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Enhancing Fisheries Management and Sustainability: A Stowage Factor Analysis of Fish Species at Mayangan Port, Indonesia

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ABSTRACT

The Stowage Factor (SF) is a crucial parameter for determining the volume-to-weight ratio of fish in a ship's hold, ensuring efficient space utilization and accurate catch estimation. This study investigates the SF of 17 fish species landed at the Mayangan Port, Probolinggo, Indonesia, using a fishing hold model to optimize fish storage in sampling boxes. Fish were placed in sampling boxes, which were sized to match the fish sampled. SF was calculated as the ratio of fish weight in tons to box volume in cubic meters. Packing density and spatial arrangement were controlled to reflect typical storage practices. Measurements were conducted on fish from frozen storage rooms with refrigeration to ensure consistency and accurate weights. The SF values measured across species ranged from 0.28 to 0.66 ton/m³, with an average SF value of 0.47 ton/m³. Significant variations were observed, influenced by species-specific morphology, packing density, and spatial arrangement. The results highlight that the average SF value, while useful as a general benchmark, may introduce bias when applied to species with SF values at the extremes of the range. These findings provide a scientific foundation for improving stowage design, emphasizing the importance of using species-specific SF values to support efficient logistics operations and data-driven fisheries management. Accurate SF measurements enable more precise estimates of fish weight in holds, contributing to the implementation of measured fisheries policies aimed at sustaining marine biodiversity and optimizing resource use. This research not only supports the design and management of fishing logistics but also aligns with ecological principles to promote the sustainable development of fisheries.

1. INTRODUCTION

Fisheries are a vital source of food, income, and employment worldwide, particularly in coastal nations like Indonesia. However, unsustainable practices, such as overfishing and poor fisheries management, pose significant threats to the long-term viability of fishery resources [1, 2]. To ensure the preservation of marine biodiversity and maintain sustainable yields, it is crucial to develop precise methods for managing fisheries operations [3]. One such method involves the calculation of the Stowage Factor (SF), which represents the volume per unit weight of fish. The SF is essential for estimating the volume and weight of fish stored in fishing vessel holds and directly influences the efficiency of fisheries logistics and catch estimation [4, 5].

Indonesia's rich marine biodiversity, which includes a variety of demersal and pelagic species, underscores the need for precise fish stock estimations. SF values, which vary significantly across fish species due to differences in morphology, packing density, and spatial arrangement, enable more accurate assessments of the quantity and weight of fish in fishing holds. However, the reliance on SF values for fish stock estimations can be complicated by species-specific morphological differences and environmental conditions [6]. For instance, variability in packing density and spatial arrangement of fish species can lead to inaccuracies in stock assessments, if not properly accounted for, potentially undermining the sustainability of fisheries policies [7].

Previous studies have explored various SF estimation methods, including empirical measurements, water displacement methods, and the use of refrigerated compartments for frozen fish [8]. However, limited research has been conducted on the SF of fish species in Indonesian waters, particularly those landed at key ports such as Mayangan in Probolinggo. This gap is critical, as accurate SF values are necessary for effective fisheries management and policy implementation [6]. Research indicates that while various methods exist for estimating SF, the application of these methods can yield varying results due to species-specific characteristics and environmental conditions. For instance, the empirical measurement of fish density and volume can be influenced by factors such as fish morphology and packing density, which differ significantly among species [7]. This study aims to bridge this gap by addressing the limitations of generalized SF values and focusing on deriving species-specific data for fish commonly found in Indonesian waters. By doing so, it contributes to improving the precision of fish stock assessments and enhancing the sustainability of local fisheries.

Moreover, the implications of using generalized SF values can lead to mismanagement of fish stocks. Studies have shown that overfishing and destructive fishing practices can severely impact fish populations and marine ecosystems. In Indonesia, where artisanal fisheries are prevalent, the need for precise stock assessments is further emphasized by the pressures of overfishing and habitat degradation [9]. Thus, relying on generalized SF values without considering local species characteristics may exacerbate these issues, leading to unsustainable fishing practices.

The proposed study utilizing the 'fish in a box' method aims to address this gap by providing accurate, species-specific SF values for fish landed at the Mayangan port. By implementing standardized methods—such as using sampling boxes with specific dimensions and controlling the packing density of fish—this study offers a robust framework for SF measurement tailored to the conditions of Indonesian fisheries. The findings are expected to inform the design of better stowage systems and support data-driven policy-making for sustainable fisheries management.

The objective of this study is to develop precise and species-specific SF measurements that can enhance the efficiency of fisheries logistics and improve the accuracy of stock assessments. By integrating these findings into practical applications, the study aims to contribute to the optimization of fisheries management strategies, promote sustainable utilization of marine resources, and support the formulation of evidence-based policies that align with ecological and operational needs [10].

2. METHOD

The study was conducted at Mayangan Fish Port, Probolinggo, East Java, Indonesia, one of the key fish landing sites in the region, as indicated on the map in Figure 1. The data collection took place between August and September 2023 during peak fishing seasons, ensuring diverse and abundant fish landings for reliable sampling.

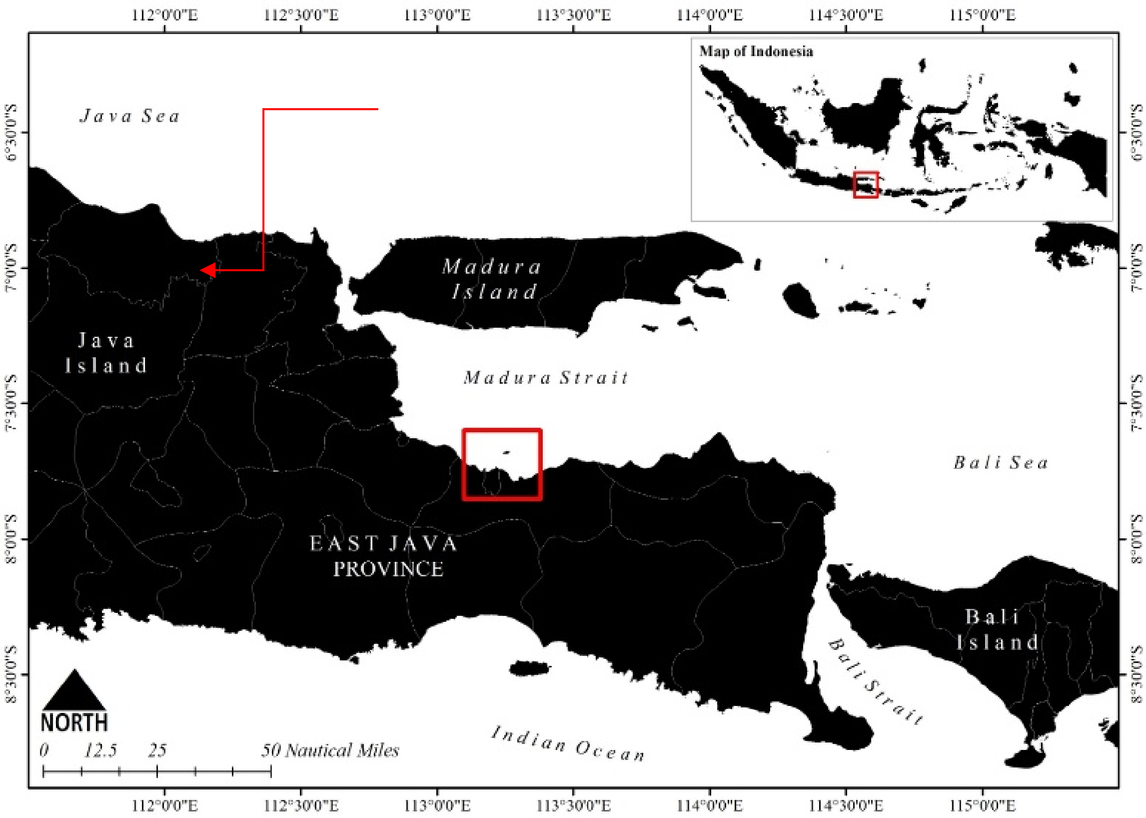


Figure 1. Data sourced locations

Fish samples were collected from purse seine and handline fishing vessels that landed at Mayangan Port. Sampling was conducted randomly on fishing vessels that landed at the port, ensuring a representative cross-section of the fish species landed. Fish were randomly selected from all holds, capturing the diversity of the catch. A subset of fish from each species was randomly plucked and placed into a sampling box with a specific volume. The size of the sampling box was adjusted according to the size of the fish being sampled to ensure accuracy in measurements. This process was repeated at least 10 times per species to ensure representativeness and statistical reliability of the sample. There was no special monitoring of environmental parameters such as temperature and humidity. However, fish were measured in their frozen state, taken directly from the refrigerator-cooled fishing holds. These conditions ensured consistency in the fish's condition during measurement and minimized any potential weight changes. Measures were taken to prevent dehydration or rehydration of fish samples before weighing, as all fish remained in a frozen state throughout the sampling and measurement process. The frozen fish were immediately placed into the sampling box for measurement, ensuring the accuracy of the Stowage Factor (SF) calculations.

The Stowage Factor (SF) for each species was calculated by dividing the total weight of fish in kilograms (kg) by the volume occupied in cubic meters (m^3). The results were expressed in ton/m^3 to standardize the measurements across species. Packing density and spatial arrangement of fish in the measuring box were controlled to reflect typical storage practices and to ensure consistency. The sampling method is visually detailed in Figure 2, illustrating the procedure of fish selection and placement into sampling box.

Figure 2. SF data collection using the in-box sampling method

Figure 3. Length-weight measurement

The study utilized various tools to ensure precision during data collection. A 1×1 meter grid was employed for spatial measurements to standardize the packing density of fish, while digital scales provided precise weight readings. To facilitate movement between sampling locations, walking boards were used. Boxes were utilized for temporary storage of fish samples to avoid rehydration or dehydration, ensuring accuracy in weight measurements. The necessary stationery was employed to document length, weight, and species information. Additionally, technological tools such as cameras were used for photographic documentation of fish morphology and computers were employed for real-time data recording and analysis, as shown in Figure 3.

The Stowage Factor (SF) for each species was calculated by dividing the total weight of fish in kilograms (kg) by the volume occupied in cubic meters (m^3). SF was then expressed in ton/m^3 to allow for standardization across different species. The SF calculation is pivotal, denoting the weight-to-volume ratio of the fish, and is derived using the formula [11]:

$$\mathrm{SF} = \frac{Weight_{fish}}{Storage\ Volume} \quad (1)$$

The SF values were analyzed for each species separately to account for variations due to species-specific morphology, packing density, and other biological factors.

Furthermore, the length-weight relationship of fish as shown in Formula 2, indicative of their growth patterns, is investigated using the formula [12]:

$$W = a\ L^b \quad (2)$$

where, ‘W’ represents weight in kilograms, ‘L’ is the total length in centimeters, and ‘a’ and ‘b’ are constants [12, 13]. The coefficient ‘b’ is particularly telling; a value near 3 suggests isometric growth, while a deviation from 3 implies allometric growth. This comprehensive approach not only augments the accuracy of the results but also significantly contributes to the fisheries research domain. Furthermore, fish morphology is determined based on characteristics such as body shape, head, mouth, teeth, barbel, finlets and fins. The length of the fish was measured using measurement software *ImageJ*, and the weight of the fish was measured using a digital scale.

3. RESULTS AND DISCUSSIONS

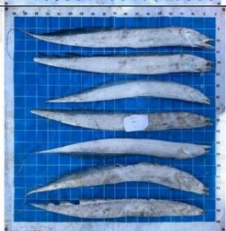
3.1 Stowage Factor (SF) values

The Stowage Factor (SF) is defined as the volume-to-weight ratio of fish, expressed in tons per cubic meter (ton/m^3). It measures how much space one ton of fish occupies in a storage container, making it a crucial metric for optimizing storage efficiency in fishing vessels**.** In this study, the SF values for 17 fish species landed at Mayangan Port ranged from 0.28 to 0.66 ton/m^3, with an average of 0.47 ton/m^3. As illustrated in Table 1, species with compact, robust bodies, such as Sparidae (0.66 ton/m^3) and Lutjanus vitta (0.63 ton/m^3), had higher SF values due to their efficient packing density. Conversely, elongated species like Trichiurus lepturus (0.34 ton/m^3) and Lutjanus malabaricus (0.28 ton/m^3) exhibited lower SF values, reflecting reduced packing efficiency due to their body morphology.

The average SF value of the fish landed at Mayangan Port is approximately 0.47 ton/m^3, indicating that, on average, one cubic meter of space holds about 470 kg of fish. The median SF value of 0.49 ton/m^3 is close to the mean, suggesting that the data distribution is relatively symmetric with no extreme outliers. The standard deviation of 0.11 ton/m^3 indicates moderate variability in SF values, reflecting differences in fish species' body morphology and packing density. The range of SF values spans from 0.28 ton/m^3 to 0.66 ton/m^3, illustrating the diversity of species, from elongated fish to more compact ones, influencing their storage efficiency.

Table 1. SF Values of the fish landed in Mayangan Port, Pprobolinggo

No.	Fish on 1m² Grid	Name of Fish and the Characteristics	SF Value (ton/m³)
1		 ***Pristipomoides multidens***. Habitat rocky coral area, depth 40–360 m; dorsal and anal fin bases without scales, 48–50 lateral line scales, yellowish to pink, 2 golden stripes on snout and cheeks, top of head with transverse brown lattice, dorsal fin with yellowish markings; Indo–West Pacific; maximum length up to 100 cm [14-16].	0.48
2		 ***Lutjanus vitta***. Coral reef habitat, depth 10–70 m; row of scales rising above lateral line, vomerine tooth patch extending to middle of back, pale brown to pink, narrow dark central stripe on sides, faint brownish line following row of scales on sides; East India & West Pacific; maximum length up to 40 cm [14, 17, 18].	0.63
3		 ***Epinephelus maculatus***. Habitat coral reefs, depth 0–100 m; 11 dorsal fin spines, slightly rounded caudal fin, tallest dorsal fin at the front, 49–52 lateral line scales, pale brown with many small dark brown spots close together, 2 large faint black spots on the body below dorsal fin; Midwest Pacific; up to 60 cm [14, 19].	0.53
4		 ***Caranx ignobilis***. Habitat close to coral reefs with a depth of 0–190 m; thick scales at the base of the tail, scaleless area on the chest separated from the plain base of the chest by a large area of scales, steep head shape, 20–24 gill sieves on the 1st-gill arch, 18–21 dorsal fin soft rays, silvery to black; Indo–Western & Central Pacific; 165 cm [14, 20-22].	0.53
5		 ***Netuma thalassina***. Habitat, depth 0–195 m; 3 palatine teeth on each side of the roof of the mouth with the most bottomless triangular band of most enormous size, head not flattened, snout pointed, 14–17 anal fin rays, brownish with a golden sheen; Indo–Central West Pacific; up to 185 cm [14, 22].	0.56
6		 ***Plicofollis dussumieri***. Habitat on soft substrate bottom, depth 0–50 m; 2 palatine teeth slightly separated on each side of the roof of the mouth, palatine teeth in the posterior band have blunt tips, second adipose dorsal fin has a black edge, head is not too flat; Indian Ocean; up to 80 cm [14, 23].	0.53
7		 ***Sparidae***. Coastal and estuarine waters, depth 0–50 m; teeth on jaws including molars, space between eyes scaly, 3½ scales above lateral line, second anal fin spines robust and long, body silvery grey, caudal fin blackish, black markings between anal fin rays; Western Pacific; up to 40 cm [14, 24].	0.66
8		 ***Rhinoprenes pentanemus***. The hard rays of the first dorsal fin and the first segments of the weak rays of the pelvic fin are very elongated, forming filaments. The 4 weak rays of the upper pectoral fin are simple, and the fourth weak rays are very elongated and form filaments, snout protruding forward. The north coast of Australia and the Gulf of Papua [14, 25].	0.45

No.	Fish on 1m² Grid	Name of Fish and the Characteristics	SF Value (ton/m³)
9		 ***Eleutheronema tetradactylum***. Habitat on muddy and sandy bottoms, depth 0–25 m; the elongated base of pectoral fins well below the midline of the body, lower lip small, 4 pectoral filaments, 71–80 lateral line scales, usually 10 (9–12) rows of scales above the lateral line, pectoral fins bright yellow in fresh fish; Indo–West Pacific; up to 200 cm [14, 26].	0.53
10		 ***Plicofollis argyropleuron***. Habitat on the bottom with a soft substrate, depth 0–40 m; the front palatine teeth on the roof of the mouth are much smaller than the back teeth, the palatine teeth on the back have blunt ends, the head is long and flat, the eyes are positioned low near the head; East Indies & West-Central Pacific; up to 150 cm [14, 27].	0.33
11		 ***Lobotes surinamensis***. Habitat coastal areas, river estuaries, and offshore areas around floating objects; dorsal and anal fins with rounded rear lobes form a 'three-tail' with rounded caudal fins; the spines of the third anal fin are longer than the second, evenly dark brown to olive or mottled; circumglobal; maximum length 110 cm [14, 28].	0.45
12		 ***Trichiurus lepturus***. Bentopelagic Habitat, depth >200 m; body elongated like a ribbon, single very long dorsal fin, no caudal and pelvic fins, no slit at the base of the lower jaw, eyes rather ample, space between eyes almost flat or slightly concave; West Central Pacific; maximum length up to 100 cm [14, 29].	0.34
13		 ***Johnius carouna***. habitat in shallow coastal waters and estuaries; the front of the air sac is hammer-shaped, the size of the lower jaw teeth is uniform, the tail fin is sharp, there is no barbel on the chin, 26-30 dorsal fin rays, the length of the second anal fin spines is about ¼ the length of the head, the body is silvery, the fins are primarily yellowish; India–China; up to 30 cm [14, 30].	0.46
14		 ***Parastromateus niger***. Habitat in soft-substrate bottom Habitat, usually 15–40 m; thick scales at the base of the tail, pelvic fins absent in specimens >10 cm, anterior part of the dorsal fin with 5 or 6 very short spines (not visible in adults), body wide and flat, silvery grey to brownish; Indo–West Pacific; maximum length up to 75 cm [14, 31].	0.49
15		 ***Lethrinus nebulosus***. Habitat in shallow coastal habitats and coral reefs, depth 0–75 m; 9 dorsal fin rays, 8 anal fin rays, scaly pectoral fin tips, 5½ scales between lateral line and dorsal spines, yellowish with pale bluish spots on scales, 3 blue lines between eyes and mouth; Indo–West Pacific; up to 80 cm [14, 32].	0.34
16		 ***Lutjanus malabaricus***. Habitat in coral and rocky reefs, depth 10–100 m, have a larger mouth (maxillary length nearly equal to the distance between the last dorsal and anal fins vs. much shorter), a more humped head shape, and a shorter caudal fin; Indo–West Pacific; up to 100 cm [14, 33].	0.28

No.	Fish on 1m² Grid	Name of Fish and the Characteristics	SF Value (ton/m³)
17		 ***Rachycentron canadum***. Habitat in pelagic, coastal and offshore waters; 6–9 short spines separate dorsal fin, dorsal and anal fins long, head broad and flat, caudal fin like a crescent with longer lobes in adults, dark brownish or black with 2 narrow pale stripes visible; Indo–West Pacific; maximum length 200 cm [14, 34].	0.45

This variability aligns with the findings of FAO [35], which reports that the SF values for commonly frozen fish species such as Tuna, Mackerel, and Herring range between 0.59 and 0.88 ton/m³, demonstrating that SF values can vary widely based on species composition and morphology. In comparison, Alham [36] and Ramadhanti et al. [37] documented SF values of 0.5 and 0.54 ton/m³, respectively, for multi-species catches with similar compositions, reinforcing that SF values for frozen fish typically lie within this range. Although the fish species analyzed in this study differ from those reported by FAO (2004), the findings align closely with Alham's and Ramadhanti's observations, further validating that the stowage factor for multi-species catches tends to range from 0.5 to 0.54 ton/m³. The range of SF values observed at Mayangan Port, from 0.28 ton/m³ to 0.66 ton/m³, reflects the diversity of fish species—from elongated forms with lower SF values to compact-bodied species with higher values, influencing their packing efficiency.

These findings provide species-specific SF data, addressing gaps in the existing literature, particularly for fish commonly landed in Indonesian waters. The results highlight the variability of SF values across species and emphasize the need for precise measurements to support fisheries management practices.

Table 2. The correlation between the length and weight of the fish

No.	Fish Species	Equation	b Value	R²
1	*Pristipomoides multidens*	$\mathbf{W} = 0{,}0379\ \mathbf{L}^{2{,}7396}$	2.74	0.8805
2	*Lutjanus vitta*	$\mathbf{W} = 0{,}3827\ \mathbf{L}^{2{,}0284}$	2.03	0.5947
3	*Epinephelus maculatus*	$\mathbf{W} = 0{,}0731\ \mathbf{L}^{2{,}4969}$	2.50	0.7374
4	*Caranx ignobilis*	$\mathbf{W} = 1{,}966\ \mathbf{L}^{1{,}7434}$	1.74	0.6947
5	*Netuma thalassina*	$\mathbf{W} = 0{,}0264\ \mathbf{L}^{2{,}6938}$	2.69	0.8917
6	*Plicofollis dussumieri*	$\mathbf{W} = 0{,}1321\ \mathbf{L}^{2{,}3908}$	2.39	0.772
7	*Sparidae*	$\mathbf{W} = 0{,}31\ \mathbf{L}^{2{,}2576}$	2.26	0.7582
8	*Parastromateus niger*	$\mathbf{W} = 0{,}9661\ \mathbf{L}^{1{,}9368}$	1.94	0.7527
9	*Johnius carouna*	$\mathbf{W} = 0{,}5801\ \mathbf{L}^{1{,}9532}$	1.95	0.6774
10	*Rhinoprenes pentanemus*	$\mathbf{W} = 0{,}1552\ \mathbf{L}^{2{,}3452}$	2.35	0.8576
11	*Eleutheronema tetradactylum*	$\mathbf{W} = 0{,}0261\ \mathbf{L}^{2{,}8145}$	2.81	0.9463
12	*Plicofollis argyropleuron*	$\mathbf{W} = 0{,}0765\ \mathbf{L}^{2{,}541}$	2.54	0.8155
13	*Lobotes surinamensis*	$\mathbf{W} = 0{,}0264\ \mathbf{L}^{2{,}865}$	2.87	0.909
15	*Trichiurus lepturus*	$\mathbf{W} = 0{,}2612\ \mathbf{L}^{1{,}783}$	1.79	0.500
16	*Lethrinus nebulosus*	$\mathbf{W} = 2{,}668\ \mathbf{L}^{1{,}6973}$	1.70	0.7288
17	*Lutjanus malabaricus*	$\mathbf{W} = 2{,}6549\ \mathbf{L}^{1{,}7369}$	1.74	0.6528
18	*Rachycentron canadum*	$\mathbf{W} = 0{,}0026\ \mathbf{L}^{2.944}$	2.94	0.8012

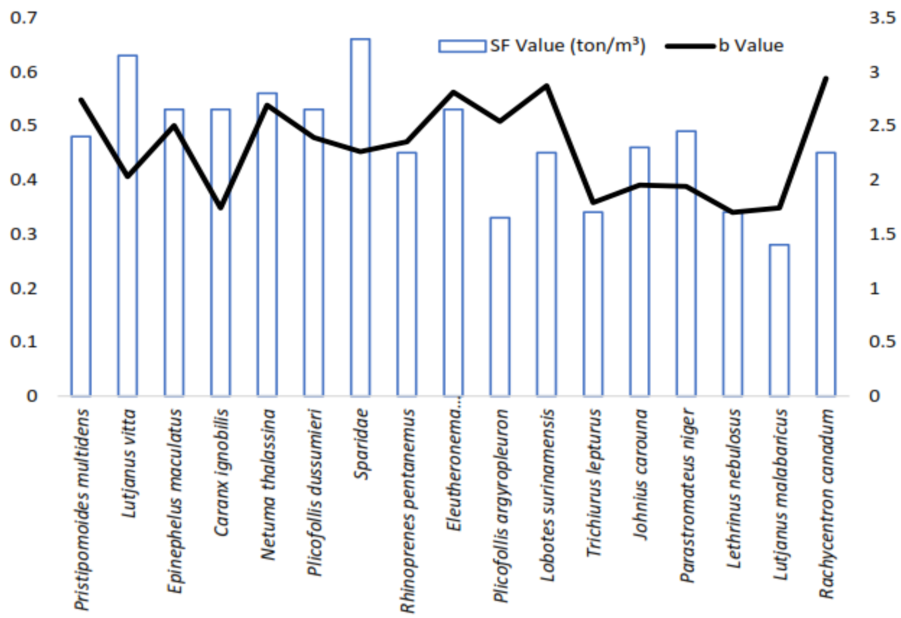


Figure 4. The correlation between the SF and b value

3.2 Morphological analyses

The relationship between fish morphology and SF values was explored using the "b value" from the length-weight relationship formula, the results reflect the strength of the allometric growth relationship for each species, with the b values indicating whether the growth is isometric (b≈3) or allometric (b<3 or b>3). This table highlights species-specific growth patterns, providing insights into how length influences weight, which is essential for accurate biomass estimation and fisheries stock assessments. Table 2 and Figure 4 present the correlation between the length and weight of the fish species analyzed in this study.

The relationship between the b value and the SF (Stowage Factor) value as shown in Figure 4 offers insights into the biological characteristics of fish species and how these traits influence their packing efficiency during storage. However, these two metrics—though both biologically significant—reflect different aspects of fish morphology and behavior. The b value is a parameter from the allometric growth equation, describing how the weight of a fish scales with its length, and is often used to assess the growth pattern and body condition of the species. Meanwhile, the SF value measures the volume occupied per unit weight (expressed in ton/m³), indicating how efficiently a fish species fits within the available storage space, influenced by body shape, size, and packing arrangement.

From the data, species with higher SF values—such as the Brownstripe Snapper (*Lutjanus vitta*) with an SF of 0.63 ton/m³ and the Porgies (*Sparidae*) with 0.66 ton/m³—tend to have compact, relatively thick bodies. However, their b values of 2.03 and 2.26, respectively, suggest moderate growth patterns. This indicates that while these species may grow steadily in weight relative to their length, their body shapes allow them to fit efficiently into storage boxes, resulting in higher SF values. In contrast, species with lower SF values, such as the Malabar Blood Snapper (*Lutjanus malabaricus*) (0.28 ton/m³) and the Largehead Hairtail (*Trichiurus lepturus*) (0.34 ton/m³), exhibit b values ranging from 1.74 to 1.79. These lower b values indicate slower growth in weight compared to their length, suggesting elongated or thin bodies. The elongated body of the Largehead Hairtail, for example, occupies more volume relative to its weight, resulting in a lower SF value, which reflects poor packing efficiency. While certain patterns exist between body shape and SF values, the overall relationship between b values and SF values across all species is not straightforward. For example, species such as the Atlantic Tripletail (*Lobotes surinamensis*) show a high b value of 2.87, reflecting rapid growth in weight, but their SF value is only 0.45 ton/m³. On the other hand, the Fourfinger Threadfin (*Eleutheronema tetradactylum*), with a similar SF value of 0.53 ton/m³, has a lower b value of 2.81, indicating that other factors, such as body shape and density, are more influential in determining SF than growth patterns alone.

The data from this study suggest that the relationship between Stowage Factor (SF) values and b values derived from the length-weight equation is weak or inconsistent. While species with compact bodies tend to exhibit higher SF values, there is no clear or consistent linear correlation between growth patterns, as indicated by the b values, and packing efficiency. Moslen and Miebaka's [38] findings implied that both SF and b values could still be linked through underlying morphological traits, such as body thickness and shape, which affect both growth patterns and packing efficiency. Moreover, the study by Yates et al. [39] showed that morphological traits can respond predictably to environmental factors, which may also impact SF values. This suggests that SF, although directly related to packing density, might not be completely independent of growth patterns indicated by the b values. Environmental influences, such as habitat type and resource availability, could affect both the morphology and growth patterns of fish, resulting in subtle interactions between SF and b values. Similarly, the findings of Huo et al. [40], which revealed high correlation indices between morphological and weight traits in clams, reinforce the idea that morphological traits significantly affect weight. This analogy supports the notion that SF and b values, although distinct, may still be influenced by shared morphological characteristics in fish. For instance, the body structure of fish—whether elongated or compact—affects both the volume occupied in storage and the way weight scales with length, thus indirectly linking SF and b values.

The analysis of morphological traits provides new insights into how body shape and growth patterns affect packing efficiency. These findings bridge biological characteristics and operational efficiency, offering a framework for designing species-specific storage systems in fisheries.

3.3 Habitat impacts on SF values

Table 3 presents the distribution of fish species across different habitats, highlighting their ecological niches and corresponding Stowage Factor (SF) values. The species are grouped into categories such as pelagic, demersal, large pelagic, and estuarine/coastal to illustrate how habitat preferences influence packing efficiency and storage characteristics. This classification provides insights into the relationship between habitat type and SF values, offering a practical perspective for optimizing fisheries logistics and sustainable management practices.

Fish species within the same habitat often exhibit similarities in their Stowage Factor (SF) values, reflecting the influence of their body morphology, packing density, and environmental adaptation on how they occupy space within storage holds. Packing density refers to how tightly fish are arranged within a given volume of a storage container. It is determined by the spatial arrangement of fish and their morphology, with compact-bodied species generally having higher packing densities than elongated species. However, certain habitats demonstrate more variability than others, indicating that ecological and morphological differences impact their SF values and spatial arrangement. In muddy and sandy bottom habitats, species such as the Giant Catfish (*Netuma thalassina*), Blacktip Sea Catfish (*Plicofollis dussumieri*), and Fourfinger Threadfin (Eleutheronema tetradactylum) display similar SF values around 0.53 ton/m³. This consistency suggests that benthic species, often adapted to bottom-dwelling conditions, have comparable densities and packing behavior. However, Silver Sea Catfish (*Plicofollis argyropleuron*), with a lower SF of 0.33 ton/m³, stands out, likely due to its thinner body or differences in packing within the storage containers. Similarly, pelagic species in nearshore or coral-associated habitats exhibit comparable SF values. Giant Trevally (*Caranx ignobilis*) and Black Pomfret (*Parastromateus niger*) both have SF values ranging from 0.49 to 0.53 ton/m³, indicating streamlined bodies that facilitate efficient spatial utilization during storage. These species share similar ecological roles as fast-swimming predators, contributing to their consistent SF values. In contrast, species from nearshore coral reef habitats show more variability. Goldbanded Jobfish (*Pristipomoides multidens*) and Spotted Grouper (Epinephelus maculatus) have moderate SF values between 0.48 and 0.53 ton/m³, while Malabar Blood Snapper (*Lutjanus malabaricus*) and Spangled Emperor (*Lethrinus nebulosus*) exhibit lower values around 0.28 to 0.34 ton/m³. This difference suggests that body thickness and compactness influence the packing density of reef-associated species, with snappers tending to have more compact bodies than emperors and groupers.

Table 3. SF values based on the fish habitat

No.	Fish Species	Habitat	SF Value (ton/m³)
1	*Pristipomoides multidens*	Nearshore / Coral Reef	0.48
2	*Lutjanus vitta*	Nearshore / Coral Reef	0.63
3	*Epinephelus maculatus*	Nearshore / Coral Reef	0.53
4	*Lutjanus malabaricus*	Nearshore / Coral Reef	0.28
5	*Caranx ignobilis*	Pelagic / Near Coral	0.53
6	*Rachycentron canadum*	Large Pelagic / Offshore	0.45
7	*Netuma thalassina*	Muddy / Sandy Bottom	0.56
8	*Plicofollis dussumieri*	Muddy / Sandy Bottom	0.53
9	*Plicofollis argyropleuron*	Muddy / Sandy Bottom	0.33
10	*Parastromateus niger*	Pelagic / Nearshore	0.49
11	*Lobotes surinamensis*	Estuarine / Coastal	0.45
12	*Rhinoprenes pentanemus*	Nearshore / Coastal	0.45
13	*Johnius carouna*	Estuarine / Coastal	0.46
14	*Eleutheronema tetradactylum*	Muddy / Sandy Bottom	0.53
15	*Trichiurus lepturus*	Large Pelagic / Deep Water	0.34
16	*Lethrinus nebulosus*	Nearshore / Coral Reef	0.34

Species from estuarine and coastal habitats exhibit closely aligned SF values. Atlantic Tripletail (*Lobotes surinamensis*) and Karouna Croaker (*Johnius carouna*) both have SF values of 0.45 to 0.46 ton/m³, indicating similar adaptations to fluctuating salinity and environmental conditions. This suggests that these species, which frequently inhabit transitional environments between freshwater and marine systems, exhibit predictable storage characteristics due to their ecological adaptations. In large pelagic habitats, SF values show more variability. Cobia (*Rachycentron canadum*), with an SF value of 0.45 ton/m³, reflects its robust body structure and efficient packing arrangement. In contrast, the Largehead Hairtail (*Trichiurus lepturus*) has a lower SF value of 0.34 ton/m³, likely due to its elongated, ribbon-like body shape, which occupies more space relative to its weight. This variability emphasizes the importance of body morphology in determining SF values for large pelagic species.

In conclusion, fish species from muddy bottom, nearshore pelagic, and coastal estuarine habitats tend to exhibit more consistent SF values, suggesting predictable packing densities within these ecological niches. However, species from coral reef and large pelagic habitats display greater variability in SF values, likely driven by differences in body morphology and spatial arrangement. Research suggests that environmental variability plays a significant role in shaping the traits of fish species, including their SF values. Pinca et al. [41] emphasized that fluctuations in environmental conditions, such as resource availability and habitat structure, impact fish communities and may cause variability in SF values across habitats. Similarly, assemblage variability in fish populations is closely linked to changing environmental conditions, affecting traits relevant to packing efficiency. Oberdorff et al. [42] highlighted the influence of climate and hydrology on fish habitats, demonstrating that shifts in environmental factors can alter fish morphology and, consequently, their SF values. Furthermore, Riofrío-Lazo et al. [43] emphasized that environmental factors significantly influence species assemblages along coastal habitats, affecting how species occupy space in storage. Finally, Moslen and Miebaka [38] asserted that morphological traits respond predictably to macrohabitats, reinforcing the importance of considering environmental and morphological interactions when analyzing fish traits like SF values.

The Stowage Factor (SF) values per fish species vary greatly due to the complexity of multiple variables, such as morphology, body structure, packing density, and environmental factors. The relationship between the length-weight ratio and the habitat of the fish alone is insufficient to derive a single, representative SF value applicable to all the fish species in the dataset. Each species exhibits unique biological and morphological characteristics that affect how efficiently they can be packed, resulting in SF values ranging from 0.28 to 0.66 tons/m³. Although the SF values obtained in this study are accurate and reliable per species, applying the average SF value of 0.47 ton/m³ to other species introduces bias, especially for species with SF values at the extremes of the range. Using a single average value risks misrepresenting the packing efficiency of certain species, potentially impacting logistics planning and fisheries management decisions. Therefore, it is recommended to use species-specific SF values to ensure precision, rather than relying solely on the average SF value for broader applications.

This study contributes significantly to the existing body of knowledge by providing species-specific Stowage Factor (SF) data tailored to fish commonly landed in Indonesian waters, addressing a critical gap in previous research that relied on generalized SF values. The findings demonstrate how fish morphology, growth patterns, and packing density directly influence storage efficiency, offering practical insights into improving stowage systems on fishing vessels. By emphasizing the relationship between biological traits and operational efficiency, this research supports more accurate resource allocation and logistical planning, reducing space wastage and operational costs. Furthermore, the study provides a foundation for evidence-based policy development by integrating precise, localized SF data into fisheries management systems, promoting compliance with sustainable catch limits and reducing ecological impacts. These insights align with broader sustainability goals, emphasizing efficient resource use and minimizing environmental degradation to ensure the long-term viability of marine ecosystems. By connecting biological, environmental, and operational perspectives, this research advances a comprehensive framework for sustainable fisheries management, offering practical solutions to optimize resource use while supporting ecological and economic resilience.

4. CONCLUSIONS

This study highlights the critical importance of species-specific Stowage Factor (SF) values in enhancing the accuracy of fish stock assessments and improving storage efficiency in fisheries operations. The findings demonstrate that SF values vary significantly across species due to differences in morphology, growth patterns, and packing density, underscoring the need for tailored approaches in fisheries management. Fisheries authorities should incorporate species-specific SF values into catch limit guidelines and quotas to improve resource assessments and prevent overfishing. Standardized practices for measuring SF values, such as consistent container sizes and frozen storage conditions, are recommended to enhance catch reporting accuracy. Adopting species-specific SF values reduces waste, optimizes storage, and lowers operational costs while supporting sustainable stock management and preserving biodiversity. Accurate SF data also benefit fisheries economically through better resource planning and cost savings. This research bridges biological and operational perspectives, providing a robust framework for policy development and practical applications. Implementing these recommendations will support sustainable fisheries practices, ensuring the long-term viability of marine ecosystems and economic resilience of fishing communities.

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