Acoustic Estimation of Biomass and School Character of Anchovy
Engraulis japonicus in the East China Sea and the Yellow Sea

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The biomass of anchovy Engraulis japonicus in the East China Sea and the Yellow Sea was estimated by using a quantitative echo sounder (Furuno FQ-70) combined with the analysis of midwater trawling catches. The shape of anchovy schools were calculated from echograms. The acoustic survey, conducted in May and June 1992, was executed along 7 east-west transect lines ranging from latitude 30°00' to 35°45'N. Trawling was made at 5 areas. Over the 5 trawling areas, 97.8% of caught fish were anchovy in the daytime, but the percentage of anchovy decreased to 67.4% at night. Anchovy behaviour differed between day and night. In the daytime anchovy compactly shoaled in midwater or near-bottom layers with the mean packing density of 53.6 g/m³. The mean vertical height and the mean horizontal width of anchovy schools in the daytime were 3.3 (±3.4, S.D.) m and 16.3 (±7.7) m, respectively. At night, they were scattered at midwater or surface water layers. The total biomass of anchovy over the survey area was estimated to be 1,960,000 tons using TS kg = −31.4 dB/kg (204,289 km²). Some problems inherent with acoustic method for the estimation of the biomass are discussed.

Key words: acoustic Survey, Anchovy Engraulis japonicus, Biomass, fish School, East China Sea, Yellow Sea, school character

Biological productivities are considered to be very high in the East China Sea and the Yellow Sea. This high productivity supports activities of various fisheries of Japan, China, and the Republic of Korea in this region. From 1984 to 1989 China and Norway carried out joint acoustic and trawling surveys to the biomass of anchovy Engraulis japonicus among other fishes in these seas, and the biomass was estimated to be about 3,000,000 tons. After the Chinese-Norwegian joint survey, there have been no reports on the population abundance of anchovy in the area.

Japan has not been fishing anchovy in the area for several reasons; problems with freezing technology, long distance to fishing grounds, low cost benefit, and others. In order to establish rational management scheme of anchovy resources it is primarily important to gain an accurate estimate of total anchovy biomass.

The present study aims at testing feasibility of acoustic method using a quantitative echo sounder for a rapid estimate of anchovy biomass, and shapes and packing densities of its schools.

Survey area and Method

The acoustic survey was carried out from 27 May to 2 June, 1992, along 7 east-west transect lines. CTD (Neil Brown MARK3B) casts were conducted at 20 stations in the East China Sea and the Yellow Sea (Fig. 1). A quantitative echo sounder (Furuno, FQ-70) operated continuously during acoustic survey. The ship speed was kept at about 10 knots on the transect lines. The calibration of the echo sounder was done by hydrophone prior to the survey.

Table 1 shows the conditions and the results of the calibration.

The vertical thickness and horizontal width of fish schools were measured on echograms. The packing density D (in kg/m³) of schools was calculated as:

\[ D = \frac{10^{(SV-30)}}{10} \times 100 \text{ per s}, \]

where, SV is the mean of volume back-scattering strength.
in each integration interval, TS is the target strength ($-31.4 \text{ dB/kg}^2$), and s is the percentage of square measure of fish school in each integration interval. The SV and s value was logged on diskette automatically. The anchovy biomass was calculated with total SV value and the volume of water of the present survey area.

The trawlings were conducted at 5 areas (A to E, Fig. 1) from 3 June to 8 June, 1992. A cover net (20 mm mesh) was attached to the midwater trawl on outside of cod end (60 mm mesh). In order to monitor net conditions, Emmar Transducers (Emmar catch control system) were mounted on both sides of the net as well as the top and bottom of the net, near the mouth. Also, a Net Recorder (Furuno, FNR-200II) was mounted on the bottom at the mouth of the net. Midwater trawl hauls were carried out twice in the day and twice at night in areas A, B, and C (Fig. 1). In area D, it was done twice in day and once in night. In area E, it was done twice only during the daytime. The midwater trawl net was towed for 30 minutes or 1 hour. The warp length of the trawl net and towing speed were adjusted in order to aim the net opening at the strata of fish schools. The towing speed ranged 2 to 3 knots during the trawling.

Trawl catches were frozen immediately on board the vessel. If the catch was numerous, about 30 kg of subsamples were picked up after the measurement of total weight of catches. Samples were weighed by species at land laboratory after the survey. For individual anchovy, the body length, body weight, and gonad weight were measured to the nearest 1 mm and 0.1 g, respectively. A gonad somatic index (GSI) for anchovy was calculated from total body weight (BW) and gonad weight (GW) in both sexes,

$$\text{GSI} = \frac{GW}{BW} \times 100.$$

### Results

**Hydrographic Structure**

Figure 2 shows the distribution pattern of the surface water temperature over the present survey areas on 2 June, 1992 (data from Japan Fisheries Information Service Center). There were two main areas characterized by warm water. One was in the Yellow Sea and the other was near the estuary of the Yangzi River. According to CTD observations made in this study, low salinity areas were detected at near the Yangzi River, especially on the western side of transect 2, together with the Yellow Sea Central Cold Water at the center of the Yellow Sea.

**Fish Catches**

Total catches in all areas was 924.8 kg. Catches varied with the duration of towing time. The average catch for 30 minutes trawling was 44.2 kg; and for 1 hour trawling it was 63.4 kg. However, there were cases that the catches for 30 minutes trawling were more than those of 1 hour trawling in the same area.

The percentage of anchovy in total catches was 92.0% (850.9 kg/924.8 kg \times 100). Day and night-time catch data were pooled and areal differences in the catch and species composition were analyzed (Fig. 3). While anchovy was the dominant species in all areas (71.2 to 98.5% of total catches), the quantities of other fish species increased at southern areas. Excepting anchovy, the next dominant species were ribbon fish (Trichiuridae), yellow croaker Larimichthys polyactis, velvetfish Erisphex pottii, lantern fishes (Myctophidae).

When the catch data gained from all areas were grouped into daytime and night-time (Fig. 4), the mean was 74.9 kg/haul in the daytime (749 kg/10 stations) and 25.1 kg/haul (175.8 kg/7 stations) at night. Further sub grouping of the catch sizes into towing time revealed that daytime catches were 88.0 kg for 60 minutes, 61.8 kg for 30 minutes; night-time catches were 32.7 kg for 60 minutes and 15.0 kg for 30 minutes. In terms of fish composition, anchovy occupied 97.8% of catches in the daytime but it decreased to 67.4% at night.

The anchovy’s biological characters found out in this study were summarized in Table 2. The entire range of anchovy body length caught by a midwater trawl net was 60 to 145 mm. The body length of anchovy at southern areas was larger than that at northern areas; 60 to 120 mm in area A, and 110 to 145 mm in area E. Most anchovies of both sexes obtained in this study were at mature in all areas.
Day and night-time data at each area were summed up. Because goosefish *Lophius litulon*, 9 kg in body weight, was caught in area A, the percentage of others fish was increased.

Mean body length did not differ significantly between area A and area B, and between area C and area D, but the difference in other combination was statistically significant (Z-test, \( p = 0.05 \) level). Mean GSI value was not significantly different between area C and area D, but the difference between area A and area B was statistically significant (Z-test, \( p = 0.05 \) level).

### Echogram Analysis

The vertical and horizontal distribution matrix of acoustic intensity was constructed for each of the 7 transect lines (Fig. 5). As a general pattern, the SV value was large in the areas near China. An especially strong SV value was recorded in the warmer water. From figure 5, it is seen that the swimming layer of fish was consistently above the Yellow Sea Central Cold Water masses\(^3\) in the Yellow Sea and above the vertical thermal front in the East China Sea.

### School Shape, Packing Density and Biomass

Based on the results from trawl catches, it may be assumed that all of the echograms were considered to be those of anchovy. The results of echogram analysis showed that the shape of anchovy schools changed with time of the day. The large differences in anchovy school shape occurred in between day and night. The anchovy schools shoaled compactly in midwater or near-bottom layers in the daytime. The schools immediately rose toward the surface water layer just after sunset. Anchovy were scattered widely in midwater or near-surface layers during night-time. After dawn, the scattered fish immediately shoaled again in midwater or near-bottom layers. The mean height and width of anchovy schools in the daytime

<table>
<thead>
<tr>
<th>Area</th>
<th>Body Length (mm)</th>
<th>Body Weight (g)</th>
<th>Gonad Weight (g)</th>
<th>GSI Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>95.6±9.9</td>
<td>9.42±3.25</td>
<td>0.599±0.321</td>
<td>5.84±2.17</td>
</tr>
<tr>
<td></td>
<td>((n=314))</td>
<td>((n=314))</td>
<td>((n=164))</td>
<td>((n=164))</td>
</tr>
<tr>
<td>B</td>
<td>96.8±11.4</td>
<td>9.82±3.98</td>
<td>0.548±0.495</td>
<td>4.87±2.11</td>
</tr>
<tr>
<td></td>
<td>((n=424))</td>
<td>((n=424))</td>
<td>((n=224))</td>
<td>((n=224))</td>
</tr>
<tr>
<td>C</td>
<td>109.5±6.5</td>
<td>14.7±2.93</td>
<td>0.607±0.314</td>
<td>3.93±1.78</td>
</tr>
<tr>
<td></td>
<td>((n=590))</td>
<td>((n=590))</td>
<td>((n=335))</td>
<td>((n=335))</td>
</tr>
<tr>
<td>D</td>
<td>110.6±11.1</td>
<td>16.3±5.28</td>
<td>0.692±0.578</td>
<td>3.81±2.25</td>
</tr>
<tr>
<td></td>
<td>((n=640))</td>
<td>((n=640))</td>
<td>((n=300))</td>
<td>((n=300))</td>
</tr>
<tr>
<td>E</td>
<td>125.1±7.1</td>
<td>21.4±3.30</td>
<td>1.18±0.429</td>
<td>5.60±1.95</td>
</tr>
<tr>
<td></td>
<td>((n=255))</td>
<td>((n=255))</td>
<td>((n=155))</td>
<td>((n=155))</td>
</tr>
</tbody>
</table>
Fig. 5. The vertical distribution of acoustic intensity (SV value) along transect lines 1 to 7 (see Fig. 1).

It is noted that western parts of transect 2, 4 and 6 exhibited high acoustic intensities. The distribution depth of fishes at night was shallower than that in the daytime, and the acoustic intensity at night was lower than that in the daytime.
were estimated as 3.3 m (±3.4) and 16.3 m (±7.7) respectively, with the mean packing density of 53.6 g/m³ (ranged from 4.6 to 171.3 g/m³).

Because most of catches in present survey area was anchovy (92.0%), it was assumed that all SV value was regarded as anchovy. Using a TS kg = -31.4 dB/kg, the estimated anchovy biomass was 1,960,000 tons over the present survey areas (204,289 km²).

Discussion

Acoustic Problems for Biomass Estimation

Although anchovy was the most abundant, various fish species were caught by midwater trawling over the present survey area, particularly in its southern part. Fishes other than anchovy included ribbon fish, yellow croaker, velvetfish, and lantern fish. The presence of these other species is a possible source of error in estimating biomass of anchovy. The difference in catches between day and night is another source of error: the average catch in the daytime was greater than that of the night. Most of the daytime catch was anchovy, but the percentage of anchovy decreased at night in each area. Judging from trawl catch analysis, all daytime fish echos in midwater layer were considered to be anchovy, whereas the night echograms were a mixture of anchovy and the other fishes.

Several reports have described the relationship between light intensity and the behaviour of pelagic fishes, including herring Clupea harengus,68 mackerel Scomber scombrus48 and others. These pelagic fishes scatter in dark conditions and migrate diurnally and vertically. Details about differences between day and night trawl catches have been discussed by other workers.6,7 Japanese sardine Sardinops melanostictus were not caught at all with midwater trawling in day but they were captured at night.68 As the results of diel vertical migrating behaviour, the diurnal variations in trawl catches has been observed for herring, and vertical distribution changed from the deeper layers by day to the upper water layers by night.68

In the present study, anchovy rose toward the water surface immediately after sunset, and swarm in midwater or surface layers during the night. The acoustic intensity could not be determined for the stratum between water surface and the depth at which the transducer was installed on the ship’s bottom. With this reason, the estimation of anchovy biomass should be done using only data taken in the daytime when all anchovy are below the transducer.

The TS used in the present study was -31.4 dB/kg, however, the TS is known to be variable with physiological conditions, swimming angle and the other conditions of target fishes.68 Barange et al.10 measured in situ TS of anchovy Engraulis capensis at 38 kHz. The in situ TS of anchovy was -31.58 dB/kg for 7.50 cm anchovy (total length) and -31.16 dB/kg for 7.34 cm anchovy. For future work, it is desirable to estimate biomass of anchovy using in situ TS.

School Shape, Packing Density and Biomass Estimation

Not only diel vertical migrating behaviour, but the character of anchovy school is an important component for acoustic determination of fish biomass. In this study, the vertical height of 3.3±3.4 m and the horizontal width of 16.3±7.7 m were recorded for the anchovy school in the daytime, with its mean packing density of 53.6 g/m³ (ranged from 4.6 to 171.3 g/m³). Strictly speaking, this vertical height and horizontal width of anchovy school was not exact. Because, the vertical height and horizontal width were acoustically influenced by pulse duration and beam width, respectively.12

For the northern anchovy Engraulis mordax in the California Current a study with scanning sonar revealed that it school ranged from 4 to 5 m in vertical thickness and 5 to 30 m in horizontal dimensions. The packing density of the northern anchovy varied from 0.52 to 533 in individuals/m³.13 Thus, school characters of Engraulis japonicus are within those of E. mordax. Mais10 identified and described seven school patterns observed for the northern anchovy in the California Current. However, I found no difference in shape of anchovy school in the daytime. In the night-time, these characteristics did not find out, because fish schools were scattered.

Most anchovy specimens caught with the midwater trawl were at mature in all areas. Probably, anchovy were spawning in all of the areas.14 According to Chinese report,13 anchovy migrates widely in the East China Sea and the Yellow Sea, but closes to near China for spawning during May and June. From this view, a time period from November to December may be recommended as the most appropriate time for biomass surveys because anchovy are widely distributed. Strong acoustic intensities were also obtained near China continent in the present study. Judging from the Chinese report13 mentioned above, anchovy found in the waters near the China continent in this study might be the spawning population.

The effect of surface water temperature on the vertical distribution of anchovy was observed in this study. The swimming layer of anchovy was above the Yellow Sea Central Cold Water masses.14 Anchovy was concentrated in western sides of transect 2, 4, and 6, where the thermal front between warm water and Chinese coastal water was located. The surface waters of western side of transect 2 shows low salinity attributed by the Yangzi River. Mori15 reported on the relationship between fishing grounds for jack mackerel Trachurus japonicus and water masses in the East China Sea, suggesting that the areas near the Chinese coastal water masses in the intermediate zones were favourable fishing grounds of this fish in spring. Aoki and Murayama,46 and Aoki and Inagaki7 analyzed the relationship between the distribution of spawning Japanese sardine and water temperature in the waters offshore southern coast of Kyushu in Japan, and found that most adult sardines with immature gonads were located in the coastal waters, and the spawning adult sardines were mainly in the Kuroshio Current. These results of other workers suggest a close relationship between the distribution of pelagic fishes and surface water temperature. From this view, it may be necessary to monitor surface temperature in future study to determine the fishing grounds of anchovy in the East China Sea and the Yellow Sea.

The biomass of anchovy was estimated as 1,960,000 tons using TS kg = -31.4 dB/kg in the present survey area. Combining all acoustic sources of error, the present biomass of the anchovy was probably underestimated, because the present estimation includes night-time data. Of
course, the other fish biomass has to be considered, however, the other fish biomass was ignored in the present study, because catches of anchovy was the most abundant species in total catches. It is assumed that the accurate biomass estimation of anchovy must only conduct in the daytime.

My estimate (1,960,000 tons) of the anchovy biomass is less than 3,000,000 tons of Chinese and Norwegian survey in the East China Sea and the Yellow Sea. Greater biomass of the latter may be in part due to its wider coverage of survey areas (26° to 39°N, in contrast to 30° to 35°45'N). Since many problems in acoustic estimation of anchovy biomass mentioned above are common to the Chinese and Norwegian study, accurate comparison can not be made.

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