A Study on the Characteristics of Fishery Resources Distribution in Coastal Waters of Yeongil Bay Using Acoustic Survey

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Abstract: In this study, the identification of dominant fish species in the East Sea was conducted using the dB-difference method. The survey was conducted using the two frequencies of 38 and 120 kHz in transect 6 of the southern part of the East Sea. Information on fish species was identified using fishing gear and e-DNA, and the dominant target fish species were selected and analyzed as cod, anchovy, common squid, and herring. The dB-difference range for each fish species was set to $-0.86 \text{ dB} < \Delta \text{MVBS}_{38-120 \text{kHz}} < 0.82 \text{ dB}$ for cod and to the range of $2.66 \text{ dB} < \Delta \text{MVBS}_{38-120 \text{kHz}} < 2.84 \text{ dB}$ for anchovy. The dB-difference of the common squid was set to $-0.36 \text{ dB} < \Delta \text{MVBS}_{38-120 \text{kHz}} < 1.25 \text{ dB}$ and to the range of $0.88 \text{ dB} < \Delta \text{MVBS}_{38-120 \text{kHz}} < 2.28 \text{ dB}$ for herring; the fish species were then identified in the echograms. When comparing the results of swimming depths by fish species and previous studies, cod was detected mainly at the bottom of the sea, and anchovy and common squid were detected mainly at a depth of 50 m. Herring was detected to be mainly distributed in water depths from 50 to 150 m.

Keywords: acoustic survey; identification of fish species; distribution of fish

1. Introduction

The Korean Peninsula is surrounded by water on three sides with the East Sea, the West Sea, and the South Sea, and the characteristics of the ocean and the distribution of fishery resources differ for each sea area. The East Sea has no islands or bays, and the coastline is relatively straight and featureless. The width of the continental shelf is less than 25 km and is very narrow, with an average of 18 km [1–3]. The southern part of the East Sea is affected by the Tsushima Warm Current with high temperature and high salinity and the North Korea Cold Current with low temperature and low salinity. In this sea area, warm-water species and cold-water species show mixed distribution. Thus, various types of water masses are formed in the southern part of the East Sea, and the area is rich in nutrients and food organisms. The main fish species caught include Pacific cods (Gadus macrocephalus), common squids (Todarodes pacificus), herrings (Clupea pallasii), anchovies (Engraulis japonicus), and Japanese amberjacks [4,5]. Currently, the leading countries in the fishery industry have adopted the TAC (total allowable catch) system for the efficient management of fishery resources, managing fish stock for major species. However, accurate information on the fish stocks needs to be obtained for efficient management of fishery resources. The estimation of fish stocks using a hydroacoustic survey uses acoustic data to identify the presence of marine organisms. The hydroacoustic survey enables a survey of large sea areas in a short time as well as acquiring real-time information for all water columns, and it is widely used as a useful tool for estimating fish stocks in major countries in the fishing industry, such as Norway, the United States, and Canada. Among the...
techniques of hydroacoustic survey, the dB-difference method is actively utilized as a tool for evaluating the density and biomass of the target organisms, as the method identifies fish species by the difference in frequency characteristics. There are various methods for evaluating fishery resources and the density and biomass of organisms using acoustic survey, such as echo counting, school detect, and time-varied threshold, but in this study, we use dB-difference in order to determine the spatiotemporal distribution of fish species, identifying the target strength of the target fish species and the length distribution of the collected fish species [6–9].

In this study, acoustic data were collected by means of a hydroacoustic survey in the southern part of the East Sea of South Korea, and the total length–body weight information of fish species was obtained using the bottom trawl survey. Then, seawater was collected, and e-DNA was analyzed to obtain information on fish species. For the efficient management and evaluation of fisheries resources, it is very important to understand the spatiotemporal distribution of fish species. Therefore, this study identifies fish using two frequency dB-difference methods and compares the spatiotemporal distribution of each fish species with that of a prior study.

2. Materials and Methods

2.1. Study Waters and Period

A training ship named Gaya (1737 G/T) belonging to Pukyong National University was used, and the acoustic survey was performed using the scientific echosounder mounted on the training ship Gaya. Acoustic data from the southern part of the East Sea were collected from 4 to 5 January 2020, and acoustic survey and trawl survey were conducted in parallel with a total of five survey lines from coastal waters of Pohang to coastal waters of Ulsan. Acoustic data were collected while maintaining the speed of the ship at 7–10 knots. During the survey period, fish sampling using the bottom trawl was performed four times, and the survey locations are shown in Table 1 and Figure 1.

Figure 1. Survey Area.
Table 1. Trawl sampling location in the survey area.

| Trawl Sampling Location | Latitude       | Longitude       |
|------------------------|----------------|-----------------|
| 1st                    | 36°08.64′ N    | 129°38.84′ E    |
| 2nd                    | 35°59.96′ N    | 129°38.14′ E    |
| 3rd                    | 35°50.01′ N    | 129°37.32′ E    |
| 4th                    | 35°39.88′ N    | 129°35.97′ E    |

2.2. Acoustic Equipment System and Data Analysis Method

The acoustic system used for the survey was a split-beam scientific echosounder (EK60, Kongsberg Simrad, Norway), and acoustic data were collected for frequencies 38 and 120 kHz. The acoustic data were stored by continuously receiving position information from DGPS (SPR-1400, Samyoung, Seongnam, Korea). The acoustic data collected in situ were subsequently processed in the laboratory using acoustic data analysis software (Echoview V 8.0, Echoview Software Pty Ltd., Hobart, Australia). The flow diagram of data processing for the fish species identification is shown in Figure 2. As shown in the figure, after filtering the noise around the sea surface, sea bottom, and other places, the integration section is set to compose a matrix for each frequency, thus creating a new echogram. In this study, a cell size of 5 ping × 5 m (width × height) was used to examine the dB-difference. When the dB-difference between fish species becomes clear, the range of values is set, the data range bitmap is created, and the mask is created with an echo that matches the size of the cell at 38 kHz. We then extract echoes consistent with the 38 kHz echo, which is removed noise, by dividing them again into ping intervals. Through the above methods, fish species can be identified by separating the echoes of fish suitable for each characteristic.

Using the above method and procedure, each species can be identified by separating the echoes of the respective fish species suitable for the characteristics [10].

2.3. Analysis of Sampled Fish Species

In order to identify fish species in the target waters for survey using the acoustic data, biological information of the fish species, such as composition and total length–body weight information of the fish species inhabiting the sea area, is required. Therefore, in
this study, the total length–body weight information of fish was obtained using the bottom trawl survey, and the eDNA information of fish was acquired by collecting surface seawater within the survey area [11]. As a result of identifying fish species using eDNA information, the sampled species were 33.9% of *Gadus macrocephalus*, 28.3% of *Clupea pallasii*, 12.7% of *Glyptocephalus stelleri*, 4.6% of *Engraulis japonicus*, 4.2% of sea bass (*Lates calcarifer*), and 3.0% of jack mackerel *Trachurus symmetricus*. Therefore, the target fish species of this study were selected to be *Gadus macrocephalus*, *Clupea pallasii*, and *Engraulis japonicus*, which appeared as dominant fish species as a result of eDNA analysis. *Todarodes pacificus*, a major fish species in the East Sea, was additionally selected as the target species (Table 2).

### Table 2. List of fish species for analysis.

| Species (Name)                  | Seq. Identity (%) |
|---------------------------------|-------------------|
| Pacific cod (*Gadus macrocephalus*) | 33.92             |
| Pacific herring (*Clupea pallasii*) | 28.33             |
| Blackfin flounder (*Glyptocephalus stelleri*) | 12.73             |
| Anchovy (*Engraulis japonicus*) | 4.61              |
| Seaperch (*Lateolabrax japonicus*) | 4.27              |
| Jack mackerel (*Trachurus symmetricus*) | 3.09              |
| Spanish mackerel (*Scomberomorus miphonius*) | 2.58              |
| Yellow goosefish (*Lophius litulon*) | 2.22              |
| Cubed snailfish (*Liparis tessellatus*) | 1.68              |
| Chub mackerel (*Scomber japonicus*) | 1.46              |
| Torachi (*Trachipterus ishikawaei*) | 1.27              |
| Butterfish (*Psenopsis anomala*) | 1.26              |
| Pointhead flounder (*Cleisthenes pinetrum*) | 0.79              |
| Silver croaker (*Pennahia argentata*) | 0.63              |
| Slender ponyfish (*Leiognathus elongatus*) | 0.32              |
| Hatchetfish (*Maurolicus muelleri*) | 0.28              |
| Bastard halibut (*Paralichthys olivaceus*) | 0.11              |
| Long shanny (*Stichaeus grigorjewi*) | 0.10              |
| Sailfin (*Arctoscopus japonicus*) | 0.09              |
| Starry flounder (*Platichtys stellatus*) | 0.05              |
| Horse king fish (*Kaiwarinus equula*) | 0.04              |
| Amberjack (*Seriola quinqueradiata*) | 0.04              |

#### 2.4. Acoustic Backscattering Strength

The range of total length of *Gadus macrocephalus* was 36.4–74.0 cm, and that of *Engraulis japonicus* was 9.5–15.4 cm. In addition, the range of total length of *Todarodes pacificus* was 16.0–27.0 cm, and that of *Clupea pallasii* was 12.0–27.0 cm. The total weight of the collected *Gadus macrocephalus* was 3459 g, and the total weight of *Engraulis japonicus* was 1910 g. *Todarodes pacificus* had a collection weight of 1235 g, and *Clupea pallasii* had a collection weight of 4617 g.

The frequency characteristics of each fish species for the dominant species were identified, and the results of a previous study were applied for the acoustic scattering characteristics for each frequency. Information on the acoustic scattering strength of the dominant species is presented as follows [12–15].

\[
\text{Gadus macrocephalus: } T_{38kHz} = 24.8\log (\text{TL}) - 73.1, T_{120kHz} = 17.9\log (\text{TL}) - 61.5
\]

\[
\text{Engraulis japonicus: } T_{38kHz} = 16.7\log (\text{TL}) - 62.8, T_{120kHz} = 15.9\log (\text{TL}) - 64.7
\]

\[
\text{Todarodes pacificus: } T_{38kHz} = 12.9\log (\text{TL}) - 63.7, T_{120kHz} = 20\log (\text{TL}) - 73.5
\]

\[
\text{Clupea pallasii: } T_{38kHz} = 21.79\log (\text{TL}) - 66.01, T_{120kHz} = 25.30\log (\text{TL}) - 72.07
\]

For the identification of fish species, the range of total length for each species and acoustic scattering strength were used to represent acoustic scattering strength for each frequency, and the frequency range was set using the dB-difference method. There-
fore, the dB-difference range for *Gadus macrocephalus* was set to be $-0.86 \text{ dB} < \Delta \text{MVBS}_{38-120 \text{ kHz}} < 0.82 \text{ dB}$, and the dB-difference range for *Engraulis japonicus* was set to be $2.66 \text{ dB} < \Delta \text{MVBS}_{38-120 \text{ kHz}} < 2.84 \text{ dB}$. In addition, the dB-difference range for *Todarodes pacificus* was $0.36 \text{ dB} < \Delta \text{MVBS}_{38-120 \text{ kHz}} < 1.25 \text{ dB}$, and the range for *Clupea pallasii* was $0.88 \text{ dB} < \Delta \text{MVBS}_{38-120 \text{ kHz}} < 2.28 \text{ dB}$. These ranges were set for fish species identification.

For the identification of fish species, it is necessary to first identify the frequency characteristics for the fish’s frequencies of 38 and 120 kHz and differences between them. In this case, the dB-difference represents the difference in the mean volume backscattering strength (MVBS) at multiple frequencies. To set $\Delta \text{MVBS}$ as positive values, target strength (TS) for each frequency of the target species for separation is compared, and the frequency with the smaller TS value is subtracted from the frequency with the large TS value. In general, the frequency of fish showed higher values at 38 kHz than at 120 kHz. Therefore, in a new echogram of 38 kHz and 120 kHz generated in the form of a matrix, $\Delta \text{MVBS}$ can be expressed by the following (Equation (1)).

$$
\Delta \text{MVBS} = \text{TS}(38 \text{ kHz}) - \text{TS}(120 \text{ kHz}) = \text{SV}(38 \text{ kHz}) - \text{SV}(120 \text{ kHz})
$$

(1)

The method for identifying each fish species is shown in the figure below by applying the sampled data and the acoustic scattering strength for each fish species (Figures 3–6).

**Figure 3.** Pacific cod identification example.

**Figure 4.** Anchovy identification example.
3. Results

Vertical Distribution by Species

Using the dB-differences, the vertical distribution of Gadus macrocephalus is shown in the figure below, and the depth of the survey area was found to be in the range from 50 m to 250 m or more. The horizontal axis represents the time, the number at the top indicates the number of the survey line according to the movement of the survey line, the vertical axis represents the depth of water, and the thin solid line represents the water depth at 50 m intervals. The color scale on the right shows the intensity of sound waves received after they were reflected by the fish school. The higher the fish School, the darker brown that represents it.

At line 1, acoustic scattering layers in the range of −61 to −64 dB were distributed at the sea bottom with a depth of 50 m, and at line 2, acoustic scattering layers in the range of −52 to −64 dB were distributed at the sea bottom with a depth of 150 m. At line 3, with 100 m depth, acoustic scattering layers in the range of −52 to −64 dB were distributed, and at lines 4 and 5, acoustic scattering layers in the range of −56 to −67 dB were distributed. At lines 6 and 7, acoustic scatterers in the range of −61 to −70 dB were distributed at the sea bottom with a depth of 150 m. At lines 9 and 10 with 50 and 120 m depths, acoustic scattering layers in the ranges of −37 and −52 to −70 dB were distributed (Figure 7).
Figure 7. Vertical distribution of pacific cod.

As a result of examining the distribution of *Engraulis japonicus* using the dB-difference, lines 1 and 2 did not show the echogram of *Engraulis japonicus*, and at lines 3 and 4, acoustic scattering layers in the ranges of −46 to −64 dB and −52 to −64 dB were distributed at 100 m depth. At line 5, acoustic scattering layers in the range of −64 to −70 dB were distributed at 100 m depth, and at lines 6 and 7, acoustic scatterers in the range of −64 to −70 dB were distributed. At lines 9 and 10 with 50 and 100 m depths, acoustic scatterers in the ranges of −43 and −61 to −70 dB were distributed (Figure 8).

Figure 8. Vertical distribution of pacific cod.

As a result of examining the distribution of *Todarodes pacificus* using the dB-difference, at line 1, acoustic scatterers in the range of −61 to −67 dB were distributed at a depth of 50 m, and at lines 2 and 4, acoustic scatterers in the range of −64 to −67 dB were distributed at a depth of 50–100 m. At line 5, acoustic scatterers in the range of −37 to −55 dB were distributed at 80 m depth, and at lines 6 and 7, acoustic scatterers in the range of −61 to −70 dB were distributed. At lines 9 and 10 with 50 m depth, acoustic scatterers in the range of −61 to −70 dB were distributed (Figure 9).
As a result of examining the distribution of Clupea pallasii using the dB-difference, at line 1, acoustic scattering layers at −46 and −61 dB were distributed at a depth of 50 m, and at lines 2 and 4, acoustic scatterers in the ranges of −37 to −46 dB and −52 to −64 dB were distributed at a depth of 50–100 m. At line 5 with 90 m depth, acoustic scattering layers in the range of −37 to −46 dB were distributed, and at lines 6 and 7, acoustic scattering layers in the range of −52 to −64 dB were distributed at a depth of 150 m. At line 8, acoustic scattering layers in the range of −37 to −46 dB were distributed at a depth of 50 m. At line 9, with 10 and 70 m depths, acoustic scattering layers in the ranges of −34 to −40 dB and −40 to −46 dB were distributed (Figure 10).

As a result of examining the vertical distribution of each fish species, Gadus macrocephalus was mostly detected at the sea bottom, and Engraulis japonicus and Todarodes pacificus were mainly detected at a depth of 50 m. Clupea pallasii was mostly detected at a depth between 50 and 150 m.

4. Discussion

The results of previous studies on the distribution of fish species by water depth showed that Engraulis japonicus shoal was mainly distributed at a depth range of 12–50 m, and the volume scattering strength distribution of Engraulis japonicus shoal was around −50 dB. In addition, in another previous study, the volume scattering strength of the large Engraulis japonicus shoal with a high level of aggregation was in the range of −44.0 to −28.0 dB, and the large Engraulis japonicus shoal was distributed at a depth range of 10–75 m.
Furthermore, the previous study on the distribution of Atlantic herring (Clupea harengus) by water depth showed the distribution of the species in the range of 10–125 m. A previous study on the distribution of Todarodes pacificus in the East Sea of South Korea showed the distribution of the species mainly at 60 m depth. Therefore, when comparing the results of this study with those of previous studies, it can be concluded that the distribution of species by depth was similar [14–19].

The spatiotemporal distribution of each fish species was represented by extracting the Nautical Area-Scattering Coefficient (NASC m²/nm²) and is illustrated in the figure below, and the size of NASC was represented by the height of the bar graph.

The results of the spatiotemporal distribution of Gadus macrocephalus showed a higher level of distribution in the south of the area, and a higher level of distribution was identified in coastal waters than in the open ocean. In addition, Gadus macrocephalus was distributed in the open ocean waters of Ulsan (Figure 11).

Figure 11. Spatiotemporal distribution of pacific cod.

When comparing the results of this study with the results acquired by using the pop-up electronic tag for the movement route of Gadus macrocephalus, the location of recovering the Gadus macrocephalus pop-up tag in 2011 was 34.53° N, 128.49° E. Additionally, in the analysis result of the hydroacoustic survey, the identified location of distribution in the coastal waters was 35.5° N, 129.5° E. Furthermore, the location of recovering the pop-up tag in 2014 was 34.93° N, 128.84° E. In the analysis result of the hydroacoustic survey, the identified location of distribution in the open ocean was 35.5° N, 129.85° E. It was concluded that the movement route of Gadus macrocephalus shown in the result of previous studies and the location of the distribution of Gadus macrocephalus obtained using hydroacoustic survey were very similar. However, there is little research on Gadus macrocephalus movement, and, thus, it is thought that further studies are needed to obtain data on various routes of Gadus macrocephalus by year (Figure 12).
The results of the spatiotemporal distribution of *Engraulis japonicus* showed high aggregation of the species in the coastal waters and open ocean of Ulsan in the survey area and low aggregation in the adjacent waters of Pohang. In a previous study that identified the distribution of *Engraulis japonicus* in the southern part of the East Sea, lower aggregation of the species was shown in coastal waters of Pohang, and high aggregation was observed in coastal waters and open ocean of Ulsan. Comparing the two sets of results, it is judged that the two results are considerably similar in many aspects [16]. However, the *Engraulis japonicus* shoal is a migratory species and shows aggregation at various depths, and, thus, further research is thought to be necessary (Figures 13 and 14).
The spatiotemporal distribution of *Todarodes pacificus* showed a high aggregation in the coastal waters and open ocean in Ulsan and a relatively low aggregation in the coastal waters of Pohang (Figure 15).

The spatiotemporal distribution of *Clupea pallasii* was relatively high in the coastal waters and open ocean of Ulsan and the northern waters of Ulsan, whereas the distribution was relatively low in the coastal waters of Pohang and adjacent sea (Figure 16).

This study used dB-difference to identify the species, space, and time distribution in the southern part of the East Sea waters of the Republic of Korea using various methods and distribution. Fish species were identified using frequencies of 38 and 120 kHz, but the distribution of fish species with similar target strengths and lengths can be mixed. However, since the fish species mainly distributed in the research waters of this study are the target fish species of the study, it is considered that the rate of other fish species is quite low.
Figure 15. Spatiotemporal distribution of common squid.

Figure 16. Spatiotemporal distribution of herring.

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