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Target strength measurement of *Nemipterus peronii* and *Nemipterus japonicus* (Perciformes: Nemipteridae) in Aceh, Indonesia

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Abstract. *Purnawan S, Manik HM, Hestirianoto T, Amri K. 2025. Target strength measurement of* Nemipterus peronii *and* Nemipterus japonicus *(Perciformes: Nemipteridae) in Aceh, Indonesia. Biodiversitas 26: 2992-2999.* Threadfin breams (Nemipteridae) are ecologically and commercially important demersal fish in the Indo-Pacific region. Accurate estimation of fish population abundance using hydroacoustic methods depends on species-specific Target Strength (TS) reference values. However, no standardized TS data currently exist for threadfin breams. This study aimed to establish TS reference values for two threadfin breams species, namely *Nemipterus peronii* (n: 15) and *Nemipterus japonicus* (n: 13), collected from coastal waters of Aceh, Indonesia. The Total Length (TL) and weight (W) were measured to determine the length-weight relationship for both species. TS values were measured using a scientific single-beam echosounder operating at a frequency of 200 kHz in a water tank. *Nemipterus japonicus* showed positive allometric growth, while *N. peronii* showed negative allometric growth, as evidenced by *b* values of 3.0628 and 2.1831, respectively. Significant TL-TS relationships (P<0.05) were observed with $TS = 46.47\ log(TL) - 104.49$ for *N. peronii* and $TS = 22.89\ log(TL) - 72.69$ for *N. japonicus*. Adjusted regression models with a standardized slope of 20 produced intercept values of b_{20}: -70.96 for *N. peronii* and b_{20}: -68.78 for *N. japonicus*. The result suggested that even within the same genus, morphological differences led to varying TS values for the same body length. Furthermore, species-specific acoustic survey models were important to improve stock assessment accuracy and contribute to effective fisheries management.

Keywords: *Kurisi*, *Nemipterus japonicus*, *Nemipterus peronii*, single beam, TL-TS

INTRODUCTION

Threadfin breams (Nemipteridae) are economically important fish that are widely distributed in the Indo-Pacific region, including Indonesian waters (Imtiaz et al. 2016; Perangin-angin et al. 2016; Yi et al. 2021). These demersal fish inhabit sandy and muddy bottoms and are caught using traditional methods, such as handlines, gillnets, and mini trawls (El-Ganainy et al. 2018; Wora et al. 2024). The abundance of threadfin breams makes local fishermen harvest a large amount, making this species a critical component of the economy (CMFRI 2019; IISD 2021; Balachandran et al. 2024). According to data from the Indonesian Ministry of Marine Affairs and Fisheries (KKP 2021), threadfin breams production increased from 56,962 tons in 2011 to 131,951 tons in 2021. This production value represents nearly 2% of the total marine fish production by 2021 in Indonesia. Although the Indonesian threadfin fishery is still a potentially under-exploited resource (Kantun and Moka 2022), some other areas have shown over-exploited (El-Ganainy et al. 2018; Akgun and Akoglu 2023).

The long-term sustainability of fisheries is highly dependent on the accuracy of stock estimation (Amri et al. 2019; Tirtadanu et al. 2022). Traditional methods, such as Catch Per Unit Effort (CPUE) and population models are the most frequently used to estimate fish populations and stocks in Indonesia (Suman et al. 2018). However, these methods are labor-intensive and expensive, leading to inefficiency. In this regard, hydroacoustic technology is an efficient alternative to address the challenges, enabling direct and rapid estimation of fish presence and abundance across large water columns (Amri et al. 2023; Purnawan et al. 2024).

Acoustic surveys rely on volume backscattering strength (SV), which quantifies the total intensity of sound reflected from the water column. SV values correspond to the density and biomass of fish aggregations. However, converting SV into absolute biomass requires an appropriate Target Strength (TS) reference (Domokos 2021), as TS serves as a crucial scaling factor in this estimation (Purnawan et al. 2025). Inaccurate TS reference can lead to 40% errors in biomass calculations (Mamun et al. 2018), thereby showing the necessity of specific TS reference for fish stock estimates and analyses using acoustic technology (Purnawan et al. 2024). TS is defined as a logarithmic measure of the ratio between acoustic energy reflected by a single target (Manik 2015), such as an individual fish. The reflected intensity is influenced by various factors, including fish length, species, shape, and orientation (Boyra et al. 2018; Apdillah et al. 2021). Fish length is the most important predictor, as it explains most of the variation in TS when the orientation (aspect) is known (Wanzenböck et al. 2020).

There are several methods for obtaining the TS values, such as in situ, which have the advantage of obtaining data for target fish under natural conditions (O'Driscoll et al. 2018; Manik et al. 2022). However, in situ measurements face several challenges, including interference from non-target echoes (e.g., zooplankton and micronekton) and background noise (Dufour et al. 2017; Islaminingdiah et al. 2018). TS measurement can also be acquired using nets or tethering where fish are left alive (Manik et al. 2022), but uncontrolled movement during this process can introduce variation. Alternatively, ex-situ methods using an unconscious or dead fish, enable the control of measurements (Rodríguez-Sánchez et al. 2016; Purnawan et al. 2025), even though the natural authenticity of the fish's behavior and conditions are sacrificed.

Nemipterus peronii (Valenciennes 1830) and *N. japonicus* (Bloch 1791) are two species of threadfin breams frequently caught and landed by fishermen from Aceh, Indonesia. Although threadfin breams are abundant in Indo-Pacific waters, no TS references currently exist to support acoustic-based stock assessments. Both species belong to the same genus and share morphometric similarities. However, subtle morphological differences, particularly in body shape, can influence the acoustic backscattering cross-section. This cross-section refers to the effective area of the fish that interacts with incoming sound waves (Tong et al. 2022). Variations in this area affect the intensity of the reflected echoes and ultimately lead to species-specific TS values (Gastauer et al. 2016). Therefore, applying a unified TS. value across species with different morphologies can result in significant bias in abundance estimates (Domokos 2021). In this context, the present study aims to determine TS values for *N. peronii* and *N. japonicus*, and to assess whether morphological differences between closely related species within the same genus led to significantly different TS responses. Since Total Length (TL) is a simple proxy for body shape via the Length-Weight Relationship (LWR), this study uses TL as the primary variable to assess its relationship with TS across species. By establishing TS references for threadfin breams, the accuracy of stock assessments using acoustics can be improved and contribute to sustainable fisheries management in the Indo-Pacific region.

MATERIALS AND METHODS

Fish samples collection

Fish samples were collected from local fishermen at the landing sites of *Pelabuhan Perikanan Samudera* (PPS) Lampulo and Alue Naga Beach in Banda Aceh, Indonesia (Figure 1). PPS Lampulo is the main fishing port in Aceh Province that supports the landing of fishermen's catch from Aceh waters (Purnawan et al. 2018). The high biodiversity in this area is supposed by Aceh's waters bordering the Indian Ocean, Andaman Sea, and Malacca Strait (Damora et al. 2022; Agustina et al. 2024; Haditiar et al. 2024). Meanwhile, Alue Naga Beach is a small landing site used by traditional fishermen from Banda Aceh (Purnawan et al. 2023). These fishermen typically engage in one-day fishing trips, operating small boats approximately 5 miles from shore. They catch fish using traditional methods such as longline or bottom-longline around the reef.

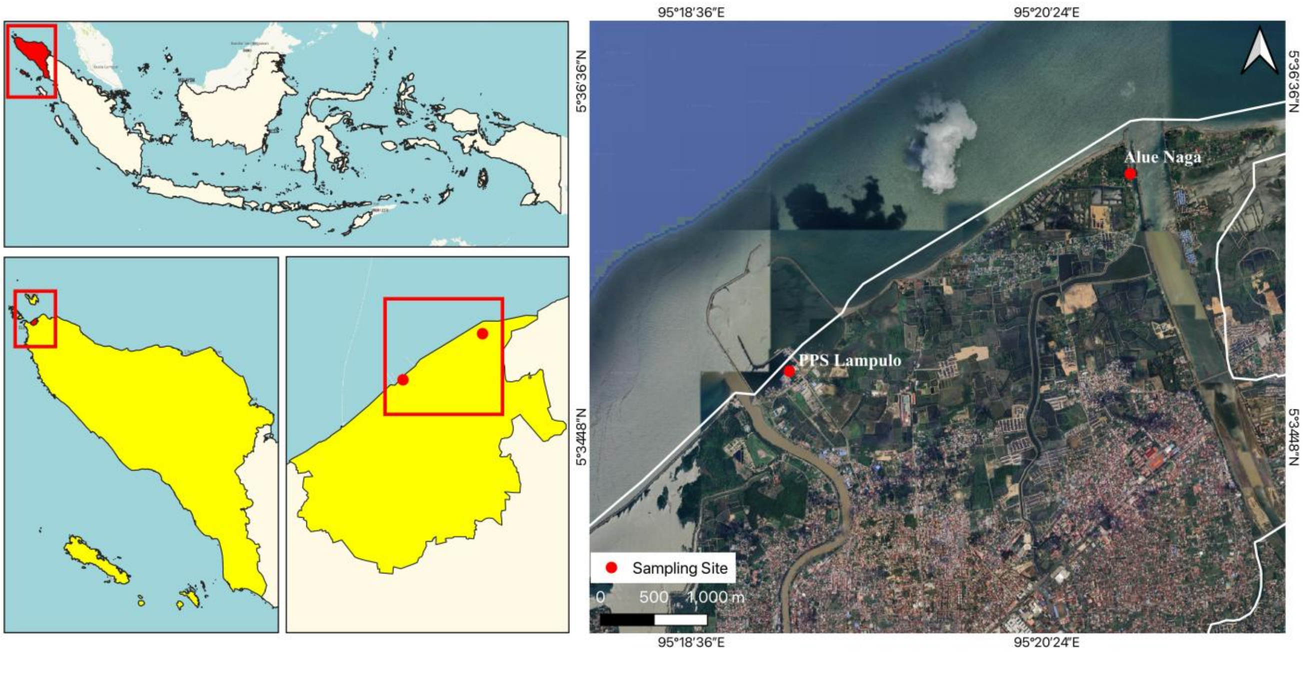

Figure 1. Location of PPS Lampulo and Alue Naga. These two sites support fish landing from the northern waters of Aceh, Indonesia

Nemipterus peronii and *N. japonicus* were chosen based on the prevalence in the landing site and frequent capture by traditional fishermen. *Nemipterus japonicus* is easily recognizable by the upper lobe caudal fin that produces a short or moderately long filament. Meanwhile, *N. peronii* is often mistaken for *N. furcosus* because of its general resemblance. *Nemipterus peronii* can be distinguished by the deeply incised membrane between its dorsal spines, which is absent in *N. furcosus* (Ning et al. 2011). All fish samples were received in a deceased state from fishermen and then transported to the laboratory for further analysis, as shown in Figure 2.

Length-Weight Relationship (LWR)

Before measurement, the species *N. peronii* and *N. japonicus* were identified based on morphological characteristics, following the FAO catalog of genus *Nemipterus* (Russell 1990). After identification, the length-weight relationships of both species were examined. Specimens of *N. peronii* (n: 15) and *N. japonicus* (n: 13) were measured for wet weight (*W*, g) and total length (*TL*, cm) using the following equation:

$$W = a\ TL^b \quad [1]$$

Where,

W : Wet weight of the fish (gr)
TL : Total length of the fish (cm)
a : coefficient
b : growth factor

Based on the value of "*b*", the growth factor can be determined as:

$b > 3$: Positive allometric,
$b < 3$: Negative allometric,
$b = 3$: Isometric.

TS measurement

TS measurement was conducted in a water tank at the Faculty of Marine and Fisheries, Universitas Syiah Kuala, Aceh Province. The tank has a diameter of 3 m and a depth of 3 m, providing sufficient space for determining the TS using the tethering method. Each fish was tied at the head and tail using a 0.32 mm nylon line to ensure that the acoustic waves interacted with the dorsal surface. A weight was attached to the nylon line approximately 30 cm below the ventral side, allowing echoes from the fish and the weight to be distinguished during the analysis.

The transducer was operated vertically and positioned approximately 0.15 m below the water surface. The target fish was placed approximately 2 m from the water surface, centered on the main axis of the acoustic beam to ensure that it was outside the transducer near-field area. In addition, the distance between the fish and the tank bottom was approximately 1 m, allowing a clear separation between target and the tank floor, as shown in Figure 3.

TS was measured using a Simrad EK-15 single-beam echosounder operating at a frequency of 200 kHz, as shown in Table 1. Meanwhile, TS is defined as the logarithmic ratio of the intensity of the acoustic wave reflected by target (I_r: reflected intensity) to the intensity that initially strikes target (I_i: incident intensity), as observed within the water column. The *TS* value was calculated using Equation (2).

$$TS = 10 \log (I_r / I_i) \quad [2]$$

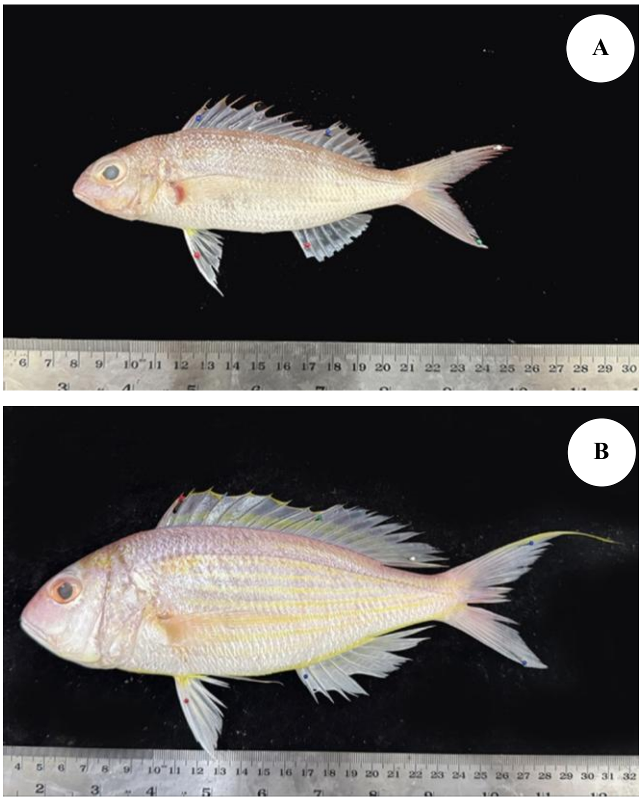

Figure 2. Fish samples. A. *Nemipterus peronii*, B. *Nemipterus Japonicus*

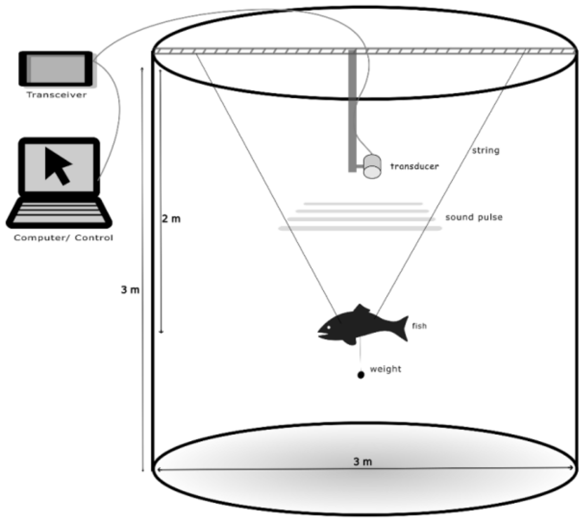

Figure 3. Setup for hydroacoustic TS measurements of threadfin bream with a transducer and tethered fish in a water tank

Before taking TS measurements, the transducer was calibrated using a 38 mm tungsten sphere, following the standard sphere calibration methodology (Foote 1987). The measured average TS of the standard sphere was consistent with the theoretical value. Furthermore, the minimum detection threshold was set to -70 dB re 1 m^2 to eliminate the background noise during the TS measurements. A pulse duration of 0.16 ms was selected as appropriate for shallow marine environments where target fish naturally occur. Data were recorded at a ping rate of 2 Hz for approximately 1 min per fish.

Data analysis

The files recorded by Simrad EK-15 were initially stored in *.raw format, which must first be converted for processing using Sonar5-Pro post-processing software. The Sonar5-Pro software only reads *.uuu format and can be obtained by converting *.raw files using a dongle. Following the method of (Balk and Lindem 2019), TS values were estimated based on Single-Echo Detection (SED).

Due to the controlled conditions under which the fish were measured, the data recorded over one minute tended to produce homogeneous values. Consequently, 50 ping samples were analyzed to integrate and assess the average TS value. Echo integration was carried out carefully, focusing only on predetermined depth to ensure that echo from the weights was excluded from the analysis. The mean in the integration cell was calculated by first converting TS to the backscattering cross-section (σ_{bs}) to obtain a linear value (eq. 3). This linear value was then used to compute the mean *TS* value, as shown in Equation (4):

$$\sigma_{bs} = 10^{\,(TS/10)} \qquad [3]$$

$$TS_{mean} = 10 \log (\Sigma\sigma_{bs} / n_i) \qquad [4]$$

Where, sigma σ_{bs} is the backscatter cross-section of the fish.

Table 1. Parameters used for TS measurements of threadfin bream (*Nemipterus* sp.)

System parameter	Detail
Simrad EK15 single beam echosounder	
Operating frequency	200 kHz
Transducer type	Single beam
Output power	45 Watt
Ping rate	2 ping/s
Pulse duration	0.16 ms
Beam width	26^o
Depth	2 m
Transducer gain	14.2 dB
TS calibration sphere 38 mm	-40.45 dB
Near field	0.33 m
Sonar5-Pro post-processing software	
Minimum target size	-70 dB
Minimum echo length	0.5
Maximum echo length	1.8
Maximum gain compensation	3 dB
Maximum Allowable Detection Threshold (ADT)	0.2

The value of σ_{bs} can be described as a quadratic function of fish length, which follows equation (5).

$$\sigma_{bs} = a_{bs}\, TL^2 \qquad [5]$$

Equations (4) and (5) were combined to obtain (6). The *TS* function was fitted to the TS data using least-squares regression, with *TL* as the independent variable. The analysis used two linear fitting models, where the second variant (eq. 7) of the equation has a fixed slope of 20, as proposed by Foote (1987). In this process, the constant value of b_{ts} was changed to b_{20}.

$$TS = a_{ts} \log (TL, \text{cm}) + b_{ts} \qquad [6]$$

$$TS = 20 \log (TL, cm) + b_{20} \qquad [7]$$

Where, a_{ts} is the slope (with 20 being the standardized slope), b_{ts} and b_{20} are the intercepts.

RESULTS AND DISCUSSION

Length-Weight relationship (LWR)

Both species, *N. peronii* and *N. japonicus*, exhibit distinct morphological characteristics consistent with the reference by Russell (1990). Subsequently, the Length-Weight Relationship (LWR) analysis was conducted, revealing a balance between length and weight growth over time. LWR played a critical role in understanding the contribution of fish length to weight gain for both species. This parameter was also used to understand the contribution of fish length to the TL-TS relationship. The LWR of *N. peronii* and *N. japonicus* showed statistically significant exponential growth patterns ($P<0.05$).

The LWR for *N. peronii* (n: 15) was represented by an equation W: $0.1281TL^{2.1831}$ with an R^2 value of 0.9439. Exponent 2.1831 shows negative allometry ($b<3$), suggesting that weight increases at a slower rate than length. Meanwhile, *N. japonicus* (n: 13) exhibited a positive allometric growth pattern, as shown by the equation W: $0.0125TL^{3.0628}$ and an R^2 value of 0.9772. Exponent 3.0628 suggests that *N. japonicus* prioritizes weight gain over length as it grows (Figure 4).

The differences in LWR between *N. peronii* and *N. japonicus* showed distinct growth patterns, suggesting the ecological diversity within the family of threadfin breams. However, these patterns may show regional variation, as suggested by previous studies (Perangin-angin et al. 2016; Tirtadanu et al. 2022).

TL-TS relationship

Figure 5 shows the relationship between TL and TS for *N. peronii* and *N. japonicus*. The analysis compared normal and adjusted regression models to evaluate the correlation strength between TS and length for each species, while also considering the impact of using adjusted values on these correlations.

Nemipterus peronii showed a significant relationship ($P<0.05$) between TS (dB) and fish length (*log*(*TL*)). The standard regression (blue line) was TS = 46.474 *log*(TL) −

104.49, with an R^2 value of 0.6625. This model showed that approximately 66.25% of the variance in TS could be attributed to fish length, suggesting a significant correlation and the importance of fish length in predicting TS.

After adjusting the regression (orange line), characterized by a slope of *a*=20, the new model was TS = 20 *log*(TL) − 70.96 for *N. peronii*, with a lower R^2 value of 0.4475. Although this adjusted model explains 44.75% of the variance in TS, the significance is in the consistency with the widely accepted empirical values in fisheries acoustics. The intercept values were used for comparison across different species in hydroacoustic studies.

Figure 5.B shows the TL-TS relationship for *N. japonicus* ($P<0.05$). The standard regression model (blue line) for this species, described by the equation TS = 22.89 *log*(TL) − 72.69, has an R^2 value of 0.4751, explaining 47.51% of the variance. This model showed a moderate fit, suggesting that length plays a significant role in predicting TS but to a lesser degree than in *N. peronii*. The adjusted regression for *N. japonicus* (orange line), with a slope of *a:* 20, led to a model, TS = 20 *log*(TL) − 68.78, with an R^2 value of 0.4675.

Discussion

LWR plays a fundamental role in fisheries biology and stock assessment by providing insight into the condition, growth patterns, and biomass estimation of fish populations (Jisr et al. 2018). Fish growth generally follows the cube-law relationship ($W \propto L^3$; b: 3), as described by Froese (2006). In our samples, *N. peronii* exhibits negative allometry ($b<3$), a pattern that has been linked to adaptations such as limited food resources or altered body form (Froese 2006; Su et al. 2020). In contrast, *N. japonicus* exhibited slightly positive allometric growth ($b>3$), a pattern commonly observed in species from productive environments where surplus energy supports both somatic growth and reproductive investment (Xie et al. 2024).

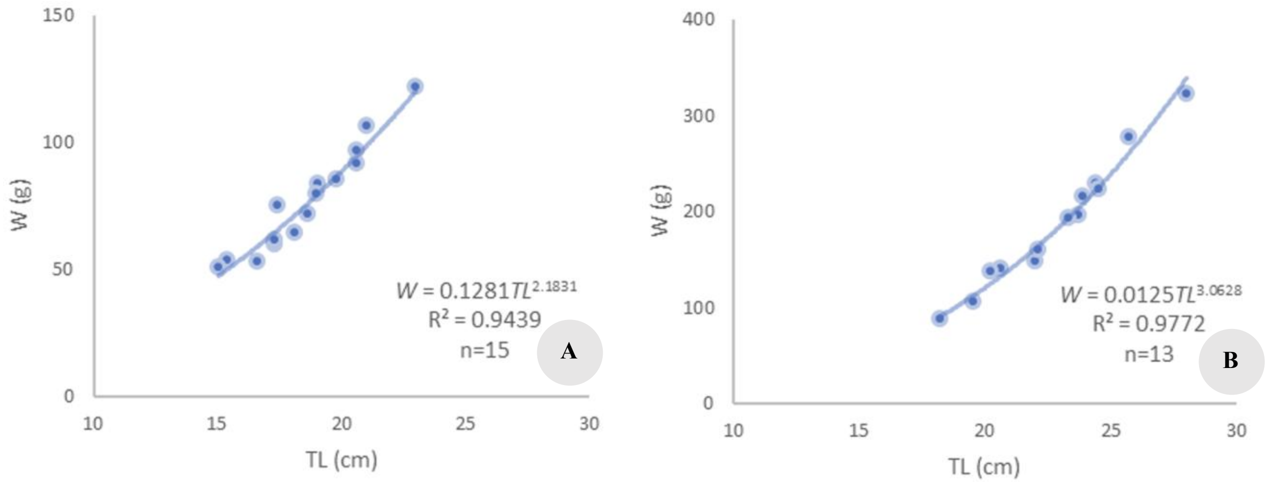

Figure 4. LWR for: A. *Nemipterus peronii*, showing negative allometric growth, and B. *Nemipterus japonicus* with positive allometric growth

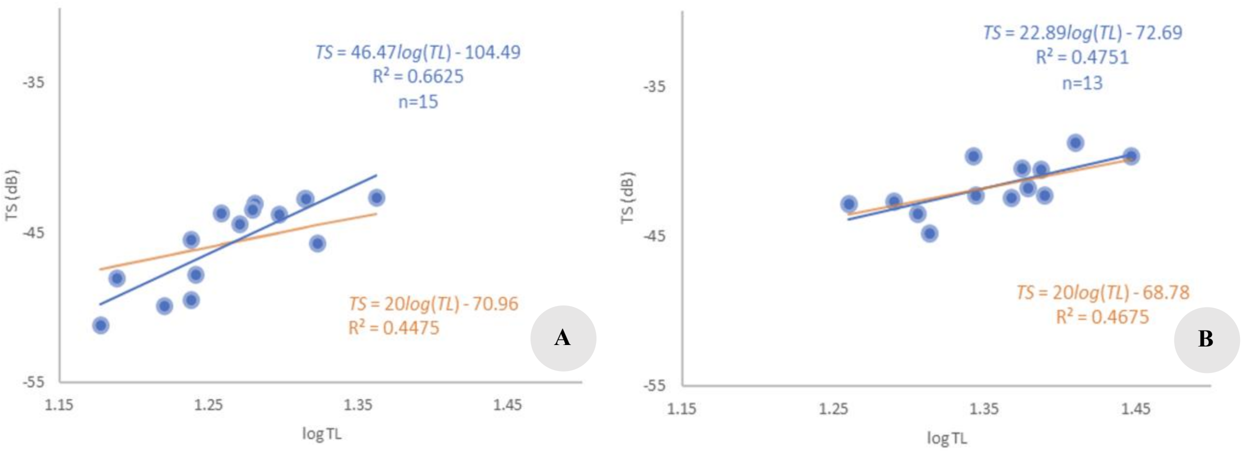

Figure 5. The TL-TS relationships for two species of threadfin bream of: A. *Nemipterus peronii*, B. *Nemipterus japonicus*

The near-isometric growth exponent for *N. japonicus* in our samples aligns closely with values reported by Dash et al. (2023) with b ranging from 2.927 to 2.967 in West Bengal, and Rajesha et al. (2011), who reported b: 3.007 off Mangalore. Several earlier studies have also documented similar values for this species across Indo-Pacific waters. By contrast, the exponent we determined for *N. peronii* ($b<3$) diverges from the b: 3.096 reported by Wu et al. (2008) in southwestern Taiwan, likely due to differences in local environmental conditions. Unfortunately, references on the LWR of *N. peronii* remain scarce, with only a few studies available (e.g., Wu et al. 2008). The limited documentation likely because of its close morphological similarity to *N. furcosus* (Ning et al. 2011).

A significant difference in b values was observed between the two analyzed species, specifically when compared to studies where species within the same genus exhibit similar b values. For instance, Mol et al. (2019) reported b values ranging from 2.61 to 3.29 among five *Labeo* species, while Aqmal-Naser et al. (2021) showed a range of 2.67 to 3.27 in various *Clupeichthys* species. These results suggest that, unlike some genera where species share similar b values, *N. peronii* and *N. japonicus* follow clearly divergent growth patterns. While our focus here is on interspecific differences in b between *N. peronii* and *N. japonicus*, intraspecific shifts in b have also been documented within single species due to factors, such as environmental conditions, growth rates, or sex differences. For example, Olopade et al. (2015) observed b values of 2.62 for males and 2.38 for females in *Leuciscus niloticus* (Joannis 1835), showing how sex can influence growth. Similarly, Jisr et al. (2018) reported intraspecific variations in b values, showing the impact of environmental and biological factors on fish growth. These observations capture the complexity of growth patterns in fish and the influence of both interspecific and intraspecific factors on the development.

When converting TS-TL data into fish biomass estimates, the Length-Weight Relationship (LWR) is used to translate measured TS at a given length into weight. Because LWR parameters a and b reflect overall body form, differences in these values indirectly modulate the TS-weight conversion. This is driven by the fact that body shape determines the acoustic backscattering cross-section, which represents the surface area of the fish exposed to acoustic waves (Yan et al. 2024). In our study, species-specific LWR differences mirror the distinct TL-TS relationships for *N. peronii* and *N. japonicus*. Although no statistical test in this study confirms a direct causal relationship between LWR and TS, the divergence in TL-TS relationships indicates that morphological variation contributes to TS variability. Furthermore, these differences must be examined through the adjusted models (b_{20}) for a direct comparison. The adjusted models showed differences in the intercept (b_{20}) values between *N. japonicus* and *N. peronii* but were smaller than those observed in the original models. *Nemipterus japonicus* specifically exhibited higher TS compared to the more elongated *N. peronii* at the same length, which is consistent with its bulkier body shape.

A standardized slope of 20 provided a useful reference for comparing TL-TS relationships across species, yet adjusting the slope might reduce the general model fit. For example, adjusting the slope of *N. peronii* for a_{ts}: 20 produced a higher intercept (b_{20}: -70.96) but a lower R^2 (0.4475) compared with the original model. The normal regression for *N. peronii* showed a significant steep slope (a_{ts}: 46.474) due to the morphological variations. The elongated shape increased the cross-sectional area proportionally to the fish's length. According to theoretical and empirical findings suggest that acoustic backscattering cross-section scales with the square of fish length (Tong et al. 2022), as explained in Equation (5). This relationship follows the geometric principle that cross-sectional area grows proportionally to TL^2. However, not all fish exhibit body morphologies similar to those of gadoid species (Lillo et al. 1996). The elongated body shape of *N. peronii*, for example, results in a smaller cross-sectional area relative to total length compared to more plump-bodied species such as *N. japonicus*. This morphological difference contributes to lower TS values at equivalent lengths, deviating from the expected geometric scaling assumption.

Froese (2006) attributed these deviations to species-specific variations in body shape (e.g., elongation vs. plumpness) that directly influence the slope (b) in LWR models. Consequently, many non-gadoid species exhibit body shapes that deviate from the cube-law assumption ($W \propto L^3$), leading to slopes that differ significantly from 20 (Froese 2006). This limits the applicability of a single slope across all fish types. The results of this study showed the importance of designing acoustic survey models tailored to the specific morphological and acoustic characteristics of each species. While a standardized slope of 20 offers a useful reference for interspecies TL-TS comparisons, such adjustments may compromise the overall model fit and reduce the accuracy of species-specific acoustic assessments.

Previous studies did not specifically focus on TS for threadfin breams, which prevented direct comparisons with similar species. In general, the observation in this present study is consistent with previous results (Islaminingdiah et al. 2018; Liu et al. 2024). A similar case was observed within the genus *Merluccius*, where *M. gayi* and *M. australis* differed by 1 dB but morphological examination was not conducted in that study (Lillo et al. 1996). The differences observed between the two species in this study are higher, reaching 2.18 dB. This significant difference could be attributed to the considerable morphological characteristics of the two species, with a growth exponent of 3.0628 and 2.1831 for *N. japonicus* and *N. peronii*, respectively. The results further showed the importance of species-specific characteristics in TS, as evident by the different intercepts (b_{20}) among the same genera.

To conclude, this study has generated LWR and TL-TS values for each *N. peronii* and *N. japonicus*. The contrasting LWR patterns of *N. peronii* (negative allometry, b: 2.1831) and *N. japonicus* (positive allometry, b: 3.0628) reflected divergent growth strategies shaped by ecological pressures. Consequently, these results deviated from the expected cube-law relationship (W ∝ L^3) due to species-specific body morphologies. The morphological differences, particularly in body shape, influenced the acoustic backscattering cross-section. *Nemipterus japonicus* exhibited higher TS (*TS* = 20 *log*(TL) − 68.78) than *N. peronii* (*TS* = 20 *log*(TL) − 70.96) at identical lengths. The result of this study also showed that adjusting slopes to a_{ts}: 20 reduced model fit, thereby suggesting the limitations of uniform models for non-gadoid species. These results advocate for species-specific acoustic models that account for morphological differences to enhance biomass estimation accuracy, as relying on standardized slopes may lead to inaccurate ecological generalizations.

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