niño. It has been noted that during May to June, which is considered the winter season, sea temperatures rise significantly to 39-42ºC, particularly in the intertidal zone of station 1, where the depth was less than 5 m and near the river mouth, with water depths ranging from 0.5 to 8 m. Nevertheless, the J' value in September was not significantly different from the J' value in August. This phenomenon may indicate that during the study conducted, the effect of temperature was relatively homogeneous across all stations, from station 1 in waters with a maximum depth of around 5 m to station 4 in deeper waters with a depth approaching 30 m. The high J' indicates that there was no species dominating over others, or there was no centered individual of a particular species. On the other hand, if there was a dominance of a particular species, the J' value for that species would be low. The high J' of DCs in the Tiworo Strait found at all stations (spatial) from March to September (temporal) indicated that DCs communities did not yet show the presence of a dominant species, despite knowing that the BSC was consistently higher in abundance than other DCs species in each sampling event. The high J' values suggested that DCs species at those stations (spatial) and months (temporal) were relatively evenly distributed. However, a change in DCs J' values was observed from May to June (temporal) at all stations (spatial). This may suggest that the water ecosystem conditions at these stations and during these months were becoming unstable, leading to a relatively uneven distribution of DCs species. The catch composition data generally showed that BSCs were more abundant than other DCs species (Figures 3 and 4). When the ecosystem conditions began to change it caused a negative response in the DCs community, making it unstable. This should serve as an early warning for managers or the government to consider systematic measures for its management. If the condition of the water ecosystem undergoes significant and extreme changes, leading to a lower J' for DCs, it indicates that the DC community is experiencing high pressure. A low J' implies an inequitable distribution of species individuals, with a tendency towards species domination. This condition suggests that many DCs species are unable to adapt, and only certain species may thrive and dominate. Low J' values for DC species were observed at station 1 in April, May, and June, and station 4 in September. The June condition differed from the previous uniformity condition, particularly due to extreme temperature conditions exceeding 40°C. September, in Southeast Sulawesi, marks the transition season from long dry season to the rainy season, which typically occurs at the end of October or the beginning of November. It is possible that this seasonal change factor contributed to the instability (moderate J') and suppression (low J') of DCs species uniformity, in addition to the impact of intensive fishing exploitation using unselective fishing gears and changes in DCs habitat caused by human activities on land, such as the cutting of mangrove forests known as nurseries for BSC juveniles (La Sara et al 2016b) and other DCs species. Land clearing activities may contribute to significant sedimentation in coastal zones, leading to a dominant mud structure, which is unfavorable for BSC and other DCs, especially in their juvenile stages (La Sara et al 2016b; 2017). Juvenile DCs, in particular, prefer intertidal zones near mangrove forests with a dominant sandy substrate and less mud or clay substrates. The availability of shelter in intertidal zones becomes a crucial factor in why certain species prefer specific habitats throughout the year. Other key factors influencing DCs include fluctuations in salinity, weak currents and waves, and food availability, leading to certain species occupying specific locations in certain months.

Changes in the uniformity of DCs species in this study are reflected in the uniformity indexes (Table 2), similar to the variations in the dominance index that show moderate fluctuations spatially and temporally (Table 3). High C (>0.75) values are only observed at station 1 in March, April, May, June, and September and station 3 in March and June. The DC species dominant at station 2 in June, July, and September, station 3 in April, May, June, and July and station 4 in April, May, July, and August have a low C (C < 0.5), while the other stations and months have moderate C values (0.5–0.75). These changes at all stations and in all months indicate a shift in C species from high to moderate and low. Moderate C values imply a balanced number of dominant species among the 12 DC species (Figures 3 and 4) found in these waters, while low C indicates that only some species continue to exhibit dominance, such as BSC (*P. pelagicus*), *C. anisodon*, *C. hellerii*, and *T. crenata*. Other species like *T. ceresma*, *M. rumphi*, *A. lunaris*, *P. sanguinolentus*, and *S. serrata* show low C (Table 3), meaning that these DC species at all stations (spatial) and months (temporal) are dominated by only a few species (Rahayu et al 2017).

The ecological indexes of DCs species in these waters differed from the distribution indexes during the study period, as the Ids of DCs species at all stations were random and not significantly different ($X^2_{count} < X^2_{tab}$). Although explaining why these Ids occurred is challenging, these random distributions suggest that the habitat conditions represented by all stations in these waters throughout the study period allowed each DC species a chance to randomly select preferred habitats. The response of each DCs species to its habitat each month was not significant. However, in general, the Ids of DCs species at different habitats and months were unique and influenced by DCs species preferences within an ecosystem. Changes in environmental conditions, as observed in many other marine and coastal waters due to anthropogenic activities, lead to different organisms responding to their environment. Such conditions generally cause distribution patterns to become clumped, where individuals in a population tend to form several group sizes as they seek a suitable environment to support their lives.

Conclusions. It is proven that the ecological indexes of DCs species may be influenced by environmental factors and anthropogenic activities in the waters around the strait. The DCs species generally exhibit low H'. Moderate H' was observed at stations influenced by river mouths, areas with seagrass, and deep waters. The high H' of DCs species was not found indicating that either DCs species or water ecosystem had experienced high pressure from ecological change or fishing intensity. The trend in DCs species H' is quite similar to that of J'. Fluctuations in H' and J' may be indicated by moderate and low C, implying the presence of certain dominant DC species in the waters. This condition serves as an alarm, indicating that these waters are trending towards an unstable condition, shifting from moderate C to low C, which in turn, signifies a decrease in water productivity. Despite fluctuations in H', J', and C, the Id of DC species follows a random distribution, suggesting that these DC species can adapt to water characteristics. In general, based on all ecological indexes, the DCs species in these waters present a "high early warning of several DC species low catch composition" for management through government policies, and fishermen should work to minimize bycatch (discarded catch) by using selective fishing gears.

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