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Key words: sound scattering layer, zooplankton composition, northeastern Taiwan, I-Lan Bay.

ABSTRACT

A 36-h acoustic observation of the I-Lan Bay was conducted on board the Ocean Research II from June 2 to 4, 2013. The acoustic volume backscattering strength (SV) was measured using a scientific echo sounder (EK500, 38 and 120 kHz) to determine the acoustic characteristics of the deep scattering layers (DSLs) before and after the vertical movement. Two DSLs were found during the daytime at a depth of 80-130 m (upper DSL, UD) and 130-230 m (lower DSL, LD), with mean SVs of approximately −78 dB (UD) and −77 dB (LD) at 38 kHz and −65 dB (UD) and −60 dB (LD, 130-200 m) at 120 kHz. Two clear diel vertical movements (DVMs) were detected for both DSLs, which started to ascend at dusk at a speed of 1.04 cm/s (UD) and 1.92 cm/s (LD) and remained at 10-80 m at nighttime. These 2 DSLs started to descend at dawn with a speed of 0.59 cm/s (UD) and 1.38 cm/s (LD) and then remained at depths of 80-130 m (UD) and 130-230 m (LD) during the daytime. The habited depth of both DSLs may influenced by the change of water temperature. The dominant species of DSLs in abundance and biomass were copepods and decapods, respectively. The vertical nighttime distribution of the dominant scatterer of smaller and larger decapods was discussed in this paper.

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I. INTRODUCTION

Zooplankton are one of the most crucial biotic components of the marine ecosystem. Being the secondary food provider for fish, zooplankton constitute a crucial trophic level for energy transfer in the ocean (Chao et al., 2002). Zooplankton consist of a vast number of oceanic creatures and are distributed across the ocean (Lee et al., 2004). Zooplankton composition varies with time and space. Because of this ephemeral nature, zooplankton are a crucial index of environmental changes. In the recent decades, several international consolidation projects, such as Global Ocean Ecosystem Dynamics (Hofmann et al., 1991), have focused on zooplankton, particularly their ecology, quantity, classification, and distribution. Thus, zooplankton-related research has been a prime concern for the international research community (Kao and Lee, 2012).

Marine organisms tend to aggregate at specific depths in the ocean, and these organisms can scatter acoustic waves that appear as a scattering layer on an echogram. This so-called "sound scattering layer" has been observed in oceans worldwide (Sameoto, 1982; Lee et al., 2011). When the sound scattering layer occurs at depths of 180-900 m, it is called the "deep scattering layer" (DSL) (Urick, 1975). The DSL was first described in 1948 (Barham, 1948) and has since been observed at various depths and in various oceans worldwide (Tont, 1976; Hazen and Johnston, 2010). Generally, the DSL appears at a depth of a few hundred meters in the daytime and ascends to shallow depths at nighttime. Most of the organisms in the DSL consist of zooplankton, particularly macroplankton, and are pivotal in the food chain dynamics of marine pelagic ecosystems (Hofmann et al., 1991) because they are the major food source for juveniles of many commercially valuable fish species (Hempel, 1970; Parsons and LeBrasseur, 1970; Jeng et al., 1991). Although the basic concept of a food chain formed by phytoplankton, zooplankton, and fish has been firmly established (Lalli and Parsons, 1993), assessing the food requirements of marine fish solely on the basis of zooplankton density remains challenging (Hempel, 1970). This is because the relationship between the fish population and zooplankton density is not clearly understood, and the effects of zooplankton density on food chain dynamics remain obscure. Furthermore, the density and distribution of zooplankton are often influenced not only by tidal movements but also by their diel vertical migration. Most studies have referred to zooplankton as an indicator species of water mass in relation to tidal movement and specific difference in the diel vertical migration and its causative factors (Parsons and LeBrasseur, 1970). Although many recent hypotheses (Blaxter, 1974; Zaret and Suffern, 1976; Gliwicz, 1986) have been proposed to explain this phenomena, no universal mechanism governing the diel vertical migration of all zooplankton species has been established (Lalli and Parsons, 1993; Chou et al., 1999).

The Kuroshio, a major western boundary current in the North Pacific, is a warm current flowing northward along the east coast of Taiwan. It intrudes into the East China Sea (ESC) shelf, forming a cold dome at the shelf break, near the offshore area to the northeast of Taiwan (Fan, 1980; Lin et al., 1992; Gong et al., 1997; Wang et al., 2000). Lin et al. (1992) used satellite-derived sea surface temperature images to depict a large-scale anticlockwise frontal cold eddy caused by the Kuroshio upwelled water (Gong et al., 1997), which provides nutrients to the surface water and forms a well-known fishing ground for mackerel purse seine and torch-lighted squid fishery (Huang and Chiu, 1998; Hsieh et al., 2007) in the southern ECS. Kuroshio Edge Exchange Processes (KEEP), a multidisciplinary oceanographic program, has been conducted in these waters since 1989 (Lin et al., 1992; Liu et al., 2003; Chou et al., 2005; Hsieh et al., 2007; Lee et al., 2011). I-Lan Bay lies on the northeastern coast of Taiwan (121°57'E and 24°48'N), where the offshore continental shelf is narrow and the continental slope steeply declines to the Okinawa Trough (Fig. 1). The Kuroshio current flows northward off the Bay, and fresh water is abundant (average annual runoff: 2.773×10^9 m^3), being supplied by the Lan-Yang river that mixes with the Kuroshio and continental shelf waters because of the tidal currents inside the Bay (Lee and Hu, 1998). From April to October, the shelf water in northeastern Taiwan may flow into I-Lan Bay along the coast of Taiwan and then merge into the Kuroshio (Lee and Hu, 1998), with the upwelling of the cold water near Cape San-Diao (Fan, 1980). As a consequence of these hydrographic conditions, I-Lan Bay is one of the most critical fishing and nursery grounds of marine fish in Taiwan (Chin, 1991). Larvae and juveniles of commercially vital fish species (e.g., ribbonfish, carangids, bonito, mackerel, and squid) migrate to the Bay for feeding. Former oceanographic and fishery investigations conducted in this bay have typically focused on fishing methods and physical oceanography (Wong et al., 1991; Lin et al., 1992; Tang and Tang, 1994) but rarely on the ecological aspects of pelagic communities (Chou et al., 1999).

Sampling with a net has been commonly used in studies of zooplankton and macroplankton. This approach assists in obtaining detailed descriptions of the species and development stages of plankton but could not be used to survey over extended time scales (Greenlaw, 1979). The acoustic method can be used to rapidly survey a large area at a low operational cost and provide an accurate estimate of the population (Greenlaw, 1979; Throne et al., 1983; Chou et al., 1999). We investigated the diel variation in the mean SV of the sound scattering layer, the species composition as well as its diel vertical migration in I-Lan Bay in northeastern Taiwan, and the influence of environment on zooplankton and macroplankton, particularly shrimp distribution.

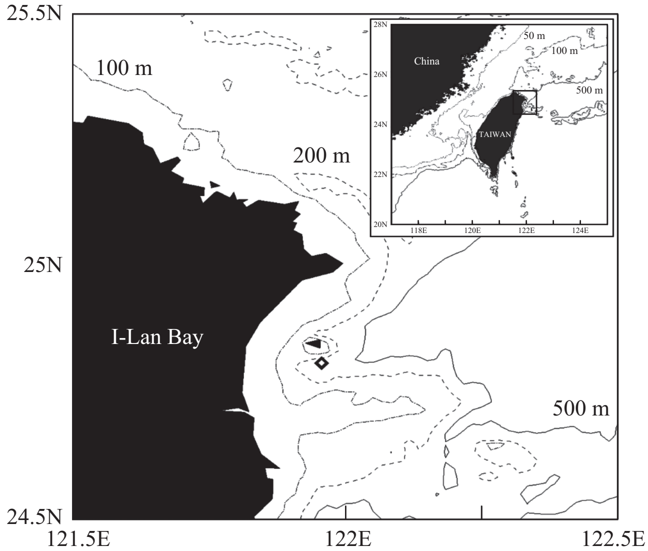

Fig. 1. Survey area and approximate drogue site for acoustic monitoring in I-Lan Bay (open diamond). The black triangle was Guishan Island.

II. MATERIALS AND METHODS

1. Acoustic Monitoring

Acoustic monitoring was conducted to observe the movement of the DSL at a station (121°57.027'E, 24°48.251'N) in the central part of I-Lan Bay (Fig. 1) in 2013 from June 2 to 4 (Cruise 1943) on board the Ocean Research II vessel of National Taiwan Ocean University. The average bottom depth was approximately 300 m. Acoustic data were obtained using a scientific echo sounder system (Simrad EK60), using 38- and 120-kHz split-beam transducers. However, because of noise problems, only the data above 200 m at 120 kHz were analyzed. Echoview postprocessing software was used to process the acoustic signals and monitor the diel distribution of the sound scattering layer. The parameters of the echo sounder are shown in Table 1. In the laboratory, the echo signals of the sound scattering layer, including surface scattering layers (SSLs) and DSL, were postprocessed such that each data point represented an average SV data cell (elemen-

Table 1. The system configures and parameter settings of the echo sounder and post-processing systems used in this study.

Name of parameter	Value		Unit
Frequency	120	38	kHz
Absorption coefficient	42.5	5.7	dB/km
Pulse length	0.256	1.024	ms
Bandwidth	8.71	2.43	kHz
Transmit power	0.6	1	kW
Equivalent 2-way beam angle	-21	-20.6	dB
Transducer gain	26.38	24.48	dB
3 dB beam width	6.39	7.59	degree
Ping interval	1	1	sec
SV threshold	-90	-90	dB
TS threshold	-90	-90	dB

tary integration unit, EIU) of 2-m depth and sampled over 1 min (60 pings). The mean SV data provided a convenient measure of the density index of the macroplankton (Throne, 1971; Wu et al., 1989), because the target strength was uncertain. The mean SV values were calculated using the following formula:

$$\mathrm{SV} = 10 \log \left(\frac{1}{n}\sum_{i=1}^{n} 10^{(SV_i/10)}\right) \tag{1}$$

where SV_i is the SV value of the observed EIU, and n is the total number of the observed EIUi. The SV echograms of the water column for 36 h were plotted using Echoview software, Version 3, and used as a biomass index of the sound scattering layer.

Vertical velocities of DSL were estimated independently from the slopes of the principal volume scattering layers. During diel vertical migration, individual DSLs were isolated subjectively on a display monitor, using postprocessing software. We used a more stringent threshold value (−80 dB) at 38 kHz to determine the boundary of the main part of a DSL, and then used the echogram edit function to draw a region as an isolated DSL. In addition, we divided the region into segments by 1 min per interval and then exported the center depth of each segment. From each isolated DSL, the center depth of each segment was calculated as a function of time, $D(t)$. The vertical migration velocity (V) was then estimated from the rate of change in DSL as the derivative of $D(t)$ with respect to time (t): $V = \mathrm{d}D(t)/\mathrm{d}t$ (Lee et al., 2011).

The Bi-frequency classification method was used to differentiate the organisms in the DSL, and this was undertaken at 38 and 120 kHz. The data on the preprocessing method of removing noise and resampling is shown in Fig. 2. First, the SV strength values of −80 dB (SV_{38} and SV_{120}) were the threshold levels to discard noise. Second, we calculated the difference between SV strength of two frequencies ($\Delta SV_{120\text{-}38}$), and combined trawl sampling data to decide the range of ΔSV

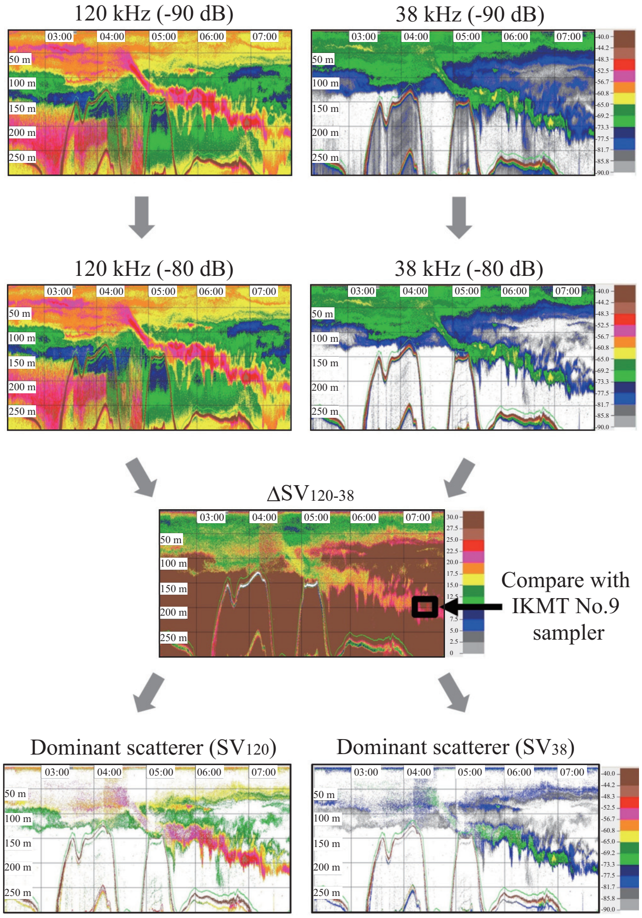

Fig. 2. Main steps of an application of the bi-frequency acoustic algorithm in order to discriminate the dominant scatterer of DSL.

for dominant scatterer of DSL, the range of ΔSV was visually decided about 1.21~16.79 dB (Chou, 2000). Finally, the distribution of dominant scatterer of DSL was displayed by 38 and 120 kHz echograms.

2. Trawl Sampling

Nineteen trawl samplings were conducted. The sites, time, and depth range are shown in Fig. 1 and Table 2. During acoustic monitoring, the Isaac–Kidd Midwater Trawl (IKMT) with a net mouth of 1.43 m × 1.54 m, a total length of 7.6 m with a mesh size of 1-5 cm, and a cod-end diameter of 0.52 m with a mesh size of 0.3 mm was used to sample animals in the DSL (Lu et al., 1995; Chou et al., 1999). The towing depth was monitored using a small CTD (Fig. 3). The net position was recorded at 5-s intervals. We allowed the track of the IKMT sampling net to superimpose over the averaged SV EIUs for calculating the mean SV value of each net (Fig. 4). IKMT was towed horizontally for 20-60 min at a speed of 3 knots at different depths of DSL, as shown on the echograms. For estimating the volume of the water filtered, we attached the flow meter at the center of the cod end. To reduce the possible contamination of organisms from depths other than

Table 2. The sampling date, operation time, and sampling depth of each net.

Net number	Sampling date	Operation time	Sampling depth (m)
1	2013/6/2	2040~2110	30
2	2013/6/2	2330~2359	30
3	2013/6/3	0230~0303	30
4	2013/6/3	0615~0645	150
5	2013/6/3	0715~0745	200
6	2013/6/3	0750~0820	30
7	2013/6/3	0850~0930	30
8	2013/6/3	1220~1305	30
9	2013/6/3	1310~1350	200
10	2013/6/3	1530~1600	30
11	2013/6/3	1825~1900	30
12	2013/6/3	2115~2150	30
13	2013/6/4	0020~0058	30
14	2013/6/4	0120~0213	200
15	2013/6/4	0330~0405	60
16	2013/6/4	0625~0700	30
17	2013/6/4	0700~0745	30
18	2013/6/4	1240~1310	180
19	2013/6/4	1320~1400	160

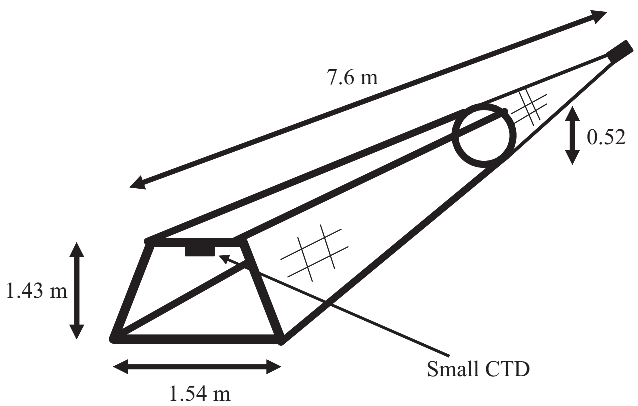

Fig. 3. Isaacs-Kidd Midwater Trawl (IKMT) net used to quantify the density of zooplankton in the sound-scattering layer. The towing depth was monitored by a small CTD. The net position was saved at 5-s intervals.

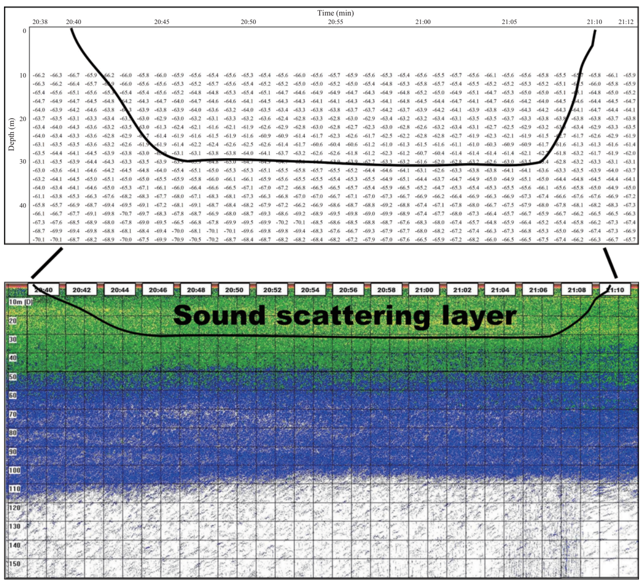

Fig. 4. A typical IKMT track (1st net sample, taken on 2 June 2013 at a depth between 30-35 m) and average SV (dB) values for twenty 2 m depth bins in the scattering layer (upper figure), and a 1-min section of the corresponding echogram (lower figure). Modified from Liao et al. (1999).

DSL, the dropping and lifting of IKMT were performed as quickly as possible so that the net mouth and body shape were not opened completely. The samples collected were preserved in a 95%-buffered alcohol–water solution. For each trawl sample, the number of individual organisms was counted, the total length (TL) of the large shrimp (TL > 10 mm) was measured, each organism was identified according to its taxonomic group, and then the abundance (inds./m^3) and biomass (g/m^3) were estimated, respectively.

3. Oceanographic Condition

A seabird CTD system (Model SBE 911) was used to obtain temperature, salinity, and density profiles (depth range 0-250 m) at 3-h intervals during the acoustic and trawl sampling periods. The initial raw CTD data were processed on board the ship, using the SeaSoft package, and the temperature and salinity (T/S) diagrams were subsequently plotted using Excel 2010. The CTD system was calibrated prior to and after the cruise trip at the vessel operation center of the R&D office, National Taiwan Ocean University. Accuracies for tempera-

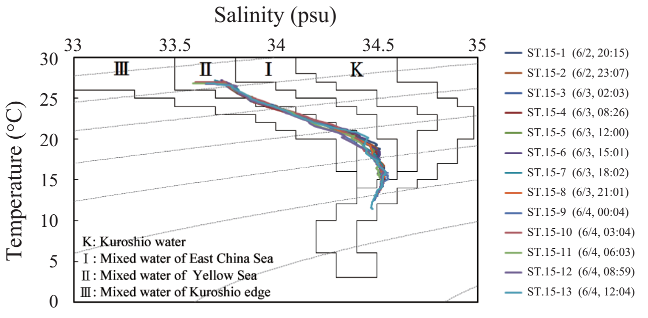

Fig. 5. Temperature and salinity diagram. The T/S range of each water mass was observed by Sawara and Hanzawa (1979). Different colors show the T/S observations at different times from June 2 to 4, 2013.

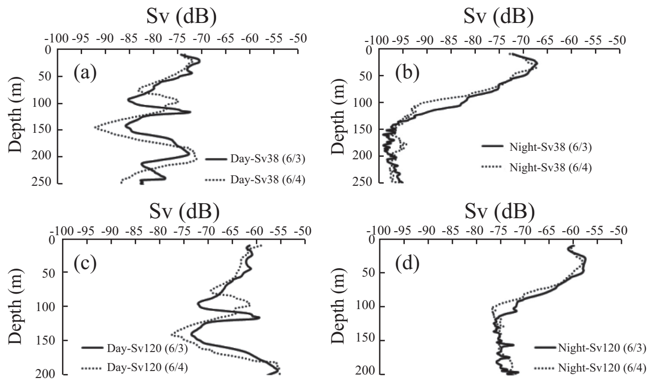

Fig. 7. Vertical distribution of backscattering in I-Lan Bay, during daytime at 38 kHz (a) and 120 kHz (c), and nighttime at 38 kHz (b) and 120 kHz (d). Solid line: 2013/6/3; dotted line: 2013/6/4.

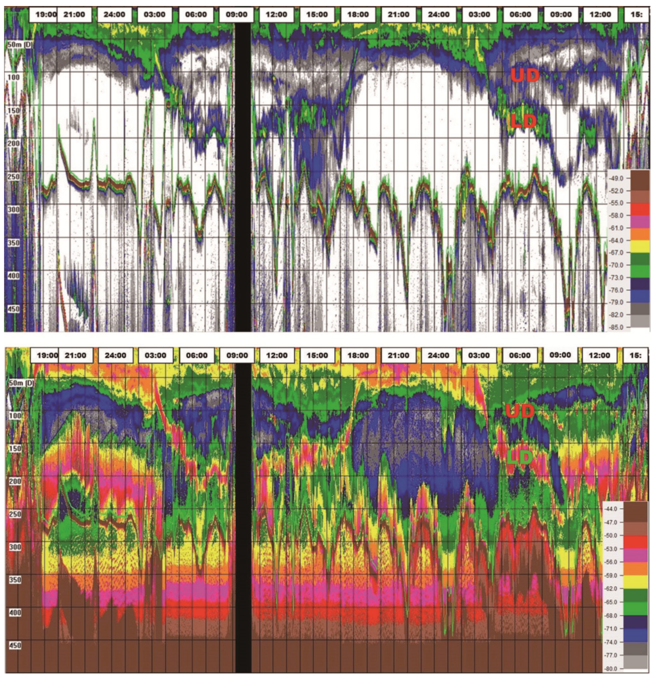

Fig. 6. The diel variation in mean volume backscattering strength of sound scattering layer in I-Lan Bay, northeastern Taiwan (a: 38 kHz; b: 120 kHz). The color bar indicated the scale of volume scattering strengths. There was no acoustic data in 10:00 AM ~11:00 AM on June 3 of 2013 (Black region), for we turned off the echo sounder because of the big waves.

ture and salinity were estimated to be 0.01°C and 0.01 psu, respectively.

III. RESULTS

1. Oceanographic Conditions

T/S diagrams generated from the data obtained from the surface to 250 m in the ocean from the fixed station in June 2013 are shown in Fig. 5. The water temperature was 11.4-27.2°C and salinity was 33.59-34.56 psu. Hydrographic characteristics of the T/S profiles were similar at 13 time points and matched the T/S ranges of the Kuroshio water, mixed water of the ECS, mixed water of the Yellow Sea, and mixed water of the Kuroshio edge, particularly best matched with mixed water of the Yellow Sea (Sawara and Hanzawa, 1979; Manuel et al., 1997; Lee et al., 2011).

2. Volume Backscattering Strength of the Sound Scattering Layer

The diel variation in the mean SV of the sound scattering layer at 38 and 120 kHz in I-Lan Bay from June 2 to 4, 2013 is shown in Fig. 6. Diel differences observed in the vertical distribution of backscattering are shown in Fig. 7. At 38 kHz, there were 3 high acoustic scattering layers at depths of 10-80 m (−74.5 ± 3.8 dB), 80-130 m (−78.5 ± 3.8 dB), and 130-230 m (−76.7 ± 6.0 dB) during the daytime on June 3 and 4. Similarly, at 120 kHz, there were 3 high acoustic scattering layers at depths of 10-80 m (−63.2 ± 2.4 dB), 80-130 m (−65.2 ± 4.1 dB), and 130-200 m (−60.5 ± 7.6 dB) during the daytime on June 3 and 4. As shown in Figs. 6 and 7, the mean SV of approximately 10-80 m SSL during the nighttime was approximately −70.5 ± 3.1 dB at 38 kHz and −60.0 ± 2.9 dB at 120 kHz. These values are approximately 4.0 ± 1.5 dB and 3.1 ± 1.4 dB higher than those obtained during the daytime at 38 kHz and 120 kHz, respectively.

The mean SV distribution exhibited 2 distinct DSLs that indicated DVM: the upper DSL (UD) and lower DSL (LD). These 2 layers were aggregated in deep waters during the daytime and in shallow waters during the nighttime. The mean SV at 38 kHz of the 2 DSLs during the daytime (08:00 AM-02:00 PM) at depths of 80-130 m and 130-230 m were higher by 6.1 ± 6.9 dB and 20.0 ± 6.4 dB, respectively, than that obtained during the nighttime (08:00 PM-02:00 AM). The mean SV at 120 kHz of 2 DSLs during the daytime at depths of 80-130 m and 130-200 m were 7.7 ± 5.3 dB and 13.8 ± 7.0 dB, respectively, which was higher than that obtained during the nighttime.

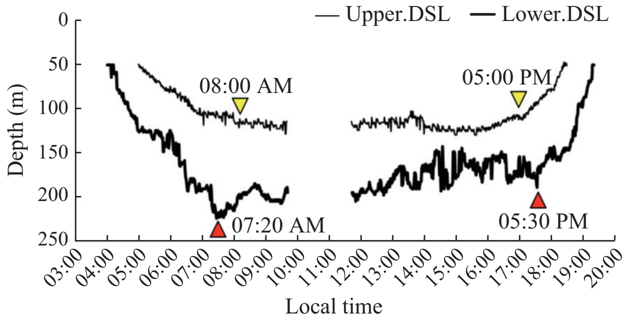

Fig. 8. Central depth of two major parts of DSLs (Light line: upper DSL; heavy line: lower DSL). Start time of descending was at 05:00 AM (upper DSL) and 04:00 AM (lower DSL); upper DSL stayed at about 110 m was from 08:00 AM to 05:00 PM, and lower DSL stayed at about 190 m from 07:20 AM to 05:30 PM; ascended to surface layer and stayed after 06:30 PM (upper DSL) and 07:20 PM (lower DSL).

3. Diel Vertical Movements and Migration Velocity

The central depths of 2 major parts of DSLs were estimated and are shown in Fig. 8. The echogram, as shown in Figs. 6 and. 8, shows that the LD started to descend at a mean speed of 1.38 cm/s at 04:00 AM and remained at approximately 190 m after 07:20 AM. The UD started to descend with a mean speed 0.59 cm/s at 05:00 AM and remained at approximately 110 m after 08:00 AM. The 2 DSLs returned to their regular depths during the daytime, and their vertical movement speed varied slightly with a mean speed of 0.02 and 0.1 cm/s for the UD and LD, respectively. After dusk, both DSLs started to ascend. The UD appeared to move vertically at 05:00 PM, 30 min earlier than the LD, and remained at the surface layer after 06:30 PM and 07:20 PM. The mean ascending speeds of the UD and LD were 1.04 cm/s and 1.92 cm/s, respectively.

4. Species Composition and Abundance

Sixteen taxonomic groups of zooplankton were identified: Copepoda, Pteropoda, Decapoda, Chaetognatha, Appendicularia, Ostracoda, Foraminifera, Amphipoda, Heteropoda, Nauplius, Medusa, Cladocera, fish eggs, Radiolaria, Thaliacea, and Echinodermata larva (Table 3). In addition, Decapoda were further classified into 2 groups: organisms larger than 10 mm in length and organisms smaller than 10 mm in length. Smaller decapods (TL < 10 mm) included lucifera, shrimp larva, srab zoea, mysids, and euphausiacea, whereas larger decapods (TL > 10 mm) included *Pasiphaea japonica* (glass shrimp), *Sergia lucens*, and *Systellaspis pellucida*, as listed in Table 4. The catch composition varied with time and depth. Copepoda and Decapoda were dominant in abundance and biomass, respectively, of the total zooplankton. The zooplankton abundance at 30 m from daytime to nighttime indicated that the decapods had the highest difference value, and the mean abundance during the daytime and nighttime were approximately 10.8 and 26.0 inds./m^3, respectively. The abundance at nighttime was approximately 2.4 times higher than that observed during the daytime, which indicated that almost all of the DVM species belonged to Decapoda in I-Lan Bay (Table 3). Lucifera and *P. japonica* were the major DVM species of the smaller and larger decapods, respectively, and both species exhibited the greatest decrease in abundance at 200 m from daytime to nighttime, as shown in Table 4.

IV. DISCUSSION AND CONCLUSION

For the IKMT net towed during the daytime at deeper depths of 200 m, *Pasiphaea japonica* constituted 89.3% of the larger decapods (Table 4b). This result is similar to those of Chou et al. (1999) and Omori and Ohta (1981). In the study by Chou et al. (1999) *P. japonica* was almost the dominant species of decapods in DSL in the I-Lan Bay. Omori and Ohta (1981) stated that the small euphausiid shrimp, *Euphausia similis*, and myctophid fishes such as *Diaphus coeruleus* and *D. grandulifer* often constitute a major component of the DSL.

Our results are also similar to those reported by Balino and Aksnes (1993) for the DVM of the sound scattering layer in Masfjorden, western Norway. Two distinct sound scattering layers at depths of 100 and 150 m were recorded in their study. These 2 layers indicated clear DVM, including ascending and descending movements. The ascending movement starts at dusk and reaches the shallowest water during the nighttime, whereas the descending movement occurs at dawn and gradually returns to its habitual depth during the daytime. This type of DVM is the most common nocturnal vertical migration, where groups of marine organisms ascend around dusk and remain at a shallower depth during the night. Around dawn, they begin to descend and remain at that depth during the day (Cisewski et al., 2010; Lee et al., 2011). A similar phenomenon was observed in the DSL-dominated mesopelagic fish, such as lantern fish and myctophid fish, with a clear nocturnal vertical migration exhibited by ascending to the surface during the nighttime and descending to the habitual depth during the daytime (Gorbatenko and Il'Insky, 1991). For example, shoals of northern lantern fish in Oregonian and Californian waters typically move between depths of 20-30 m at night and 600-700 m during the daytime (Watanabe et al., 1999; Lee et al., 2011).

Light is the most crucial external cue in DVM behavior because the time of migration typically corresponds with changes in light intensity under water at sunrise and sunset (Rogachev et al., 2000). Despite decades of studies, the proximate factors that directly stimulate the ascent and descent of zooplankton, as well as the ultimate factors (biological advantages) of DVM, are debatable. The predator evasion hypothesis is another factor, which suggests that migrating out of the well-illuminated surface layer during the daytime substantially decreases the mortality of descending animals by reducing the risk of being detected by visually hunting predators (Zaret and Suffern, 1976). However, there are other reasons why zooplanktons benefit from performing DVM (e.g., using the oceanic flow field for horizontal displacement or

Table 3. The abundance (inds./m^3) of sampled zooplankton in I-Lan Bay at different depths and time. Accounted percentage were calculated using the following formula: [Total abundance (or biomass) of each species at different depths and time]/[Total abundance (or biomass) of all species] × 100%.

Net number	No. 8	No. 12	No. 9	No. 14		
Species	30 m (Day)	30 m (Night)	200 m (Day)	200 m (Night)	Abundance (%)	Biomass (%)
Decapoda	10.8	26.0	28.8	1.8	5.09%	32.61%
Chaetognatha	4.5	11.3	12.7	1.0	2.23%	9.64%
Copepod	501.6	294.9	166.6	61.6	77.46%	9.19%
Medusa	0.6	0.0	5.1	0.4	0.46%	7.53%
Pteropoda	86.0	26.6	0.6	1.0	8.64%	6.10%
Ostracoda	1.3	6.7	1.9	1.9	0.89%	5.87%
Nauplius	1.3	1.3	3.2	0.6	0.48%	4.09%
Cladocera	0.6	0.7	4.4	0.3	0.46%	4.01%
Fish eggs	2.5	1.3	0.6	0.1	0.35%	3.87%
Amphipoda	3.2	4.7	0.0	0.4	0.63%	3.84%
Heteropoda	3.8	2.7	0.0	0.3	0.51%	3.84%
Appendicularia	0.0	4.0	10.1	0.3	1.09%	2.59%
Foraminifera	7.0	2.7	0.6	0.0	0.78%	2.52%
Thaliacea	0.0	0.7	0.6	0.0	0.10%	0.61%
Radiolaria	0.0	2.7	0.0	0.0	0.20%	0.58%
Echinodermata larva	0.6	0.0	0.0	0.0	0.05%	0.25%
Other	6.4	1.3	0.0	0.0	0.58%	2.86%

Table 4. The smaller (a: TL < 10 mm) and bigger Decapoda (b: TL > 10mm) abundance (inds./m^3) and accounted percentage (which accounted percentage for the group Decapoda species) in 200 m during day and night.

a.

Smaller Decapoda species	200m (Day)	200m (Night)
Lucifera	23.43 (82.2%)	0.44 (27.2%)
Shrimp larva	4.43 (15.5%)	0.15 (9.3%)
Crab zoea	0.63 (2.2%)	0.29 (17.9%)
Mysids	0 (0%)	0.15 (9.3%)
Euphausiacea	0 (0%)	0.59 (36.4%)

b.

Bigger Decapoda species	200m (Day)	200m (Night)
Pasiphaea japonica	0.509 (89.3%)	0.117 (80.7%)
Sergia lucens	0.043 (7.5%)	0.005 (3.4%)
Systellaspis pellucida	0.018 (3.2%)	0.023 (15.9%)

retention) (Manuel and O'Dor, 1997; Manuel et al., 1997). DVM may be related to changes in and the age of the ecosystem. Voss et al. (2007) investigated DVM patterns of the Baltic sprat larvae for the periods 1989-1990 and 1998-2002. They found that this behavioral change coincided with a more general change in the Baltic ecosystem (i.e., an increase in the near-surface temperature, and a general increase in the abundance of the major prey organism of the Baltic sprat larvae with greater pronounced aggregation of these larvae in surface waters).

According to the histogram of $\Delta SV_{120\text{-}38}$ for 1 min × 2 m EIUs at 30-70 m and 71-80 m (Fig. 9), the corresponding probability density indicates that the $\Delta SV_{120\text{-}38}$ at 30-70 m is higher than that at 71-80 m, which implies that smaller *P. japonica* are typically distributed at 30-70 m depths, but larger *P. japonica* are often distributed at 71-80 m depths during the nighttime (Chou, 2000).

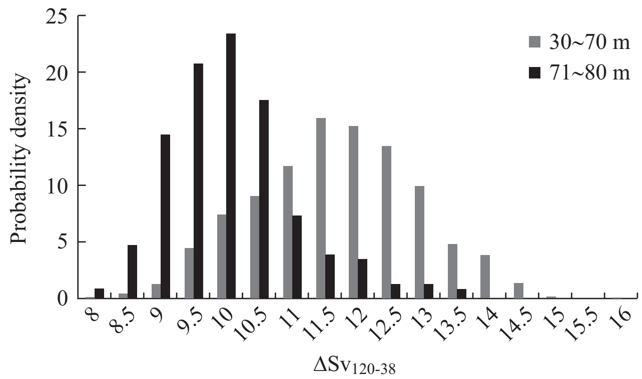

Fig. 9. Histogram of $\Delta SV_{120\text{-}38}$ for 1 min × 2 m analysis cells (EIU) identified as 30~70 m (gray bars) and 71~80 m (black bars).

The vertical distribution of 2 DSLs during the daytime is shown in Fig. 7(a), where the distributing depth of the UD was approximately 110 m on June 3 but approximately 90 m on June 4. Similarly, the LD was approximately 190 m on June 3 but approximately 180 m on June 4. Therefore, we believe that the scattering distributions changed with the environmental factors. The temperature of the UD distributing range on June 3 was approximately 16-18°C and that of the LD was approximately 14.2-14.5°C, as shown in Fig. 10. On June 4,

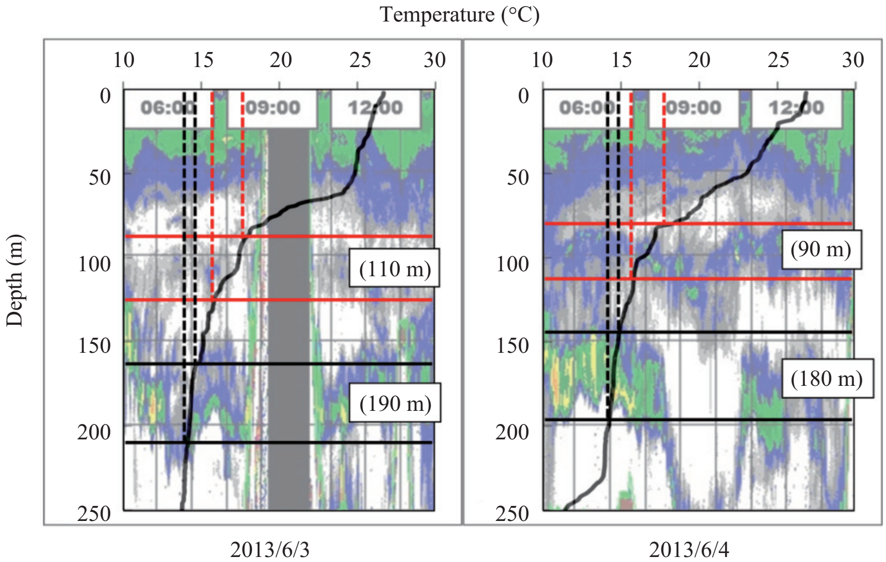

Fig. 10. Vertical distribution of temperature (°C) and the corresponded SV echogram in daytime. The red solid line indicated the distributed depth range of upper DSL, the black solid line indicated the distributed depth range of lower DSL. The dotted line showed the corresponded temperature of located depth.

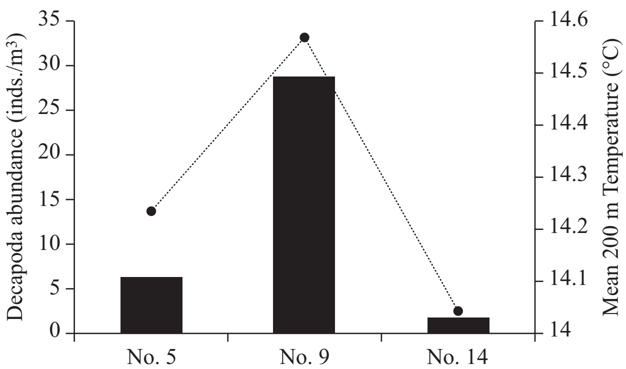

Fig. 11. The smaller Decapoda abundance (black bars) and the water temperature (°C) (dotted line) in 200 m in I-Lan Bay during daytime and nighttime.

the distributing depths of the UD and LD differed from those observed on June 3; however, the temperatures were within 16-18°C for the UD and 14.2-14.5°C for the LD. This indicates that the distributions in the DSL changed with the change in temperature in I-Lan Bay.

Similarly, the abundance of the smaller Decapoda and the corresponding temperature at 200 m indicated that the abundance of decapods was high at high temperatures, as shown in Fig. 11. However, this result is in contrast with that of Fielding et al. (2012), where the abundance and temperature had a negative correlation. We believe that this contradiction may be due to the distinct composition of the zooplankton. In the study by Fielding et al. (2012), the dominant species at 200 m during the daytime and nighttime was krill, but in this study the dominant species was Lucifera. The optimal temperature for krill is 0.5-1°C (Flores et al., 2012) but that for Lucifera is 26.4-28°C (Xu, 2010). In this study, the temperature at 200 m was 14-14.6°C; therefore, the abundance of smaller decapods increased with the increase in temperature. This is another reason for the different results obtained in these 2 studies.

Our study examined the diel change of acoustic characteristics and established the zooplankton composition through the sound scattering layer at different depths and times in I-Lan Bay. According to the sample and $\Delta SV_{120\text{-}38}$ results shown, the DVM species was mostly Decapoda in the lower DSL (LD). The dominant scatterer combined with the biological sampling in UD layer was necessary to further examine, even if the DVM of the upper DSL (UD) was clear to identify. Furthermore, though both smaller and larger Decapoda exhibited vertical movement behavior, the larger Decapoda always remained at a deeper layer than the smaller Decapoda during the nighttime. Although the reasons for this distribution pattern remain unclear, environmental factors and other possible reasons for this phenomenon can be investigated in the future.

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