Journal of Fisheries
Volume 10 Issue 2 August 2022
Peer Reviewed | Open Access

eISSN 2311-3111
pISSN 2311-729X

DOI: https://doi.org/10.17017/j.fish.346

Original Article

Using the hydroacoustic and mini trawl data for estimating fish density in the eastern part of Banyuasin coastal waters, South Sumatra of Indonesia

Fauziyah[1] • Assyifa M. Aprilita[2] • Wike A.E. Putri[1] • Ellis N. Ningsih[1] • Anna I.S. Purwiyanto[1] • Fitri Agustriani[1]

[1] *Marine Science Study Program, Faculty of Mathematics and Natural Sciences, University of Sriwijaya, Indonesia*
[2] *Research Institute for Inland Fisheries and Extension, Ministry of Marine Affairs and Fisheries, Indonesia*

Correspondence
Dr. Fauziyah; Marine Science Department, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Ogan Ilir Regency, Province of South Sumatra, Indonesia
siti_fauziyah@yahoo.com

Manuscript history
Received 28 June 2021 | Accepted 8 March 2022 | Published online 7 June 2022

Citation
Fauziyah, Aprilita AM, Putri WAE, Ningsih EN, Purwiyanto AIS, Agustriani F (2022) Using the hydroacoustic and mini trawl data for estimating fish density in the eastern part of Banyuasin coastal waters, South Sumatra of Indonesia. Journal of Fisheries 10(2): 102201. DOI: 10.17017/j.fish.346

Abstract
The hydroacoustic and mini trawl sampling was conducted to estimate a distribution pattern of fish density in the eastern part of Banyuasin coastal waters, South Sumatra, Indonesia. These surveys were carried out in September 2017 using a SIMRAD EK15 single-beam echo sounder with a 200 kHz operating frequency. Catch data obtained from the mini bottom trawl were used to examine a dominant species for refining the TS value concerning the fish density estimation along the hydroacoustic track. The ponyfishes (*Eubleekeria jonesi*) from the Leiognathidae family were found at each station with the highest relative abundance (50.98%). Hence this species was used to refine target strength values for estimating the acoustic volume density. These volume densities of 206 ESDU ranged from 0 to 9048 fish 1000m^{-3}, with an average of 930 fish 1000m^{-3}. The results also described a distribution pattern of fish densities hence this information could be valuable to the fishery manager for improving sustainable management approaches.

Keywords: Banyuasin coastal waters; distributions pattern; fish density; hydroacoustic

1 | INTRODUCTION

The estimation of fish density using the traditional methods (traps and nets) requires a great effort, financial resources, and time, therefore the recent hydroacoustic development is an essential alternative to these traditional methods (Ehrenberg and Steig 2003; Chen *et al.* 2009; Bezerra-Neto *et al.* 2013). When a substantial hydroacoustic development was introduced in the 1970s, especially the echo-integration technique (Bezerra-Neto *et al.* 2013), hydroacoustic methods and technology are being increasingly and extensively applied as a tool to describe aquatic ecosystems as well as estimating fish density, biomass, and abundance in both freshwaters and marine system (Boswell *et al.* 2007; Rudstam *et al.* 2009; Trenkel *et al.* 2011). Hydroacoustic is also used for estimating zooplankton (Greenlaw 1979; Holliday *et al.* 1989; Martin *et al.* 1996; Miyashita and Aoki 1999; Holbrook *et al.* 2006; Kim *et al.* 2019) and identifying the bottom substrate type (Costa *et al.* 2013; Fauziyah *et al.* 2018a, 2020a; Montereale-Gavazzi *et al.* 2018).

Besides being usable in the deep waters system, hydroacoustics also could be used in shallow waters (waters depths < 5 m) and ultra-shallow waters (< 2 m) due to the development advances of narrow acoustic beams (Boswell *et al.* 2007; Winfield *et al.* 2007; Martignac *et al.* 2015). These methods potentially provide a cost-effective assessment technique for obtaining estimates of pelagic fish abundance (Hassan *et al.* 1998).

There is two output throughout the hydroacoustic data processing namely the raw data of Volume Backscattering Strength (Sv) and Target Strength (TS). The Sv value is an acoustic energy integration scattered from discrete targets per unit volume of water and it's often used for estimating fish biomass while the TS value is an acoustic measurement of fish length where both fish biomass and density can be estimated using Sv that scaled by TS (MacLennan *et al.* 2002; Boswell *et al.* 2007).

Banyuasin coastal waters had high potential and diversity of fish resources (Fauziyah *et al.* 2018b, 2019a) but limited information available for their fish stock status (Fauziyah *et al.* 2020b). Even though these waters have become the centre of fishing activities in South Sumatra Province. The fisheries management objective could be reached optimally when fish density and distribution have been certainly known as well as the management policy can encourage the sustainability of fish resources in the future. Therefore, an acoustic survey for estimating fish density is essentially useful for determining the fisheries management policy. This study aimed to estimate the fish density distribution in the eastern part of Banyuasin coastal waters. This information was needed for sustainable fisheries management.

2 | METHODOLOGY

2.1 Study area

Banyuasin coastal waters is the centre of fishing activity in South Sumatra and this water was strongly influenced by the inflow of the Musi River (Fauziyah *et al.* 2018b, 2019a, 2019b). The acoustic survey with its acoustic tracking (Figure 1) was conducted in September 2017 in the eastern part of Banyuasin coastal waters. These acoustic tracking for estimating the fish density were determined by considering the water's contours and could represent all characteristics of the study area.

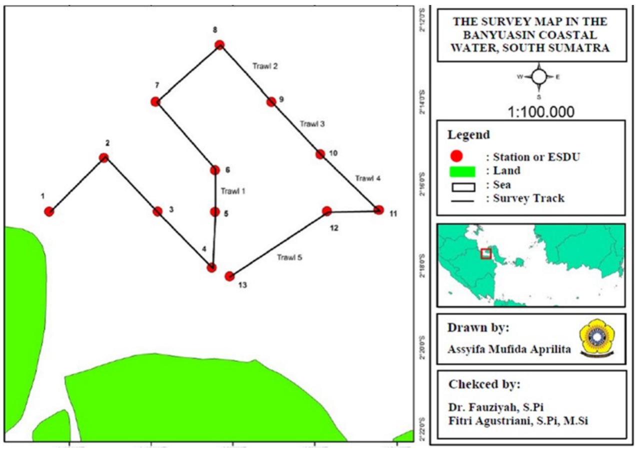

FIGURE 1 Location and survey map in Banyuasin coastal waters, South Sumatra of Indonesia.

2.2 Hydroacoustic sampling

The hydroacoustic sampling in Banyuasin coastal waters was conducted in September 2017 using a SIMRAD EK15 single-beam echo sounder with a 200 kHz operating frequency and a boat operating speed of 5 knots. A mixed survey design (Fauziyah *et al.* 2020a) with a total of 13 the Elementary Sampling Distance Unit (ESDU) was applied. The transducer was mounted on the centre-right side of the boat, positioned 1 m under the water surface. Before using the Simrad EK15, it must be calibrated for maintaining accuracy and verify the Simrad EK15 system can be fully operated.

The study area was surveyed for three days (20 – 22 September 2017). The recording process of acoustic raw data was carried out continuously during the day except when preparing to set the mini bottom trawl by spending 15 minutes at each station. The total distance covered during the entire study was 44.603 km with the distance covered between the stations being 3.431 km.

2.3 Trawl sampling

For species identification traced by the acoustic system, a mini bottom trawl was used. These trawl samplings were conducted simultaneously along the acoustic tracks (Stenevik *et al.* 2015) but in this survey, the trawl sampling was conducted randomly ranging from 5 – 6, 8 – 9, 9 – 10, 10 – 11 and 12 – 13 stations. These trawl samples were used for estimating the fish composition by species, weight, and length (Stenevik *et al.* 2015). The total length of the main species obtained from the trawl sampling was used to refine the TS measurements from the hydroacoustic survey as well as to estimate the fish density (Mackinson *et al.* 2005; Doray *et al.* 2010).

2.4 Data analysis

Acoustic data were analysed using Echoview (version 4.8) software and Microsoft Excel (version 16.0). Before analysis, each echogram was subjected to manual edit to confirm true fish echoes in the analysis. Furthermore, a sound returned from the seafloor from echo integration was excluded using the Echoview bottom detection function. An echo integration was employed to calculate the total amount of sound backscattered within an echogram. These analyses provided the NASC (Nautical Area Scattering Coefficient) namely an average amount measure of sound reflected by fish per aerial square nautical mile. For calculating the fish density, scaling the NASC using the expected size of an acoustic fish was needed.

A maximum threshold value of –30 dB was used to detect the fish targeted with the highest echo, while the minimum value was determined based on the average TS value of the smallest total length of fish obtained from a dominant species in each sampling location. This TS value obtained was then reduced by 10 dB to suit the minimum threshold value (Parker-Stetter *et al.* 2009). Acoustic data processing used the integration upper threshold minus 1.0006453902 meters from the surface, due to the transducer mounted 1 m under the surface and the presence of the nearfield transducer zone. The conventional equations that were commonly used for calculating the near-field value were as follows (Foote 2014)

$$NF = \frac{D^2}{4\lambda} \text{ or } NF = \frac{a^2}{\lambda}$$

Where *NF* is the nearfield (m), λ is the wave length (m), *D* is the transducer diameter (m), and *a* is the radius of the circular piston transducer.

The narrow beamwidth would have an acoustic dead zone (ADZ) value of 0.3 m (Parker-Stetter *et al.* 2009). Based on a simplistic approach (Ona and Mitson 1996), there was a ''definite ADZ'' that was defined as extending to a height of $c\tau/2$ above the seafloor, where *c* is the wave propagation speed in meters and τ is the transmitted pulse duration in seconds. Furthermore, the calculation of NASC, density per unit area (ρ_a), and density per unit volume (ρ_v) were expressed as follows (Foote 1987; MacLennan *et al.* 2002; Parker-Stetter *et al.* 2009; Fassler *et al.* 2013):

$$NASC = 4\pi \ 1852^2 \ 10^{\frac{S_v}{10}} \ T$$

$$\rho_a = \frac{NASC}{4\pi \, \sigma_{BS}}$$

$$\rho_v = \frac{S_v}{\sigma_{BS}} \text{ or } \rho_v = \rho_a \, r$$

$$TS = 20 \log L - 71.9 \quad \text{(for the clupeoid fish)}$$

$$TS = 20 \log L - 66.2 \quad \text{(for the swimbladder fish)}$$

$$\sigma_{BS} = 10^{\frac{TS}{10}}$$

Where ρ_a is the density per unit area, ρ_v is the density per unit volume, 4π is the steradians in a sphere-converting "backscattering" cross-section to "scattering" cross-section, 1852 is meters per nautical mile (m nmi^{-1}), *Sv* is the mean volume backscattering strength of the domain being integrated (dB re 1 m^2m^{-3}), T is the mean thickness of the domain being integrated (m), σ_{BS} is the backscattering cross-section value (m^2), and *r* is the depth of water (m).

3 | RESULTS

3.1 Catch composition from the trawl sampling

The sampling using the mini bottom trawl in this study area obtained 13 species represented by 11 families (Table 1). Leiognathidae was distributed in all sampling stations (AF = 100%) with the highest relative abundance (RA = 57.62%). *Eubleekeria jonesi* and *Secutor incidiator* of Leiognathidae family were recorded at each station. The highest relative abundance was recorded for *E. jonesi* (50.98%), therefore this species could be specified as the dominant species used to refine TS values.

TABLE 1 Fish species composition, appearance frequency (AF), and relative abundance (RA) were obtained from the trawl survey in the eastern part of Banyuasin Coastal Waters.

Family	Species	Stations										AF**	RA**	Environment*)
		6		9		10		11		13				
		SA	*n*	SA	*n*	SA	*n*	SA	*n*	SA	*n*			
Clupeidae	*Dussumeiria elopsoides*									×	5	20 L	0.49 L	Pelagic-neritic
Cynoglossidae	*Symphurus microrhynchus*					×	8					20 L	0.78 L	Demersal
Engraulidae	*Stolephorus indicus*			×	28	×	30			×	4	60 M	6.05 H	Pelagic-neritic
Leiognathidae	*Eubleekeria jonesi*	×	112	×	100	×	102	×	100	×	108	100 H	50.98 H	Demersal
	Secutor insidiator	×	11	×	14	×	21	×	7	×	15	100 H	6.64 H	Demersal
Loliginidae	*Loligo chinensis*			×	28							20 L	2.73 L	Benthopelagic
Nemipteridae	*Nemipterus hexodon*			×	29	×	73	×	20	×	3	80 H	12.21 H	Demersal
Penaidae	*Parapenaeopsis sculptilis*	×	10	×	22			×	14			60 M	4.49 M	Benthic
	Penaeus merguensis					×	12	×	5			40 L	1.66 L	Benthic
Paralichtydae	*Pseudorhombus elevates*					×	3					20 L	0.1 L	Demersal
Platycephalidae	*Platychepalus indicus*					×	3	×	6			40 L	0.88 L	Reef
Portunidae	*Scylla olivacea*	×	29					×	10	×	12	60 M	4.98 M	Demersal
Sciaenidae	*Nibea soldado*	×	19			×	4	×	15	×	44	80 H	8.01 H	Demersal
	Number of Species	5	181	6	221	9	254	7	177	7	191			

AF/RA: H, high; M, moderate; L, low. SA: species appearance; *n*, number of species; * according to www.fishbase.org and www.sealifebase.org. **The AF values were divided into 3 categories (Fauziyah *et al.* 2018b) namely low (AF ≤ 42.86), moderate (42.84 < AF < 7.42), and high (AF ≥ 71.42) whereas the RA values categories (Fauziyah *et al.* 2018b) were namely low (RA ≤ 2.845), moderate (2.845 < RA < 5.686) and high (RA ≥ 5.686).

The measurement results of 522 *E. jonesi* specimens showed that the total length (TL) ranged from 2 – 9 cm and most specimens (61%) were distributed in sizes 50 – 55 mm TL (Figure 2). The average TL and TS obtained from this dominant species were 52 mm and –57 dB respectively.

3.2 Fish density and distribution patterns

During the acoustic-trawl survey conducted in Banyuasin coastal waters, the vertical distribution of the acoustic volume densities is shown in Figure 3. The results indicated that the volume densities of 206 ESDU ranged from 0 to 9048 fish / 1000 m^3, with an average of 930 fish / 1000 m^3. The highest volume densities were occurred in the 6 – 7 m water depth (1763 fish / 1000 m^3) and the next sequence was occurred from 2 – 3 m in depth (1324 fish / 1000 m^3) as well as from 5 – 6 m in depth (1188 fish / 1000 m^3). The lowest densities ware occurred from 7 – 8 m in depth (93 fish / 1000 m^3). In this survey, there were no ESDUs between 1 and 2 m in depth, therefore, these depth ranges did not have the volume density.

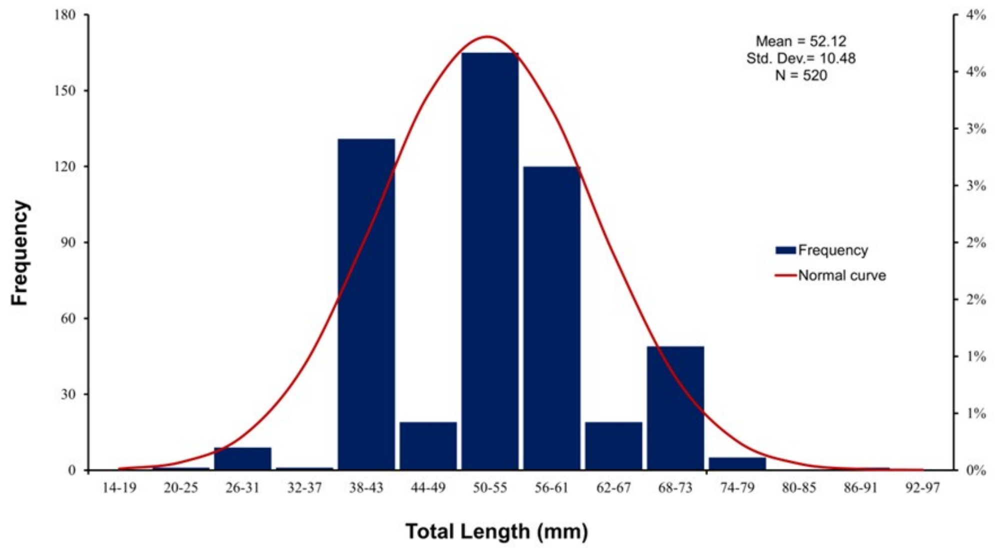

FIGURE 2 The size distribution of *Eubleekeria jonesi* obtained from the trawl sampling in the part of Banyuasin coastal waters, South Sumatra, Indonesia. These species were most abundant in the 50 – 55 mm total length.

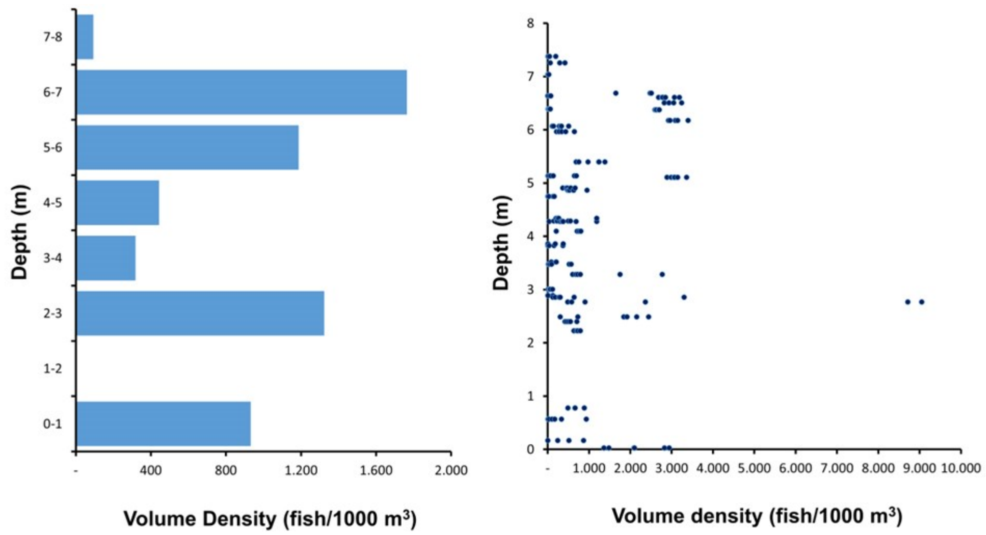

FIGURE 3 The vertical distribution of the acoustic volume density in the eastern part of Banyuasin coastal waters, South Sumatra, Indonesia; mean volume density by the depth class (left) and volume density at each ESDU by depth (right).

The ESDU in this study mostly (66%) have volume densities higher than 200 fish / 1000 m^3 and the horizontal distribution of these densities is shown in Figure 4. The values of acoustic volume densities were shown through bubble scatter, where the larger size indicated the higher fish density. The results indicated that the volume densities near the coastal zone were higher than near the offshore.

4 | DISCUSSION

This study implemented the hydroacoustic method which was validated with trawling survey data for a spatial distribution assessment of fish densities in Banyuasin coastal waters (shallow waters). Both hydroacoustic and trawl surveys were conducted simultaneously and were intended to validate hydroacoustic surveys. Bez *et al.* (2011) stated that using these two surveys can improve the accuracy and precision of the fish abundance estimates. In this study, both data were highly consistent, and the presence of the trawl behind the vessel was around a few hundred meters thus no systematic perturbation for recording the acoustic data (Bez *et al.* 2011). By contrast, Mitson and Knudsen (2003) stated that the noise of the fishing vessel can affect the fish and their hydroacoustic detection which could bias the results of hydroacoustics and trawls surveys. However, in deep water conditions with a single target species, the levels of ambient noise in the sea will not have a significant effect on the results of acoustic and trawl surveys (Reynisson 1996).

The results were sufficient to detect a distribution pattern in volume densities, where higher densities occurred near the coastal zone. These coastal zones near the mangrove area are useful nursery, feeding and spawning grounds (Walters *et al.* 2008; Eddy *et al.* 2016), consequently these waters favoured the fishes and resulted in a higher fish abundance and density. This distribution pattern was in line with the hydroacoustic survey at a Brazilian Lake - Lagoa Santa, Minas Gerais (Bezerra-Neto *et al.* 2013).

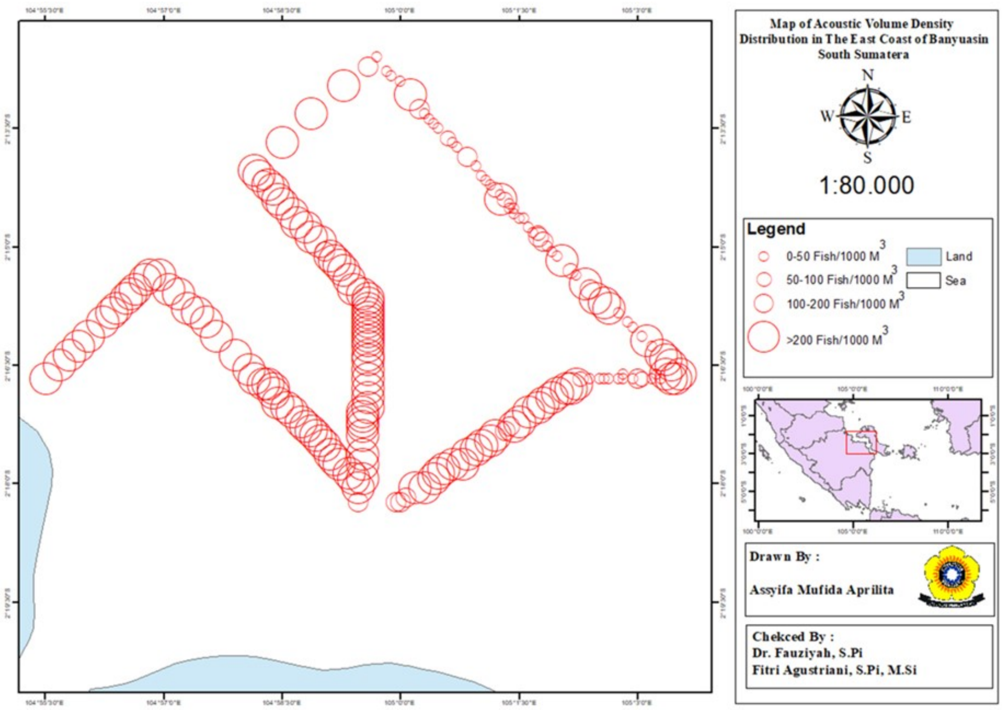

FIGURE 4 The horizontal distribution map of the acoustic volume density in the eastern part of Banyuasin coastal waters, South Sumatra, Indonesia.

The results of the trawl sampling indicated that *E. jonesi* was the dominant species and used to refine TS values for estimating the acoustic volume density. This species is commonly distributed in estuarine and inshore waters of subtropical and tropical regions (Bianchi 1985; Harini *et al.* 2018). The size range captured for this species in this study was appropriate for the hydroacoustic method application that can detect a small fish at sizes more than 1 cm TL (Arce *et al.* 2011). Overall, their horizontal distribution pattern of acoustic volume density showed a fluctuations pattern and was in line with the hydroacoustic survey in Sikka Regency Waters (Pujiyati *et al.* 2016).

Generally, the difference in horizontal distribution of fish density is influenced by the predation risk to some extent. Nonetheless, consequence of habitat selection, the spatial distribution of predators and competitors, environmental factors can affect the horizontal distribution of fish greatly (Bacheler *et al.* 2016). Lower density is commonly found during the early afternoon but the highest density can be recorded in the early morning, evening and at night (Fabi and Sala 2002). The diel variability of fish might be related to both the horizontal distribution of fish and fish's acoustic response that can be expressed by the variability of TS. In the present study, the TS value was determined based on the species composition (dominant species) and the individual size obtained from the trawl sampling due to unpredictable hydroacoustic measurement of TS.

Estimation of fish density and its distribution pattern through a hydroacoustic survey could be valuable to the fishery manager and these estimates are also useful to examine the effectiveness of any stocking programme, forage fish and predators. The hydroacoustic survey is an essential method to estimate the fish density, however, many precautions should be followed before and after conducting the survey to minimise the error. Finally, the hydroacoustic survey is useful for implementing advanced approaches to sustainable fisheries management.

ACKNOWLEDGEMENTS

This research was financed by the DIPA-UNSRI funds in 2017 through a competitive scheme [Grant Refs. SP. DIPA-023.17.2.677515, 213 2020 and 0164.02/UN9/SB3.LP2M.PT/2021]. We would like to thank Ardani and the acoustic crew for their participation and great help. We are grateful to the anonymous reviewers for their valuable comments to improve this manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

FA & WAEP data collection; ENN & AMP data analysis; AISP & F manuscript preparation; WAEP & ENN research supervision.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

REFERENCES

Arce E, Alcocer J, Chiappa-Carrara X, Zambrano L (2011) Hydroacoustic study of spatial and temporal distribution of *Poblana alchichica* (de Buen, 1945) in Lake Alchichica, Mexico. Journal of Fisheries and Aquatic Science 6: 624–632.

Bacheler NM, Schobernd ZH, Berrane DJ, Schobernd M, Mitchell WA, ... Glasgow M (2016) Spatial distribution of reef fish species along the Southeast US Atlantic Coast inferred from underwater video survey data. PLoS ONE 11: e0162653.

Bez N, Reid D, Neville S, Vérin Y, Hjellvik V, Gerritsen HD (2011) Acoustic data collected during and between bottom trawl stations: consistency and common trends. Canadian Journal of Fisheries and Aquatic Sciences 64: 166–180.

Bezerra-Neto JF, Brighenti LS, Pinto-Coelho RM (2013) Implementation of hydroacoustic for a rapid assessment of fish spatial distribution at a Brazilian Lake - Lagoa Santa, MG. Acta Limnologica Brasiliensia 25: 91–98.

Bianchi G (1985) Field guide to the commercial marine and brackish-water species of Pakistan. In: FAO identification sheets for fishery purpose, PAK/77/033 and FAO (FIRM) regular program, Rome. 200 pp.

Boswell KM, Wilson MP, Wilson CA (2007) Hydroacoustics as a tool for assessing fish biomass and size distribution associated with discrete shallow water estuarine habitats in Louisiana. Estuaries and Coasts 30: 1–11.

Chen D, Zhang X, Tan X, Wang K, Qiao Y, Chang Y (2009) Hydroacoustic study of spatial and temporal distribution of *Gymnocypris przewalskii* (Kessler, 1876) in Qinghai Lake, China. Environmental Biology of Fishes 84: 231–239.

Costa PL, Madureira LASP, de Pinho MP (2013) Seabed acoustic classification in the Pelotas basin, Brazil. Brazilian Journal of Oceanography 61: 13–22.

Doray M, Mahevas S, Trenkel VM (2010) Estimating gear efficiency in a combined acoustic and trawl survey, with reference to the spatial distribution of demersal fish. ICES Journal of Marine Science 67: 668–676.

Eddy S, Ridho MR, Iskandar I, Mulyana A (2016) Community-based mangrove forests conservation for sustainable fisheries. Jurnal Silvikultur Tropika 7: S42–S47.

Ehrenberg JE, Steig TW (2003) Improved techniques for studying the temporal and spatial behavior of fish in a fixed location. ICES Journal of Marine Science 60: 700–706.

Fabi G, Sala A (2002) An assessment of biomass and diel activity of fish at an artificial reef (Adriatic sea) using a stationary hydroacoustic technique. ICES Journal of Marine Science 59: 411–420.

Fassler SMM, O'Donnell C, Jech JM (2013) Boarfish (*Capros aper*) target strength modelled from magnetic resonance imaging (MRI) scans of its swimbladder. ICES Journal of Marine Science 70: 1451–1459.

Fauziyah, Priatna A, Prakoso WF, Hidayat T, Surbakti H, Nurjuliasti E (2018a) Measurement and analysis of acoustic backscattering strength for characteristics of seafloor sediment in Indian Ocean WPP 572-573. P. In: IOP Conference Series: Earth and Environmental Science. IOP Publishing Ltd, Denpasar, Bali, Indonesia.

Fauziyah, Agustriani F, Putri WAE, Purwiyanto AIS, Suteja Y (2018b) Composition and biodiversity of shrimp catch with trammel net in Banyuasin coastal waters of South Sumatera, Indonesia. AACL Bioflux 11: 1515–1524.

Fauziyah, Nurhayati, Bernas SM, Putera A, Suteja Y, Agustiani F (2019a) Biodiversity of fish resources in Sungsang estuaries of South Sumatra. IOP Conference Series: Earth and Environmental Science 278: 012025. IOP Publishing Ltd, Bogor, Indonesia.

Fauziyah, Agustriani F, Purwiyanto AIS, Putri WAE, Suteja Y (2019b) Influence of environmental parameters on the shrimp catch in Banyuasin Coastal Water, South Sumatra, Indonesia. Journal of Physics: Conference Series 1282: 012103. IOP Publishing Ltd, Palembang, Indonesia.

Fauziyah, Purwiyanto AIS, Agustriani F, Putri WAE, Liyani M, ... Suteja Y (2020a) Detection of bottom substrate type using single-beam echo sounder backscatter: a case study in the east coastal of Banyuasin. IOP Conference Series: Earth and Environmental Science 404 012004. IOP Publishing Ltd, Bogor, Indonesia.

Fauziyah, Purwiyanto AIS, Agustriani F, Putri WAE, Ermatita, Putra A (2020b) Determining the stock status of snapper (*Lutjanus* sp.) using surplus production model: a case study in Banyuasin coastal waters, South Sumatra, Indonesia. IOP Conference Series: Earth and Environmental Science 404: 012009. IOP Publishing Ltd, Bogor, Indonesia.

Foote KG (1987) Fish target strengths for use in echo integrator surveys. Journal Acoustical Society of America 82: 961–967.

Foote KG (2014) Discriminating between the nearfield and the farfield of acoustic transducers. Journal Acoustical Society of America 136: 1511–1517.

Greenlaw F (1979) Acoustical estimation of zooplankton populations. Limnology and Oceanography 24: 226–242.

Harini E, Shameem U, Rushinadha R (2018) Length-weight relationship of *Eubleekeria jonesi* (James, 1971) (Family: Leiognathidae) from Visakhapatnam fishing harbor, East Coast of India. International Journal of Basic and Applied Research 8: 546–552.

Hassan RBR, Ali R, Anh NL, Hai VD, Fujiwara S, ... Seman N (1998) Pelagic stock assessment by hydroacoustic method in the South China Sea, Area IV : Vietnamese Waters. In: Proceedings of the SEAFDEC Seminar on Fishery Resources in the South China Sea, Area IV : Vietnamese Waters. Southeast Asian Fisheries Development Center. pp. 1–9.

Holbrook B V, Hrabik TR, Branstrator DK, Yule DL, Stockwell JD (2006) Hydroacoustic estimation of zooplankton biomass at two shoal complexes in the Apostle Islands Region of Lake Superior. Journal of Great Lakes Research 32: 680–696.

Holliday D V, Pieper RE, Kleppel GS (1989) Determination of zooplankton size and distribution with multifrequency acoustic technology. ICES Journal of Marine Science 46: 52–61.

Kim H, Kang D, Jung SW, Kim M (2019) High-frequency acoustic backscattering characteristics for acoustic detection of the red tide species *Akashiwo sanguinea* and *Alexandrium affine*. Journal of Oceanology and Limnology 37: 1268–1276.

Mackinson S, van der Kooij J, Neville S (2005) The fuzzy relationship between trawl and acoustic surveys in the North Sea. ICES Journal of Marine Science 62: 1556–1575.

MacLennan DN, Fernandes PG, Dalen J (2002) A consistent approach to definitions and symbols in fisheries acoustics. ICES Journal of Marine Science 59: 365–369.

Martignac F, Daroux A, Bagliniere J-L, Ombredane D, Guillard J (2015) The use of acoustic cameras in shallow waters: new hydroacoustic tools for monitoring migratory fish population. A review of DIDSON technology. Fish and Fisheries 16: 486–510.

Martin L V, Stanton TK, Wiebe PH, Lynch JF (1996) Acoustic classification of zooplankton. ICES Journal of Marine Science 53: 217–224.

Mitson RB, Knudsen HP (2003) Causes and effects of underwater noise on fish abundance estimation. Aquatic Living Resources 16: 255–263.

Miyashita K, Aoki I (1999) Acoustic measurements of zooplankton using a dual frequency echo sounder. Marine Ecology Progress Series 180: 105–109.

Montereale-Gavazzi G, Roche M, Lurton X, Degrendele K, Terseleer N, Van Lancker V (2018) Seafloor change detection using multibeam echosounder backscatter: case study on the Belgian part of the North Sea. Marine Geophysical Research 39: 229–247.

Ona E, Mitson RB (1996) Acoustic sampling and signal processing near the seabed: the deadzone revisited. ICES Journal of Marine Science 53: 677–690.

Parker-Stetter SL, Rudstam LG, Sullivan PJ, Warner DM (2009) Standard operating procedures for fisheries acoustic surveys in the great lakes. Great Lakes Fishery Commission, United States. 180 pp.

Pujiyati S, Hestirianoto T, Wulandari P, Lubis M (2016) Fish stock estimation by using the hydroacoustic survey method in Sikka Regency Waters, Indonesia. Journal of Fisheries & Livestock Production 4: 1000193.

Reynisson P (1996) Evaluation of threshold-induced bias in the integration of single-fish echoes. ICES Journal of Marine Science 53: 345–350.

Rudstam LG, Parker-stetter SL, Sullivan PJ, Warner DM (2009) Towards a standard operating procedure for fishery acoustic surveys in the Laurentian Great Lakes, North America. ICES Journal of Marine Science 66: 1391–1397.

Stenevik EK, Vølstad JH, Høines Å, Aanes S, Óskarsson GJ, ... Tangen Ø (2015) Precision in estimates of density and biomass of Norwegian spring-spawning herring based on acoustic surveys. Marine Biology Research 11: 449–461.

Trenkel VM, Ressler PH, Jech M, Giannoulaki M, Taylor C (2011) Underwater acoustics for ecosystem-based management: state of the science and proposals for ecosystem indicators. Marine Ecology Progress Series 442: 285–301.

Walters BB, Rönnbäck P, Kovacs JM, Crona B, Hussain SA, ... Dahdouh-Guebas F (2008) Ethnobiology, socio-economics and management of mangrove forests: a review. Aquatic Botany 89: 220–236.

Winfield IJ, Onoufriou C, O'Connell MJ, Godlewska M, Ward RM, ... Yallop ML (2007) Assessment in two shallow lakes of a hydroacoustic system for surveying aquatic macrophytes. Hydrobiologia 584: 111–119.

Fauziyah https://orcid.org/0000-0003-3624-7956
WAE Putri https://orcid.org/0000-0002-1456-3088
AIS Purwiyanto https://orcid.org/0000-0002-9148-1713
F Agustriani https://orcid.org/0000-0003-2198-7687
AM Aprilita https://orcid.org/0000-0001-8117-2928
EN Ningsih https://orcid.org/0000-0002-1985-8977