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Daily Distribution of Seagrass Fish Community at Crepuscular Periods in Tropical Small Island of Indonesia

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ABSTRACT

The spatial distribution of ichthyofauna in seagrass habitats is influenced by habitat characteristics, its proximity to other habitats, and the daily temporal distribution of fish communities, which varies with orientation. This study aimed to analyze the crepuscular distribution of ichthyofauna by comparing the presence of species, families, and orders, as well as the structure of fish communities, between the dawn and dusk periods on Gili Noko, Bawean Island, East Java, Indonesia. The study was conducted in June 2024, with sampling during the dawn period at sunrise (5:00–6:00 AM) and the dusk period at sunset (5:00–6:00 PM), using bottom gillnets to collect fish samples. The data collected were analyzed for species presence, species composition, family and order distribution, and community structure (i.e., diversity index, evenness, and dominance index). The results were presented in tabular and graphical formats. To assess the similarities in species, families, and orders between the two crepuscular periods, a Bray-Curtis analysis was performed. The study recorded 76 individuals, 34 species, 15 families, and 10 orders. The highest number of individuals, species, families, orders, and community structures were found during the dusk period compared to the dawn period. The similarity of species between the two crepuscular periods was moderate, indicating differences in species presence between the two times. The diversity of life phases and feeding habits of the fish highlights the role of seagrass beds as both a nursery and a feeding ground. Consequently, conservation efforts aiming at protecting seagrass ecosystems are crucial for preserving fish diversity and supporting sustainable fisheries and ecotourism.

INTRODUCTION

Seagrass beds are one of the ecosystems in coastal areas and small islands in tropical areas that are used as an important habitat for ichthyofauna, both as a feeding ground, shelter, spawn, and nursery **(Ambo-Rappe *et al.*, 2013; Simanjuntak *et al.*, 2020; Manangkalangi *et al.*, 2022; Latuconsina *et al.*, 2023; Tongnunu *et al.*, 2024)**. Due to their proximity to other ecosystems such as coral reefs and mangroves, seagrass beds are rich in a variety of associated ichthyofauna **(Unsworth *et al.*, 2008; Latuconsina *et al.*, 2015; Espadero *et al.*, 2021)**. The high biodiversity of ichthyofauna in seagrass ecosystems is also supported by the ability of seagrass meadows to provide diverse microhabitats to support the life of ichthyofauna, including those from nearby ecosystems during the juvenile stage **(Jianguo *et al.*, 2020)**.

The strategic location of seagrass habitats in coastal areas and small islands makes them a crucial link in the spatio-temporal distribution of fish between habitats **(Campbell *et al*., 2011; Latuconsina *et al.*, 2015; Whitfield, 2017; Lee *et al.*, 2019)**. These habitats support fishery resources **(Unsworth *et al.*, 2010)**, providing a source of livelihood for fishers **(Syukur *et al.*, 2017; Latuconsina & Buano, 2021)**, and they play a significant role in global fishing activities **(Nordlund *et al.*, 2018; Unsworth *et al.*, 2019)**. Additionally, seagrass habitats contribute to food security for communities in coastal areas and small islands **(Unsworth *et al*., 2014; Latuconsina *et al.*, 2023)**.

Bawean Island, located in Gresik Regency, East Java, Indonesia, has significant marine tourism potential. One of the key areas for developing tourist attractions on the island is Gili Noko, a small island **(Ramli *et al.*, 2012)**. **Noor and Romadhon (2020)** reported that Gili Noko features soft, beautiful white sand and water quality that is categorized as very suitable for marine tourism development. The island has an estimated carrying capacity of 156 people/day during low tide and 148 people/day during high tide. Gili Noko spans 0.32km² and is home to at least 700 families from various ethnic backgrounds. It is located approximately 2.3km east of Bawean Island, the main island. **Afandi *et al*. (2017)** noted that the coastal area of Gili Noko has a stretch of sandy beach with clear seawater, surrounded by coral reefs rich in ornamental fish, making it ideal for tourism development. However, research on the ichthyofauna community in the waters of Gili Noko, particularly in its seagrass ecosystem and surrounding coral reefs, remains limited.

Studies of ichthyofauna in seagrass habitats are common and generally show that the presence of fish that varies in size and the frequency of presence depending on the time of day or night, the time of the month, and the season **(Latuconsina *et al.*, 2023)**. **Latuconsina and Ambo-Rappe (2013)** found variations in the structure of the ichthyofauna community between day and night. **Shoji *et al.* (2017)** concluded that nocturnal visits by piscivorous fish increase predation risk and trophic levels in seagrass habitats as fish nursery habitats. **Amaral *et al.* (2023)** also obtained different temporal daily fish assemblages with different thematic level dominance. However, research on the presence of fish at two crepuscular periods (dawn and dusk) in seagrass habitats is not common, so scientific information is still very limited. According to **Helfman (1986)**, two key factors are essential to understanding the crepuscular distribution of fish: first, dusk is a period of environmental, behavioral, and ecological transition; and second, predators capitalize on the transitional nature of the crepuscular period.

This study aimed to analyze the crepuscular distribution of ichthyofauna by comparing the presence of species, families, and orders and the structure of fish communities between the crepuscular periods (dawn and dusk). This information is crucial for efforts to preserve seagrass ecosystems and other ecosystems near coastal areas and small islands, as they play a key role in supporting sustainable fisheries and ecotourism.

MATERIALS AND METHODS

1. Fish sampling

This research was conducted in the Gili Noko seagrass ecosystem, Bawean Island, Gresik Regency, East Java - Indonesia (Fig. 1). Gili Noko waters have a seagrass expanse that is not too wide, composed of two species seagrass vegetation, namely the *Thalassia hemprichii* species with a fairly high density and dominates the seagrass area, and *Enhalus acoroides* with a low density due to its scattered distribution (patches) forming clumps with a small number.

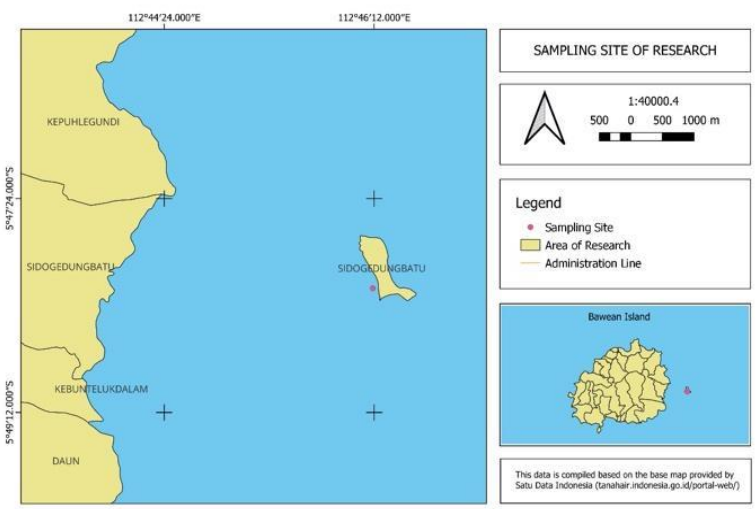

Fig. 1. Map of Gili Noko, Bawean Island, Gresik Regency, East Java – Indonesia

This study was conducted in June 2024 between the crepuscular periods (dawn and dusk); each observation period was repeated five times. Fish data were captured using a bottom gill net measuring ±75m long and 1m high with a mesh size of 2 inches. Fish identification refers to **Allen (1999)**, **Allen and Erdmann (2012a, b, c)**, **White *et al.* (2013)**, **Allen *et al.* (2015)**, **Froese and Pauly (2022)** and **Latuconsina *et al*. (2023)**. Determination of conservation status refers to The **IUCN (2024)**.

2. Data analysis

The composition of individuals/species/families/orders provides an overview of the number of individuals/species/families/orders from an observation period compared to the number of individuals/species/families/orders from all observation periods, expressed as a percentage and calculated using the equation:

$$CI = \frac{ni}{N} \text{ x } 100\%$$

Where, CI = Compotition Ichthyofauna (%); ni= Number of Individuals / species / families / orders of fish in an observation period; N= Total number of Individuals / species / families / orders of fish from all over the entire observation peri

Presence frequency (PF) is a value that states the number of species present in a predetermined research station. FK could be calculated using the following formula **(Krebs, 2014)**:

$$PF = \frac{Number\ of\ observations\ found\ of\ species\ i}{Total\ Number\ of\ observations}\ x\ 100$$

Where, PF 0-25% = Hardly ever-present; PF 25-50% = Seldom present, PF 50-75% = Sometimes present; PF 75-100% = Generally present.

The fish community at each site was determined through the Shannon diversity index (H'), evenness index (E), and dominance index (C) using Microsoft Excel software. The Shannon diversity index (H') is the most commonly used. According to **Shannon (1948)**, the formula for calculating the fish community is as follows:

$$H' = -\sum_{n=1}^{n} \left(\frac{ni}{N}\right) ln \left(\frac{ni}{N}\right)$$

Where, H' = Diversity index; Ni = Number of individuals of each type; N = Number of individuals of all kinds.

To determining the balance of communities, the evenness index was applied, showing the similarity of individuals between species in a community. The evenness index was calculated ising the formula according to **Krebs (2014)**, as follows:

$$E = \frac{H'}{ln\ S}$$

Where, E = Evenness index; H' = Diversity index; S = Number of species.

The dominance index was used to determine whether certain species dominate the fish community structure. It was analyzed using Margalef (1958) in **Odum (1983)** as follows:

$$C = -\sum_{n=1}^{n} \left(\frac{ni}{N}\right)^2$$

Where, C = Dominance index; ni = Number of individuals in the 'each' species; N = Total number of individuals.

The Bray-Curtis similarity index is used to assess the similarities of species, families, and orders among research stations with the following equation **(Bengen, 2000)**:

$$B = \sum_{k=1}^{n} \frac{|X_{ij} - X_{ik}|}{|X_{ij} + X_{ik}|}$$

Where, B = Bray Curtis similarity index, Xij,Xik= The presence value of species-i at each observation period (j,k), n = The number of types (species, families, and orders) compared. The Bray-Curtis similarity index value is from 0 – 1, approaching 1 indicates high similarity. Bray-Curtis similarity analysis was performed using Past 3.14 software.

Descriptive data analysis was conducted using tables and graphs to examine presence frequency, species composition, family & order distribution in addition to community structure (Diversity Index, Evenness, and Dominance Index) of ichthyofauna found in seagrass habitats, with Microsoft Excel software.

RESULTS

1. Composition of ichthyofauna

The results of this study obtained as many as 76 individuals, 34 species, 15 families and 10 orders (Tabel 1).

Table 1. Comparison of the Number of individuals, species, families, and orders of fish in seagrass meadows between the crepucular periods (dawn and dusk)

Variable of fish	Crespuscular Periods						Total ∑
	Dawn			Dusk			
	Range	Average ± std	∑	Range	Average ± std	∑	
∑ Individuals	4 – 8	6 ± 1.48	31	3 – 12	7 ± 3.35	34	76
∑ Species	2 – 7	5 ± 1.92	20	3 – 10	6 ± 2.61	24	34
∑ Families	2 – 6	5 ± 1.67	12	2 – 8	5 ± 2.17	13	15
∑ Orders	1 – 5	3 ± 1.58	8	2 – 6	4 ± 1.52	10	10

The number of fish individuals found at the dawn period was 31 individuals, 20 species, 12 families and 8 orders. While during the dusk period, there were 45 individuals, 24 species, 13 families from 10 orders (Fig. 2).

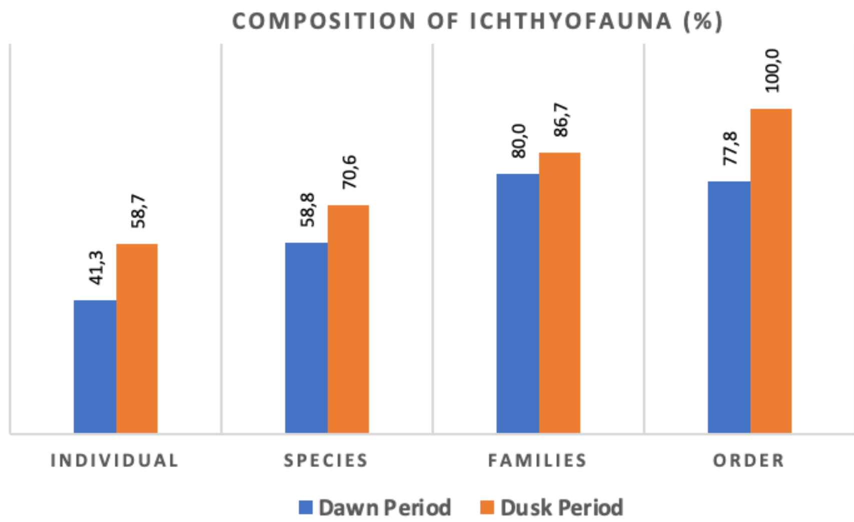

Fig. 2. Composition of ichthyofauna between dawn and dusk periods

Fig. (2) shows that the highest ichthyofauna composition (individuals, species, families and orders) was found on the dusk period compared to the dawn period. Comparison of the range, average number of individuals, species, families and orders of ichthyofauna between observation periods showed that the highest numbers were found on the dusk period compared to the dawn period, as shown in Tables (1, 2).

Table 2. Composition and frequency of presence of ichthyofauna between crepuscular periods (dawn and dusk) in Gili Noko, Bawean Island

ORDER / **Families** / *Species*	**Crepuscular periods**		**∑ Ind.**	**SC (%)**	**PF (%)**	**Trophic Guild** *
	Dawn	**Dusk**				
I. CARANGIFORMES						
1. Carangidae						
Selaroides leptolepis (Cuvier, 1833)	-	+	1	1,3	5	C
II. PERCIFORMES: PERCOIDEI						
2. Apogonidae						
Apogonichthyoides melas (Bleeker, 1848)	-	+	1	1,3	5	I
Cheilodipterus quinquelineatus Cuvier, 1828	-	+	2	2,6	10	I
Taeniamia fucata (Cantor, 1849)	-	+	1	1,3	5	I
Fibramia lateralis (Valenciennes, 1832)	-	+	2	2,6	10	I
Sphaeramia orbicularis (Cuvier, 1828)	-	+	1	1,3	5	I
Fowleria samarae (Valenciennes, 1832)	-	+	1	1,3	5	I
Nectamia savayensis (Günther, 1872)	-	+	1	1,3	5	I
Nectamia bandanensis (Bleeker, 1854)	+	-	1	1,3	5	I
3. Gerreidae						
Gerres oyena (Fabricius, 1775)	+	+	7	9,2	15	I
4. Nemipteridae						

Pentapodus trivittatus (Bloch, 1791)	+	+	4	5,3	20	IF
Scolopsis samara (Lacepède, 1802)	+	+	11	14,5	35	IF
Scolopsis margaritifera (Cuvier, 1830)	-	+	1	1,3	5	IF
5. Lutjanidae						
Lutjanus fulviflamma (Forsskål, 1775)	+	-	1	1,3	5	C
III. PERCIFORMES: LABROIDEI						
6. Labridae						
Halichoeres argus (Bloch & Schneider, 1801)	+	+	4	5,3	10	H
Leptoscarus vaigiensis (Quoy & Gaimard, 1824)	+	-	2	2,6	5	H
Scarus ghobban Fabricius, 1775	+	-	1	1,3	5	H
Choerodon anchorago (Bloch, 1791)	-	+	1	1,3	5	H
7.Pomacentridae						
Abudefduf sexfasciatus (Lacepède, 1801)	+	+	2	2,6	10	O
Amblypomacentrus breviceps (Schlegel & Müller, 1839)	-	+	1	1,3	5	O
Dischistodus perspicillatus (Cuvier, 1830)	+	+	3	3,9	15	O
Dischistodus fasciatus (Cuvier, 1830)	+	-	1	1,3	5	O
Pomacentrus littoralis Cuvier, 1830	+	-	1	1,3	5	O
IV. MULLIFORMES						
8. Mullidae						
Upeneus tragula Richardson, 1846	+	+	3	3,9	15	I
V. CLUPEIFORMES						
9. Dorosomatidae						
Herklotsichthys quadrimaculatus (Rüppell, 1837)	+	+	5	6,6	25	C
VI. ATHERINIFORMES						
10. Atherinidae						
Doboatherina duodecimalis (Valenciennes, 1835)	+	+	5	6,6	25	I
VII. ACANTHURIFORMES						
11. Leiognathidae						
Equulites elongatus (Günther, 1874)	-	+	2	2,6	10	O
12. Siganidae						
Siganus virgatus (Valenciennes, 1835)	+	-	1	1,3	5	H
VIII. GOBIIFORMES						
13. Gobiidae						
Valenciennea muralis (Valenciennes, 1837)	-	+	2	2,6	10	I
Amblygobius stethophthalmus (Bleeker, 1851)	+	-	1	1,3	5	I
Istigobius ornatus (Rüppell, 1830)	+	-	1	1,3	5	I
IX. HOLOCENTRIFORMES						
14. Holocentridae						
Sargocentron rubrum (Forsskål, 1775)	+	+	3	3,9	15	P
Neoniphon samara (Fabricius, 1775)	+	-	1	1,3	5	P
X. PLEURONECTIFORMES						
15. Bothidae						
Bothus pantherinus (Rüppell, 1830)	-	+	1	1,3	5	I

Note: *) Sourcer: Pauly and Froese (2024), SC= Species compotition, PF = Presence Frequency, I =invertebrate feeders, H =Herbivores, O = Omnivores, P Planktivores, IF = Invertebrate/Fish feeders.

Fig. (3) displays the variation of ichthyofauna composition based on its presence in seagrass habitat during the crepuscular period (between dawn and dusk). The largest composition of seagrass fish species is the invertebrate feeder category, and the lowest is planktivores.

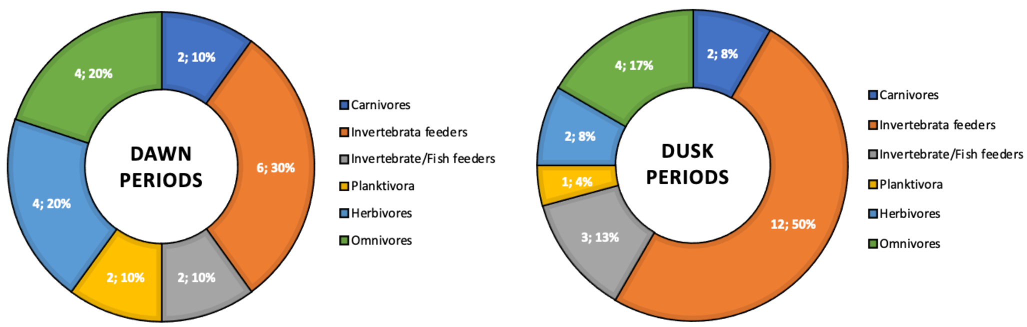

Fig. 3. Comparison of Ichthyofauna feeding habits between crepuscular periods (dawn and dusk) in Gili Noko seagrass habitat, Bawean Island

2. Similarity and community structure of ichthyofauna

The similarity of species, families and orders between crepuscular periods (Table 3) shows a moderate similarity value. This means that in general there are relatively differences in species, families and orders of ichthyofauna inhabiting seagrass beds between the dawn and dusk periods.

Table 3. Bray-Curtis similarity for species, families, and orders of seagrass ichthyofauna between crepuscular periods (dawn and dusk) in Gili Noko, Bawean Island

Bray-Curtis Similarity of Species	Dawn Periods	Dusk Periods
Dawn Periods	1	0,514
Dusk Periods	0,514	1

Bray-Curtis Similarity of Families	Dawn Periods	Dusk Periods
Dawn Periods	1	0,591
Dusk Periods	0,591	1

Bray-Curtis Similarity of Orders	Dawn Periods	Dusk Periods
Dawn Periods	1	0,591
Dusk Periods	0,591	1

The value of the fish community structure includes the diversity, evenness, and dominance index. Table (4) shows that the diversity and dominance indices were in the low category, while the evenness index was in the stable category.

Table 4. Community structure of fish in seagrass habitat between crepuscular periods

Community Structure	Crepuscular Periods				Category
	Dawn		Dusk		
	Range	Average ± Std	Range	Average ± Std	
Diversity (H')	0.56 – 1.91	1.34 ± 0.53	1.10 – 2.21	1.76 ± 0.43	Low
Evenness (E)	0.78 – 0.98	0.89 ± 0.09	0.96 – 1.00	0.99 ± 0.02	Stable
Dominance (C)	0.16 – 0.63	0.30 ± 0.19	0.13 – 0.33	0.19 ± 0.09	Low

3. Life stage, utilization, and conservation status

Based on the life stage data, it was shown that the ichthyofauna found in the seagrass habitat of Gili Noko waters, Bawean Island, East Java, can be used for ornamental fish, consumption, and can also be used as both consumption fish and ornamental fish (Table 5).

Table 5. Life stage, utilization and conservation status of ichthyofauna on Gili Noko, Bawean Island

Name of Species	Length Range (cm)	Max.Length (theory) (cm)	Life Stage	Conservation Status (IUCN)	Utilization
Selaroides leptolepis	23	24 *	Adult	LC	C
Apogonichthyoides melas	11,5	13 *	Adult	LC	O
Cheilodipterus quinquelineatus	10 – 11	13 *	Adult	LC	O
Taeniamia fucata	9	10 *	Adult	LC	O
Fibramia lateralis	9,5 – 10	11 *	Adult	LC	O
Sphaeramia orbicularis	9	10 *	Adult	LC	O
Fowleria variegata	7,5	8 *	Adult	LC	O
Nectamia savayensis	10,5	11 *	Adult	LC	O
Nectamia bandanensis	10	10 *	Adult	LC	O
Gerres oyena	13,5	30 *	Pre Adult	LC	C
Pentapodus trivittatus	10 – 14	28 *	Juvenile	LC	C, O
Scolopsis ciliata	9 – 15	25 *	Juvenile	LC	C, O
Scolopsis margaritifera	10	25 *	Juvenile	LC	C, O
Lutjanus fulviflamma	17	35 *	Juvenile	LC	C, O
Halichoeres argus	9 – 10,5	12 *	Adult	LC	O
Leptoscarus vaigiensis	15 – 17	35 *	Pre Adult	LC	C, O
Scarus ghobban	10	75 *	Juvenile	LC	C, O
Choerodon anchorago	12	50 *	Juvenile	LC	O
Abudefduf sexfasciatus	7 – 8	19 *	Pre Adult	LC	O
Amblypomacentrus breviceps	7,5	8 *	Pre Adult	LC	O
Dischistodus perspicillatus	9 – 10	18 *	Pre Adult	LC	O
Dischistodus fasciatus	7	11 *	Pre Adult	LC	O
Pomacentrus littoralis	7	11 *	Pre Adult	LC	C, O
Upeneus tragula	11 – 14	30 *	Pre Adult	LC	C
Herklotsichthys quadrimaculatus	15 – 16,5	25 *	Pre Adult	LC	C
Doboatherina duodecimalis	7 – 9	11 *	Pre Adult	LC	C
Equulites elongatus	8	8 *	Adult	LC	C

Siganus virgatus	10	30 *	Juvenile	LC	C, O
Valenciennea muralis	10	16 *	Pre Adult	LC	O
Amblygobius stethophthalmus	8	8 *	Pre Adult	LC	O
Istigobius ornatus	9,5	11 *	Adult	LC	O
Sargocentron rubrum	13	32 *	Pre Adult	LC	C, O
Neoniphon sammara	7	32 *	Juvenile	LC	C, O
Bothus pantherinus	20	39 *	Pre Adult	LC	C

Note: * Pauly & Froese (2024)

Comparison of fish presence based on life stage (Fig. 4) shows different composition between dawn and dusk, especially between adult fish category which is more found at dusk and lowest at dawn. This stage is different from the juvenile phase, which is higher at dawn period and lowest at dusk period.

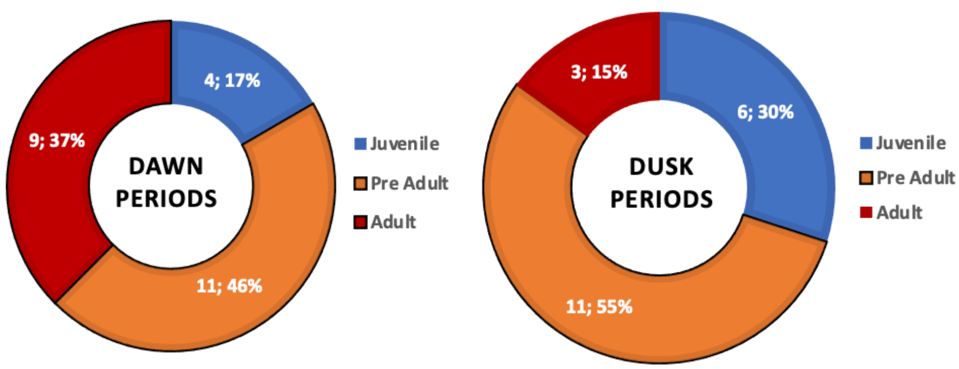

Fig. 4. Comparison of the presence of ichthyofauna composition based on life stage in the Gili Noko seagrass habitat, Bawean Island

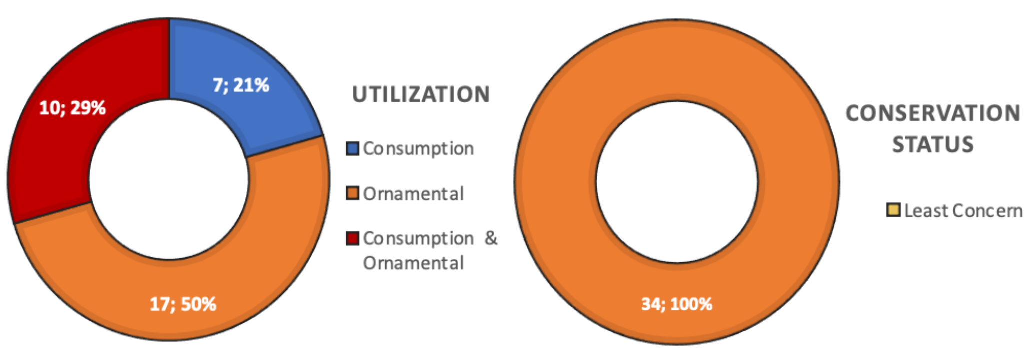

Fig. 5. Utilization, and conservation status of ichthyofauna on Gili Noko, Bawean Island

Based on utilization (Fig. 5), the ichthyofauna collected in the seagrass habitat of Gili Noko waters, Bawean Island, Gresik Regency, East Java are more dominated by fish that have the potential to be used as ornamental fish (50%), compared to those that are used as ornamental fish as well as consumption fish which is only 29%, and those that have the potential to be used as consumption fish which is 21%.

DISCUSSION

1. Composition of ichthyofauna

The numbers of individuals, species, families, and orders of fisih were higher at the dusk period compared to the dawn period (Tables 1, 2 and Fig. 2), presumably related to the abundance of fish, which is generally higher at night, when the dusk period of nocturnal fish begins to spread from coral reefs to nearby habitats such as seagrass beds, which are generally used for feeding. According to **Helfman (1986)**, the environmental transition during the crepuscular period is primarily a change in light, as surface illumination drops from about 100x at sunset to about 0.01x 30 minutes later. During this period, nocturnal fishes begin their activities, while diurnal fishes change their orientation from the daytime active mode to the inactive mode at night, and during dusk, predators appear to be most active in searching for their prey.

Hobson (1973) found a series of five overlapping events at dusk that were essentially repeated in reverse at dawn. These events were (1) vertical and horizontal migrations of diurnal fish; (2) search for shelter by diurnal fish; (3) evacuation of the water column; (4) emergence of nocturnal fish; and (5) vertical and horizontal migrations of nocturnal fish. The changes in light properties at dusk and the increased predator activity at that time suggest a direct relationship between predation and vision during the crepuscular period.

The results of this study obtained 76 individuals, 34 species, 15 families, and 10 orders (Tables 1, 2). This surpasses the findings of **Latuconsina *et al.* (2022)**, who obtained 72 individuals, 34 species from 14 families, and 4 orders. The **Latuconsina *et al*. (2022)** study also focused on a similar type of seagrass meadow dominated by *Thalassia hemprichii* and *Enhalus acoroides* vegetation but with low density. The low number of individuals, species, and fish families is undoubtedly due to the lack of support from other ecosystems other than coral reefs. **Latuconsina *et al.* (2014)** found 65 species of ichthyofauna belonging to 33 families. Seagrass habitats surrounded by mangrove forests and coral reefs have the most species, with 54 species from 29 families. In contrast, seagrass habitats adjacent to mangrove habitats without coral reef support only 23 species from 18 fish families. **Latuconsina *et al.* (2015)** also found 843 individuals, 40 species, and 25 families. The seagrass meadow area directly adjacent to coral reefs had a high fish species richness compared to seagrass meadows adjacent to mangroves. This clearly demonstrates that the fish species richness of seagrass meadows is significantly influenced by the presence of other habitats, such as mangroves and coral reefs. As **Unsworth *et al.* (2008)** assert, Indo-Pacific seagrass meadows play a crucial role as fish nurseries, influenced by the availability of coral reefs and nearby mangroves.

Table (2) clearly shows that the fish found are typical coral reef fish. These include the families Apogonidae, Pomacentridae, Labridae, Nemipteridae, and Holocentridae. These families dominate around 65.8% of the total number of individual fish found. In contrast, **Jones *et al.* (2021)** identified five fish families (Siganidae, Lethrinidae, Lutjanidae, Scaridae, and Labridae) that collectively accounted for more than 85% of the total fish abundance. **Latuconsina *et al.* (2022)** also confirmed that fish in the seagrass ecosystem are dominated by typical coral reef fish, including the families Acanthuridae, Holocentridae, Lutjanidae, Mullidae, and Nemipteridae. This fact clearly shows that seagrass habitats are used as transitional habitats by most ichthyofauna, making seagrass beds a feeding ground, shelter, nursery and spawning ground. **Espadero *et al.* (2021)** confirm that tidal seagrass beds provide permanent habitat for the fish that inhabit them and a large feeding ground for incoming fish, including commercially valuable fish.

The family of Apogonidae has the highest number of species in the Gili Noko seagrass habitat on Bawean Island. This fish is one of the dominant species in coral reefs and seagrass beds, as confirmed by **Latuconsina and Ambo-Rappe (2013)**. **Collins *et al.* (2024)** found that fish from the Apogonidae family can migrate over long distances from coral reefs, up to 145m, at night and return to coral reefs to rest during the day. This indicates the potential importance of Apogonidae in transporting energy and nutrients across coral reef habitats and nearby habitats such as seagrass meadows. This seascape's function differs from that of diurnal planktivores because Apogonids move from reefs to search for prey, while diurnal planktivores require currents to bring prey to them **(Morais *et al.*, 2021)**. However, both types of fish contribute by becoming prey for coral reef predators that generally access seagrass beds at night **(Collins *et al.*, 2024)**.

The results of this study clearly show the composition of fish species on Gili Noko, Bawean Island, based on feeding habits that vary between dawn and dusk. Invertebrate feeder fish dominate the composition of fish species during the crepuscular period, with 12 species (50%) present, and decrease in composition during the dawn period, with 6 species (30%) present. There is a clear change in fish distribution related to the active periods of the day and night, which are generally different. As **Amaral *et al.* (2023)** found, there are different fish assemblages at different times of day, with species from various trophic levels during the day, while planktivores and invertebrates dominate at night. Fish richness and abundance increase from dawn to peak in the morning or evening and decrease at dusk, reaching the lowest values at night. As for fish composition based on trophic level, **Unsworth *et al.* (2008)** reported that the trophic structure of ichthyofauna assemblages in seagrass beds shifted from predators and omnivores near corals to planktivores and herbivores near mangrove forests, with planktivores and herbivores dominating. **Manangkalangi *et al.* (2022)** found the dominance of omnivorous and carnivorous fish groups in the seagrass ecosystem of Nusmapi Island, West Papua - Indonesia.

The results of this study also found that the frequency of ichthyofauna presence was categorized as "Hardly ever-present," and only *Scolopsis ciliata* was categorized as "Seldom present" (Table 2). This finding indicates that the seagrass ecosystem in the waters of Gili Noko, Bawean Island, functions as a transitional habitat during different daily periods, both for foraging and for other biological activities. The absence of permanent residents with high frequency of presence is consistent with the findings of **Latuconsina *et al.* (2022)** in seagrass habitats similar to those in Gili Noko Waters, which are dominated by short-sized seagrass vegetation species such as *Thalassia hemprichii*. These habitats typically harbor coral reef or mangrove fish species that undergo pre-adult to adult phases. This phenomenon underscores the notion that the diversity of ichthyofauna species in seagrass habitats is predominantly influenced by their proximity to coral reef and mangrove ecosystems. According to **Hemingga and Duarte (2000)**, four salient factors contribute to the variability of ichthyofauna communities in seagrass habitats, namely: (1) seagrass vegetation structure, (2) the level of larvae and juveniles inhabiting the seagrass habitat, mortality and migration processes, (3) the location of the seagrass vegetation in relation to other nearby habitats, and (4) physical and chemical parameters in the seagrass habitat.

2. Similarity and community structure of ichthyofauna

The similarity of ichthyofauna (species, families, and orders) between crepuscular periods (dawn and dusk) is relatively low (Table 3). This phenomenon shows that there is a difference in the presence of fish between crepuscular periods, which can explain that the presence of fish temporally daily (crepuscular period) in seagrass habitats tends to be different in the waters of Gili Noko - Bawean Island. More or less the same fact is also reported by **Latuconsina *et al.* (2022)**, who found low ichthyofauna similarity between the day and night periods in seagrass habitats dominated by *Thallasia hemprichii* seagrass vegetation in Wamsisi village - Buru Island, Maluku. The results of this study tends to be different from the findings of **Latuconsina and Ambo-Rappe (2013)** in the seagrass habitat of Tanjung Tiram waters, Inner Ambon Bay - Indonesia and the findings of **Latuconsina *et al.* (2019)** in the seagrass habitat of Tatumbu Island, Kotania Bay, Maluku – Indoensia which both have habitat types dominated by *Enhalus acoroides* seagrass species, where relatively high species similarities were found between the day and night periods. In addition to the physical characteristics of the seagrass habitat, it also affects the similarity of fish species associated with it, in accordance with the study of **Hemingga and Duarte (2000)**. The difference in fish presence between the day and night periods is mainly related to the nocturnal and diurnal nature of fish **(Latuconsina & Ambo-Rappe, 2013)**. According to **Helfman (1986)**, the environmental transition during the crepuscular period is closely related to changes in light intensity in the water column, where during this period nocturnal fish begin their activities, while diurnal fish change their orientation from active daytime mode to inactive mode.

The fish community structure includes the diversity index (H') and the dominance index in the low category, while the evenness index is in the stable category (Table 4). The low value of the dominance index (C) is attributable to the absence of a substantial number of individuals from a single or multiple species. This factor also contributes to the stability of the fish community structure, as evidenced by the evenness index (E) value. A parallel can be drawn with the report of **Latuconsina *et al.* (2022)** on seagrass habitat characters, which are more or less the same as the dominance of *Thalassia hemprichii* vegetation. In that study, a low dominance index was also observed, but in contrast, the Diversity Index (H') was high, with the evenness index (E) value in the stable category. In contrast to the findings of **Latuconsina *et al.* (2014)** in seagrass habitats supported by mangroves and coral reefs, the diversity index is in the moderate category and the evenness index is in the unstable category, while the dominance index is in the low category. **Latuconsina and Ambo-Rappe (2013)** and **Manangkalangi *et al.* (2022)** obtained higher fish diversity index values in seagrass ecosystems during the day compared to the night, due to the higher number of fish species found during the day compared to the night. This phenomenon shows that the structure of fish communities in seagrass habitats is very dynamic and can change on a daily temporal scale, which is thought to be due to differences in daily activities of each fish species, including the influence of physical-chemical and biological factors of the environment. According to **Krebs (2014)**, the community structure in nature is influenced by environmental physicochemical factors and relationships between species, so that the relative abundance of individuals of a species will affect the stability of a community structure. This community structure is closely related to the food chain, so that there will be interactions between species that lead to energy transfer through the food chain, predation, and competition in communities that have high diversity.

3. Life stage, utilization, and conservation status

The present study identified the composition of fish species in the pre-adult phase as comprising 15 species (44%), while the juvenile phase exhibited the lowest species composition, with 8 species (24%) (Table 5 and Fig. 4). In a related study, **Latuconsina *et al.* (2022)** found that the ichthyofauna in seagrass beds was successively dominated by pre-adult fish at 50.0%, adults at 35.3%, and juveniles at 14.7%. The results of this study are consistent with those previously reported by **Latuconsina and Al'aidy (2015)** in the waters of Buntal Island, Kotania Bay, Maluku - Indonesia where the ichthyofauna was also dominated by the pre-adult phase at 46.2%, adults at 38.4%, and juveniles at 15.4%. **Latuconsina *et al.* (2015)** found that the ichthyofauna composition was dominated by the pre-adult phase at 44.6%, followed by adults at 27.7%, and juveniles at 13.8%. This finding is in contrast to the results reported by **Latuconsina and Ambo-Rappe (2013)**, who observed a prevalence of 41.6% for the pre-adult stage, 40.4% for the adult stage, and 18.0% for the juvenile stage in the Inner Ambon Bay, Maluku - Indonesia. This finding contrasts with the report by **Ambo-Rappe *et al.* (2013)**, which indicated that 89% of the identified specimens were in the juvenile phase. **Simanjuntak *et al.* (2020)** reported that 90% of the identified fish species were in the juvenile phase, and the report by **Manangkalangi *et al*. (2022)** found that 65.9% of the fish were in the juvenile phase.

A comparison of the fish life stages found between the dawn and dusk periods reveals that both are dominated by pre-adult phase fish, while the second largest number is the juvenile phase during the dawn period, and the adult phase during the dusk period (Fig. 4). The preponderance of pre-adult phase fish suggests that seagrass beds fulfill a crucial role as a nursery area, while the presence of adult fish indicates their function as a foraging habitat. This phenomenon is further corroborated by the findings of **Jelbart *et al.* (2007)** and **Unsworth *et al*. (2008)**, who reported a high abundance and diversity of fish in seagrass habitats adjacent to mangrove areas. This phenomenon is believed to be associated with the increasing area of protection and the provision of sustenance for ichthyofauna in the presence of mangrove habitats around seagrass beds.

The ichthyofauna observed in the seagrass habitat of Gili Noko Waters, Bawean Island, in this study was predominantly composed of ornamental fish, particularly members of the families Apogonidae, Gobiidae, and Labridae. This observation stands in contrast to the findings reported by **Jones *et al.* (2021)**, who documented that economically significant fish families, namely Lethrinidae (75% of the fish samples), Scaridae (55%), Siganidae (53%), Labridae (51%), Mullidae (35%), and Muraenidae (20%), constituted the predominant economic fish families in terms of consumption. While the study focused predominantly on ornamental fish species, the presence of these fish species significantly contributes to the diversity of fish species that comprise a complex food chain. This, in turn, attracts predatory fish to the seagrass habitat in search of food during the crepuscular period. The findings of this study demonstrate the significance of the seagrass habitat in Gili Noko waters, Bawean Island, as a crucial feeding ground for fish of a higher trophic level.

The recent discovery of diverse fish species exhibiting different trophic levels within the seagrass habitat of Gili Noko waters, Bawean Island, has significant implications for our understanding of seagrass ecosystems. The presence of herbivores, carnivores, omnivores, invertebrate feeders, and planktotrophic feeders suggests that seagrass habitats can support a wide array of fish species due to their abundance of diverse food sources, thereby facilitating complex trophic interactions. **Jianguo *et al.* (2020)** revealed that seagrass beds provide a diverse habitat role for adjacent coral reef ecosystems by providing microhabitats for various young and adult coral reef creatures. **Shoji *et al.* (2017)** reported that the number of species, abundance, and biomass of fish-eating predators and average trophic levels at night were significantly higher than during the day in all seasons, and only predation by fish occurred at night. Nighttime visits by fish-eating predators increase the risk of predation and affect trophic levels in seagrass habitats, which serve as nurseries. Although all fish species collected in the Gili Noko seagrass habitat on Bawean Island are currently classified as "Least Concern" (Fig. 5), there are concerns that this status could change in the future due to the high fish exploitation and the decline in habitat quality caused by various destructive anthropogenic activities. According to **Latuconsina *et al.* (2023)**, one of the main factors contributing to the degradation of seagrass habitat quality is the easy access to these areas in coastal zones and small islands, driven by anthropogenic activities. As a result, implementing a comprehensive conservation strategy for seagrass ecosystems should be prioritized. As demonstrated by **Espadero *et al.* (2021)**, recognizing the importance of seagrass beds in the tidal zone of tropical regions as habitats for ichthyofauna is crucial for the management and protection of fish biodiversity, ensuring the sustainable use of fisheries.

4. Future fisheries and ecotourism management in Gili Noko – Bawean Island

The carrying capacity of the Gili Noko marine environment is highly suitable for the development of marine tourism, and the support of easy accessibility from Bawean Island as the main island with a distance of 1.24 nautical miles, and inhabited by around 700 head of family **(Noor & Romadhon, 2020)**. It is predicted that the environment of the island and waters of Gili Noko in the future will be increasingly stressed due to various anthropogenic activities. This condition has the potential to have a potential negative impact on the existence of marine ecosystems including seagrass meadows and coral reefs which are potential habitats for ichthyofauna communities in the area. Thus, the development of marine tourism in Gili Noko needs to consider environmental aspects by involving the community to control various anthropogenic activities that have the potential to damage the aquatic environment as recommended by **Ramli *et al.* (2012)** and **Afandi *et al.* (2017)**. Efforts to manage the Gili Noko area as a tourist destination will certainly help protect the seagrass ecosystem and the closest ecosystems around it such as coral reefs so that they are protected from damage, thus supporting the biodiversity of the ichthyofauna associated with it. This effort also supports sustainable fisheries in Gili Noko, Bawean Island, Gresik Regency, East Java.

Efforts to preserve seagrass habitats in the waters of Gili Noko, Bawean Island, will contribute to the sustainability of seagrass-based fisheries, as they support fishery stocks **(Unsworth *et al.*, 2010)** and food security **(Unsworth *et al.*, 2014)**. As demonstrated by **de la Torre-Castro *et al.* (2014)**, **Nordlund *et al.* (2018)** and **Unsworth *et al.* (2019)**, seagrass plays a crucial role in supporting subsistence, commercial, and recreational fisheries in coastal areas. Therefore, effective management is necessary to ensure the survival of seagrass and its provision of global ecosystem services. Habitat-based fisheries management in the waters of Gili Noko - Bawean Island can be integrated with sustainable ecotourism management to further enhance conservation efforts.

CONCLUSION

The highest composition of ichthyofauna (individuals, species, families, and orders) was observed during the dusk period compared to the dawn period. The dusk period also had the highest numbers of individuals, species, families, orders, and community structure indices (diversity, evenness, and dominance). Fish species composition was dominated by pre-adult fish, with a shift in dominance observed: the juvenile phase was more prevalent during the dawn period, while the adult phase predominated at the dusk period. This increase in the adult phase during the dusk period is thought to be linked to the transition between night and day, when predatory fish are more active in seeking prey within the seagrass habitat. The diversity of life stages and feeding habits within the fish community highlights the functional importance of seagrass beds as both a nursery and a food source. Additionally, the presence of numerous coral reef fish species, such as those from the Apogonidae, Labridae, Gobiidae, and Holocentridae families, suggests strong connectivity between the seagrass habitat and the surrounding coral reef ecosystem in Gili Noko Waters, Bawean Island. Therefore, conserving seagrass ecosystems and their adjacent habitats, including coral reefs, is crucial for maintaining fish biodiversity and supporting the sustainable use of fisheries and ecotourism.

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