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Report of the Advisory Panel
on Micronekton Sampling
Inter-calibration Experiment

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Edited by
Evgeny Pakhomov and Orio Yamamura

Contents

Contributing Authors

Principal Authors

Evgeny A. Pakhomov
University of British Columbia
Vancouver, BC, Canada

Orio Yamamura
Hokkaido National Fisheries Research Institute
Fisheries Research Agency
Kushiro, Japan

Contributing Authors

Richard D. Brodeur
Northwest Fisheries Science Center
National Marine Fisheries Service, NOAA
Newport, OR, U.S.A.

Réka Domokos
Pacific Islands Fisheries Science Center
National Marine Fisheries Service, NOAA
Honolulu, HI, U.S.A.

Katy R. Owen
University of British Columbia
Vancouver, BC, Canada

Larisa G. Pakhomova
University of British Columbia
Vancouver, BC, Canada

Jeffrey Polovina
Pacific Islands Fisheries Science Center
National Marine Fisheries Service, NOAA
Honolulu, HI, U.S.A.

Michael Seki
Pacific Islands Fisheries Science Center
National Marine Fisheries Service, NOAA
Honolulu, HI, U.S.A.

Andrey V. Suntsov[*]
Northwest Fisheries Science Center, NOAA
Newport, OR, U.S.A.
* Present address: Scripps Institution of Oceanography
University of California San Diego
La Jolla, CA, U.S.A.

Hiroki Yasuma
Hokkaido University
Hokkaido, Japan

Executive Summary

Based on recommendations of PICES Working Group on *Effective Sampling of Micronekton* (WG 14), an Advisory Panel on *Micronekton Sampling Gear Intercalibration Experiment* (MIE-AP) was established in 2002 under the direction of the PICES Biological Oceanography Committee (BIO). The role of the Advisory Panel (renamed as *Micronekton Sampling Inter-calibration Experiment* in 2004) was to oversee the planning and implementation of a field program to evaluate the efficacy of sampling gears and procedures employed by different agencies to sample micronekton in the North Pacific, and to disseminate the results to the scientific community. Between 2004 and 2007, three micronekton sampling gear experiments were completed and seven gears were inter-compared:

- MIE-1: October 6–13, 2004, off Oahu Island, Hawaii, U.S.A.; acoustics and three gears [Cobb trawl, Isaacs-Kidd Midwater Trawl (IKMT), and Hokkaido University Frame Trawl (HUFT)] were compared;
- MIE-2: September 25–October 3, 2005, southeast of Hokkaido Island, Japan; acoustics and five gears [Midwater otter trawl (OT), Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS-10, MOCNESS-1), FMT (also referred to as HUFT), and Matsuda-Oozeki-Hu Trawl (MOHT)] were compared;
- MIE-3: September 22–23, 2007, eastern Bering Sea; acoustics and two gears (IKMT and MOHT) were compared.

Results of the three experiments point out that the Matsuda-Oozeki-Hu Trawl (MOHT) gear was among the most reliable and cost-effective micronekton gears examined. It provided high quality and quantity micronekton sampling. The MOHT is now available commercially and development of a closing/opening mechanism for this net is underway. Equipping the MOHT with an opening/closing mechanism on the cod-end could put this gear in the position to become a standard micronekton gear worldwide, and in the North Pacific, in particular. As a consequence, the Advisory Panel strongly supports further work in this direction.

Models were developed to predict backscattering volume to allow for comparisons between acoustic and net data. However, preliminary results indicated that the compatibility was low, which points to problems associated with both sampling techniques that have been discussed in the literature. The closest results were obtained between the MOHT and acoustics. The Advisory Panel suggests that research in improving acoustics estimates should be continued. In addition, acoustic data collected during all experiments still require some degree of editing and analysis.

A new system, J-QUEST (Sugisaki and Sawada, 2007), was shown to quantify the epipelagic micronekton and nekton but appeared to be inefficient in detecting the mesopelagic fishes, and myctophids in particular. There is a good potential for adopting this system for mesopelagic sampling but more work is required to determine which light spectrum myctophids are less sensitive to.

1   Introduction

Micronekton are structurally defined as relatively small but actively swimming organisms falling into a size class 2–20 cm, *e.g.*, between the plankton which are entirely adrift with the currents and the larger nekton which have the ability to migrate without much effect from currents (Pearcy, 1981; Brodeur *et al.*, 2005). Operationally, micronekton can be defined as taxa that avoid being caught with conventional plankton nets and are too small to be retained by most large trawls. As a consequence, different countries have developed and presently use a variety of sampling gears to catch micronekton quantitatively. Functionally, micronekton are composed of diverse taxonomic groups (Brodeur and Yamamura, 2005). Of particular interest are the cephalopods (mainly gonatid and enoploteuthid forms, as well as juvenile stages of oceanic species), crustaceans (including large euphausiids, pelagic decapods, and pelagic mysids), and fishes (mainly mesopelagic species such as myctophids, gonostomatids and bathylagids). Most of these animals undergo extensive vertical migrations and compose the sound scattering layer . Vertical migrations are conducted either on a daily or seasonal basis, with migrators occupying productive surface waters at night and descending to midwater during the daytime to reduce predation, or undertaking diapause on seasonal scales. These migrations appear to contribute significantly to the rapid vertical transport of organic material from epipelagic to mesopelagic zones (Kishi *et al.*, 2001). The mesopelagic layer, which is arguably among the largest and one of the least variable ecosystems in the world, plays a critical role in controlling marine productivity on global change time scales. This layer is also responsible for the sequestering of atmospheric carbon to the ocean floor, thus impacting climate and acting as a negative feedback to global warming. Thus it is becoming increasingly clear that the mesopelagic realm represents one of the most important ecosystem components controlling biogeochemical cycling on our planet (Tsubota *et al.*, 1999). Micronekton also include small epipelagic 'forage fishes', *e.g.*, juvenile forms of pelagic and demersal resources, which are

commonly found in diets of higher level predators (Brodeur and Yamanura, 2005). Generally not fished commercially because of their relatively small size and high lipid content, micronekton therefore represent a poorly understood but critical intermediate trophic level linking the zooplankton and highest trophic levels (including squid, fishes, seabirds, sea turtles, and marine mammals) as well as surface and midwater layers of the ocean (Seki and Polovina, 2001; Brodeur and Yamamura, 2005).

The highly mobile nature (net avoidance) and uneven (patchy) distribution of micronekton in the pelagic environment and their extrusion through the mesh of large trawls make these organisms extremely difficult to sample without bias (Pearcy, 1981). In 1998, the Biological Oceanography Committee (BIO) of the North Pacific Marine Science Organization (PICES) established a Working Group on *Effective Sampling of Micronekton to Estimate Ecosystem Carrying Capacity* (WG 14) to address the concern that there was insufficient information on the distribution, biomass and ecology of micronektonic organisms in the North Pacific. Included in the operational 'Terms of Reference' was a request to "*examine the efficacy of available micronekton sampling gears and propose new sampling devices if the available ones were not adequate for the task*". One of the recommendations included in the WG 14 final report on *Micronekton of the North Pacific* (Brodeur and Yamamura, 2005) is that, although a variety of gears are presently being used to sample micronekton in the North Pacific and other parts of the world ocean (Wiebe and Benfield, 2003), there has been little effort expended in comparing the relative sampling efficiency and selectivity of these gears.

It has been more than 20 years since the Scientific Committee on Oceanic Research (SCOR) symposium on methods of sampling micronekton was convened (Pearcy, 1981). A substantial effort through the International Council for the Exploration of the Sea (ICES)/Global Ocean Ecosystem Dynamics (GLOBEC) Sea-going Workshop was

undertaken in 1993 to compare a large variety of plankton nets in the North Atlantic (Wiebe *et al.*, 2002). Although three nets suitable for catching micronekton were used during the experiment, *e.g.*, Isaacs-Kidd Midwater Trawl (IKMT), Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) and young fish trawl (YF), most of the sampling devices used for comparison were designed to sample mesozooplankton, *e.g.*, organisms < 2 cm (Wiebe *et al.*, 2002). Overall, the absence of inter-calibration coefficients between available gear types has hampered previous efforts to make inter-decadal or regional comparisons of micronekton composition and biomass.

In 2002, PICES formed an Advisory Panel on *Micronekton Sampling Gear Inter-calibration Experiment* (MIE-AP) as a result of recommendations from WG 14. The role of the Advisory Panel (renamed as *Micronekton Sampling Inter-calibration Experiment* in 2004) was to oversee the planning and implementation of a field program to evaluate the efficacy of sampling gears and procedures employed by different agencies to sample micronekton in the North Pacific, and to disseminate the results to the scientific community (see Appendix

1). Between 2004 and 2007, three micronekton sampling gear experiments were completed:
- MIE-1: October 6–13, 2004, off Oahu Island, Hawaii, U.S.A.; acoustics and three gears [Cobb trawl, Isaacs-Kidd Midwater Trawl (IKMT), and Hokkaido University Frame Trawl (HUFT)] were compared;
- MIE-2: September 25–October 3, 2005, southeast of Hokkaido Island, Japan; acoustics and five gears [Midwater otter trawl (OT), Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS-10, MOCNESS-1), FMT (also referred to as HUFT), Matsuda-Oozeki-Hu Trawl (MOHT)] were compared;
- MIE-3: September 21–22, 2007, eastern Bering Sea; acoustics and two gears (IKMT and MOHT) were compared.

A list of fish species collected during the MIE-1 cruise off Ohahu Island is given in Appendix 2. For more details on the working history of the Advisory Panel, the reader is referred to MIE-AP Annual Reports in Appendix 3. Appendix 4 contains featured articles of the three experiments taken from the 2005 and 2008 issues of the PICES Press.

1.1   References

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2   First Micronekton Inter-calibration Experiment, MIE-1

2.1   Macrozooplankton and Micronekton off Oahu Island, Hawaii: Composition and Gear Inter-calibration

E.A. Pakhomov, A.V. Suntsov, M.P. Seki, R.D. Brodeur, R. Domokos, L.G. Pakhomova and K.R. Owen

2.1.1   Background and Methodology

The first micronekton inter-calibration experiment (MIE-1) was successfully completed in October 2004 off Oahu Island, Hawaii and subsequently discussed during the Thirteenth PICES Annual Meeting held October 14–24, 2004 in Honolulu (Brodeur *et al.*, 2005). This first experiment was intended to serve two major purposes: (1) to conduct the MIE sampling and obtain information for gear comparison as well as to examine a subtropical (oligotrophic open ocean gyre) micronekton community; and (2) to use the relatively benign weather and sea conditions to evaluate and refine protocols, logistics, and sampling design for the future experiments.

Sampling was carried out during October 6–12, 2004 in the region southwest of Oahu Island over bottom depths between 700–1200 m on board the NOAA research ship *Oscar Elton Sette* (Fig. 2.1). In total, 56 stations were completed. These included 17 Cobb trawl, 19 IKMT and 20 HUFT tows. Nets were deployed randomly mainly during the nighttime (between 20:00 and 05:00 h local time) and daytime (between 08:00 and 17:00 h local time). Sampling usually was not carried out during the crepuscular (05:00–08:00 and 17:00–20:00 h) time intervals because mictonekton were in flux, *e.g.*, migrating between surface and midwater layers (Fig. 2.2). Net deployment was dictated by the presence of pronounced backscattering layers and average tow
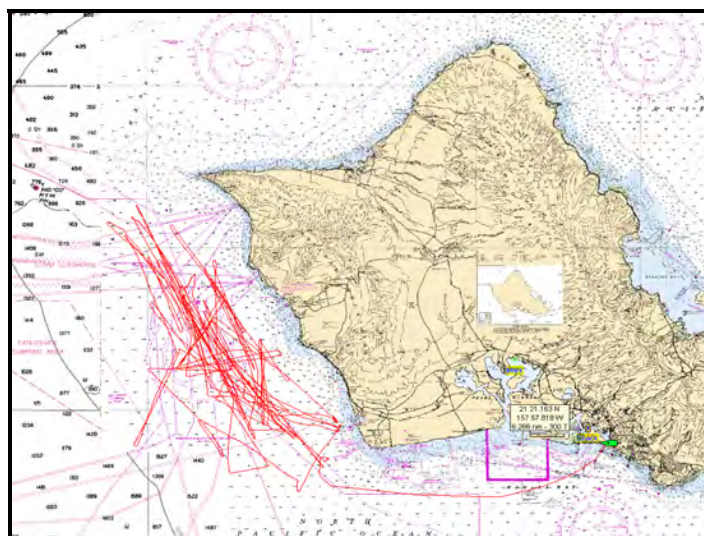
Fig. 2.1   Sampling area and sampling tracks carried out during the MIE-1 southwest of Oahu Island, Hawaii, in October 2004.

duration was 1 h (Fig. 2.3). During the nighttime, the surface layer was sampled obliquely (Fig. 2.4, upper panel). Usually, nets were deployed to a depth of approximately 120 m and slowly brought to the surface. During the day, nets were deployed to a depth of 550–650 m and towed horizontally (Fig. 2.4, lower panel). In addition, during October 10–13, 2004 several net deployments at a deep scattering layer (DSL), approximately 500–600 m, were carried out during the nighttime (Fig. 2.2).

Fig. 2.2 Sampling schedule during the MIE-1, off Oahu Island, Hawaii, October 6–13, 2004.
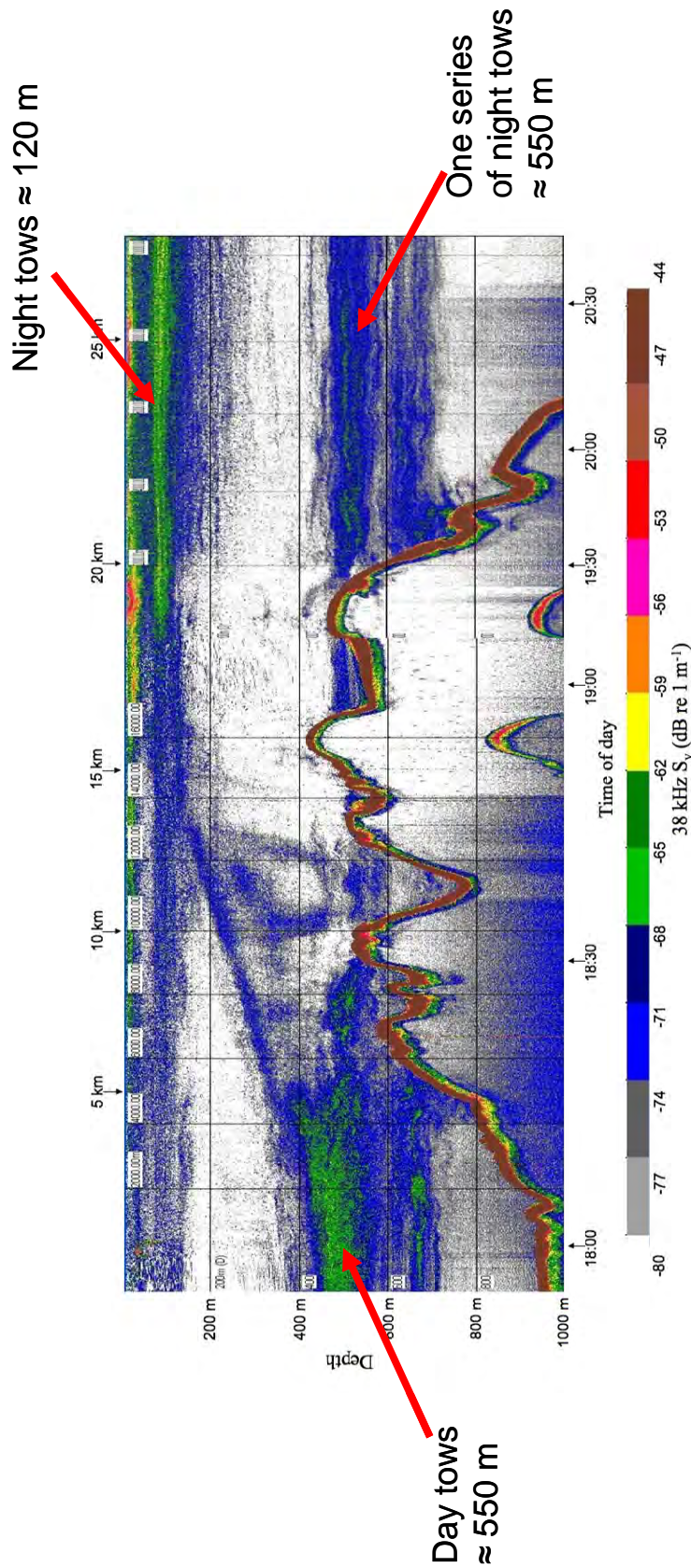
Fig. 2.3 The EK-60 38 kHz echogram in the top 750 m during October 9, 2004, southwest of Oahu Island, Hawaii, illustrating the structure of the shallow scattering layer (SSL) and deep scattering layer (DSL) during daytime (left) and nighttime (right), separated by the pronounced evening vertical migratory period. The very high S_v (> -44 dB) are backscatter from the seafloor. Note that the DSL extends vertically at the slopes and there is a resident midwater layer.
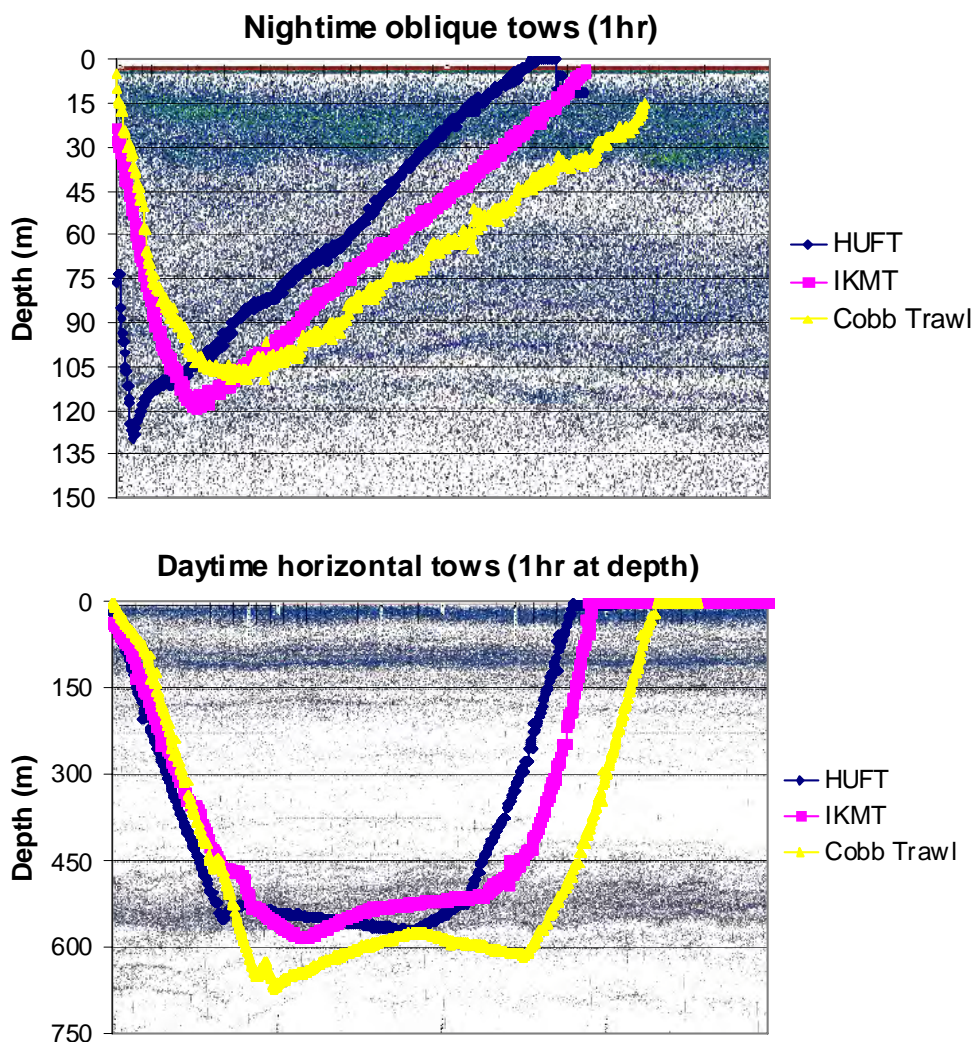
Fig. 2.4 Examples of sampling profiles during nighttime (upper panel) and daytime (lower panel) near Oahu Island, Hawaii, during October 2004.

Three different gears, a 140 m^2 pelagic Cobb trawl (mesh size in the end part of the trawl was 10 mm), a 4 m^2 Hokkaido University Frame Trawl (HUFT, mesh size was 3 mm), and a 3 m^2 Isaacs-Kidd Midwater Trawl (IKMT, mesh size was 5 mm), were used during the MIE-I. The average trawling speed was 3 knots (range 2.5 to 3.5 knots). The volume filtered was calculated using the nominal mouth opening of the net and the distance travelled. Mean volume filtered was 14,007 ± 1,159 m^3 (range 10,745–15,307 m^3), 19,744 ± 2769 m^3 (range 14,630–24,259 m^3) and 746,794 ± 50,044 m^3 (range 637,829–832,980 m^3) for the IKMT, HUFT and Cobb trawls, respectively. Densities were first calculated as ind. m^{-3} and then, according to the

average thickness of the backscattering layers during the night and daytime, multiplied by 100 to convert densities to ind. m^{-2}.

The bycatch between sampling depth and the surface layer was considered to be minimal during the daytime. This was confirmed by two oblique tows during the day that were aborted for technical reasons. These tows did not reach the midwater backscattering layer and did not retrieve any macrozooplanktonic and micronektonic organisms.

All samples were sorted immediately after they arrived onboard. Rare and large species were counted, measured and weighed from the entire

sample and preserved in 10% formalin seawater solution. The remaining part of the sample was either entirely analyzed for macrozooplanktonic and micronektonic species (only a few IKMT and HUFT samples) or subsampled (all Cobb trawl samples and a majority of IKMT and HUFT samples). Generally, ½ or ¼ of the sample was used for onboard sorting of the catch into major taxonomic groups (fish, decapods, euphausiids, tunicates, *etc.*). The total subsample was weighed and the main taxonomic groups were counted. The remaining part of the sample (*e.g.*, ½ or ¾) was preserved immediately after subsampling in a 10% formalin seawater solution for subsequent laboratory taxonomic analyses. In the laboratory, fish, decapods, euphausiids and squid were identified, where possible, to the species level, counted and measured. The remaining zooplankton were only analyzed to major taxonomic groups. Individuals of the main taxonomic groups of zooplankton were counted and measured to the nearest mm in either the entire subsample or ¼ of the subsample. The taxonomic identification of decapod and euphauiid crustaceans, as well as oegopsid squid, still requires verification and consequently only taxonomic data on fish will be presented in the current report.

The inter-comparison between gears was initially attempted at the species level but it was soon recognized that in this highly diverse tropical community such inter-comparison is impractical and impossible. As a consequence, the inter-comparison has been attempted for the best represented taxonomic groups (fish and crustaceans) and for the total catch composition only. Crustaceans included representatives of Copepoda (main size range < 10 mm), Ostracoda (< 10 mm), Mysidacea (> 20 mm, not numerous), Amphipoda (< 20 mm), Stomatopoda (< 30 mm, not numerous), Euphausiacea (< 20 mm) and Decapoda (> 20 mm). Length frequency curves, which have been used for inter-comparison, were constructed for each sampling gear and sampling time/depth by averaging organism densities expressed as ind. m^{-2} among all samples for the size intervals of 1, 5 and 10 mm.

2.1.2 Taxonomic Composition of Catches

By a conservative estimate, a total of 208 species of macroplankton and micronekton was identified in the samples of all three gears. For a comprehensive list of species, see Appendix 2. Osteichthyes (fish)

were, by far, the most species diverse group in the samples, accounting for 59% of all species verified, followed by Oegopsida and Decapoda which contributed 16% and 12% of all species provisionally identified, respectively. Among Osteichthyes, the midwater family Myctophidae accounted for almost 60% of all specimens counted. The second most abundant family (*ca*. 38%) was the Gonostomatidae, largely due to the abundant and ubiquitous *Cyclothone* spp. The remaining families contributed less than 3% of total fish counts.

Based on the preliminary taxonomic treatment, community diversity indices, *e.g.*, evenness and species richness, were very similar for the HUFT and IKMT, and higher during the nighttime (Fig. 2.5). Relatively high evenness indices were a clear indication of a numerical predominance of the Gonostomatidae and Euphausiacea in the nighttime samples. Both day and nighttime deployments of the Cobb trawl caught more species per trawl and as a consequence, clearly higher diversity indices (Fig. 2.5).

By abundance, four taxonomic groups, Euphausiacea, Myctophidae, other fish and Decapoda, consistently comprised the majority of samples of all three gears, while the contribution of all other groups generally never exceeded 4% (Fig. 2.6). Euphausiids were the most prominent group in both daytime and nighttime IKMT samples, accounting for 42–47% of the total abundance. Other fish (16–37%) and myctophids (7–16%) were the second and third most abundant groups. Finally, decapods contributed 7–12% to total abundance (Fig. 2.7). Unlike the IKMT, in HUFT catches the euphausiid contribution was modest (12–14% of total abundance). The samples were overwhelmingly dominated by other fish (44–73%, mainly of the family Gonostomatidae) followed by myctophids (7–22%) and decapods (5–14%) (Figs. 2.6 and 2.7). The euphausiid contribution to the Cobb trawl catches was intermediate compared to the IKMT and HUFT, ranging between 17 and 33%. Myctophids (15–57%) and other fish (2–35%) again were the second and third most abundant groups, followed by decapods (7–15%). Overall, a similar pattern of other fish (mainly the families Stomiidae, Serrivomeridae, Astronesthydae, and Gonostomatidae), increasing in their contribution during the deep daytime tows, was found in all gears compared. This was most pronounced in the Cobb trawls when daytime and nighttime samples were compared (Figs. 2.6 and 2.7).

The high contribution of other fish in daytime in the HUFT and IKMT samples was mainly due to the family Gonostomatidae that was missed by Cobb trawl catches because of the large mesh size of the net. Comparison of the daytime and nighttime midwater tows of Cobb trawls confirms that many representatives of the families Stomiidae, Serrivomeridae, and Astronesthydae appeared to be resident in the deep backscattering layer throughout the day. Finally, the day and nighttime comparisons also suggest that myctophids and decapods were two strongly migrating taxonomic groups (Fig. 2.6). While small sampling gears provided similar catch abundances, densities measured using both the HUFT and IKMT were generally significantly higher than densities obtained by the Cobb trawl for either the main taxonomic groups or total macroplankton/ micronekton abundance and biomass sampled during the MIE-1 (Figs. 2.7 and 2.8). This was largely because these nets had finer mesh sizes than the Cobb trawl.
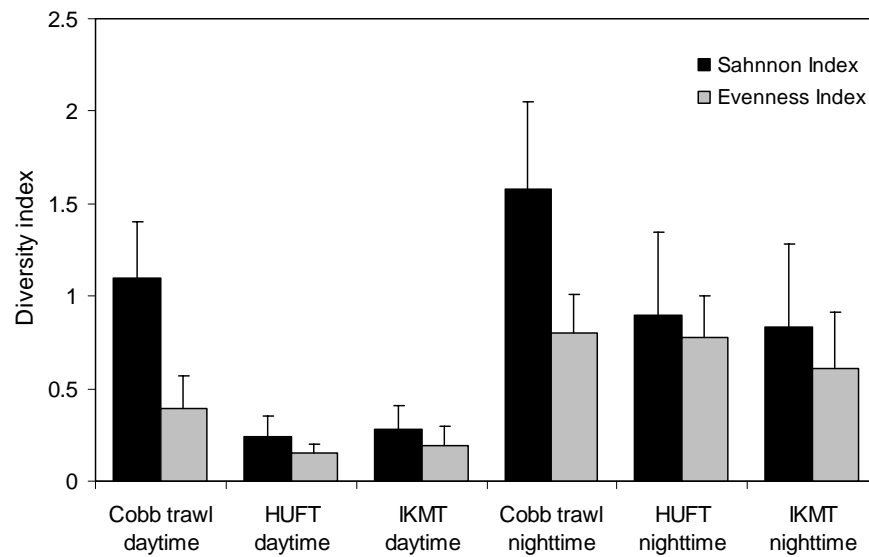
Fig. 2.5 Diversity indices (bars show 1 SD) of micronekton samples collected during the MIE-1 in October 2004 off Oahu Island, Hawaii.
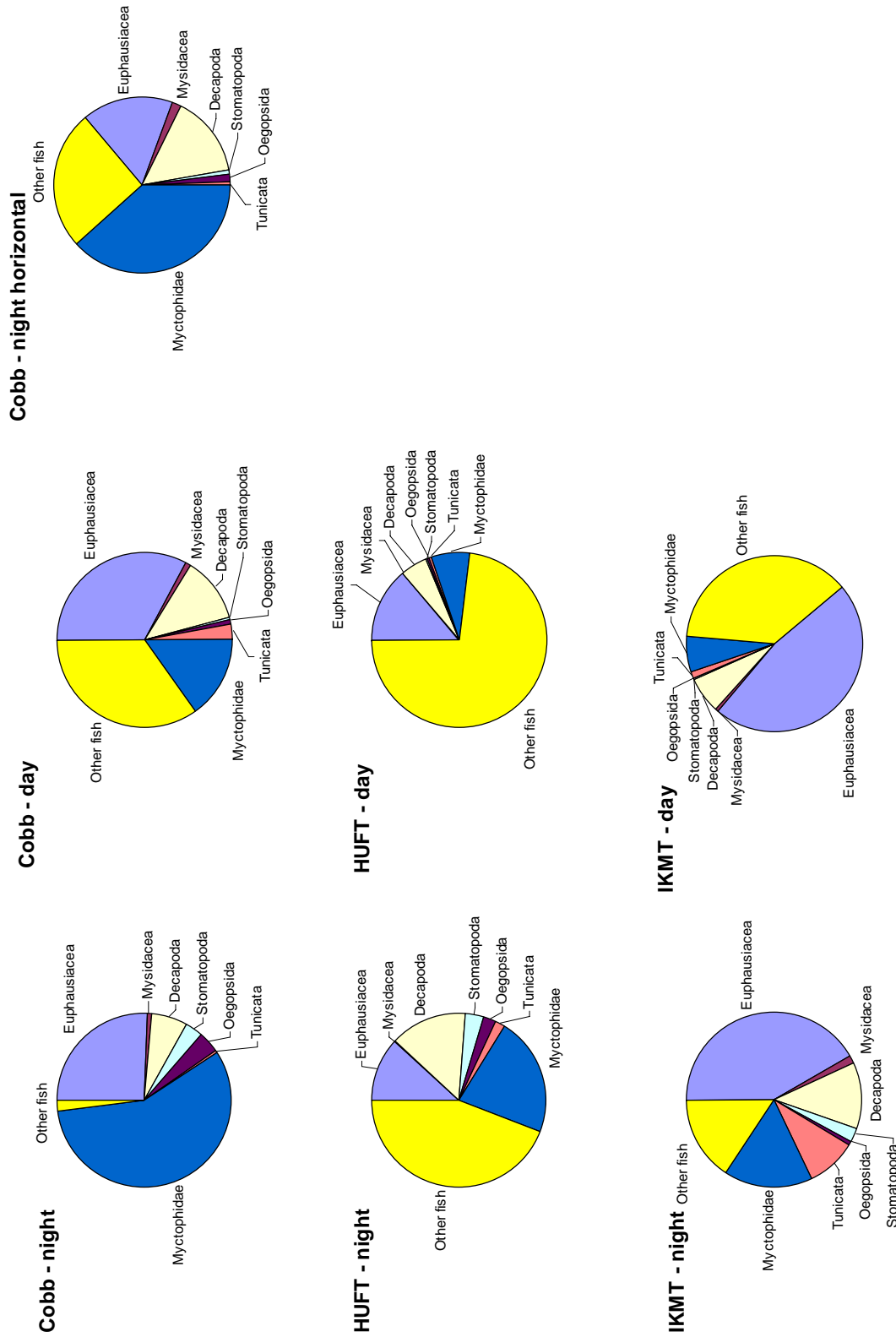
Fig. 2.6 Taxonomic composition of catches (by abundance, ind. m^{-2}) during the MIE-1 in October 2004 off Oahu Island, Hawaii.
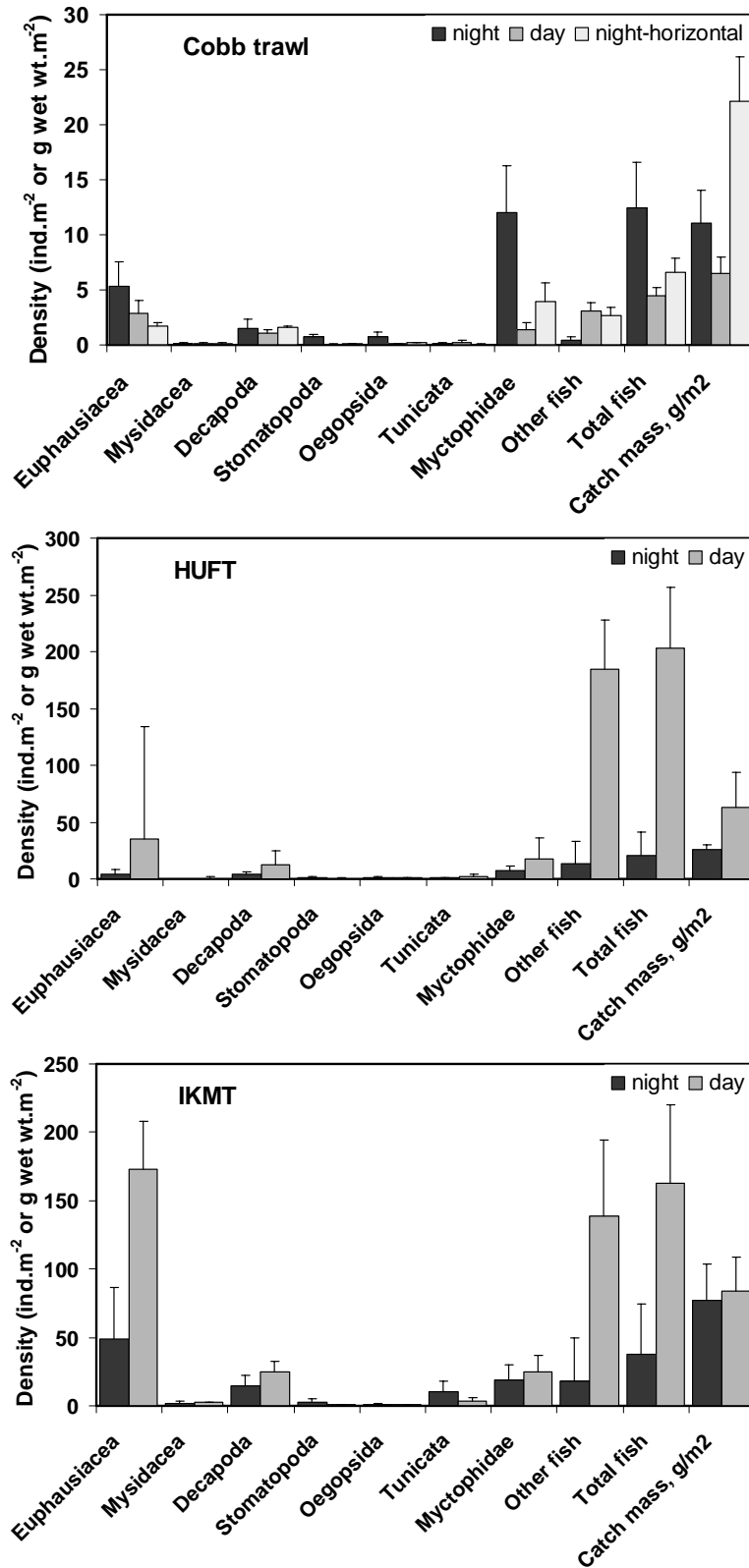
Fig. 2.7 Average density (bars show 1 SD) of major macroplankton and mictonekton taxonomic groups (expressed as ind. m^{-2}) as well as total catch biomass (g wwt m^{-2}) caught by different gears during the MIE-1 in October 2004 off Oahu Island, Hawaii.
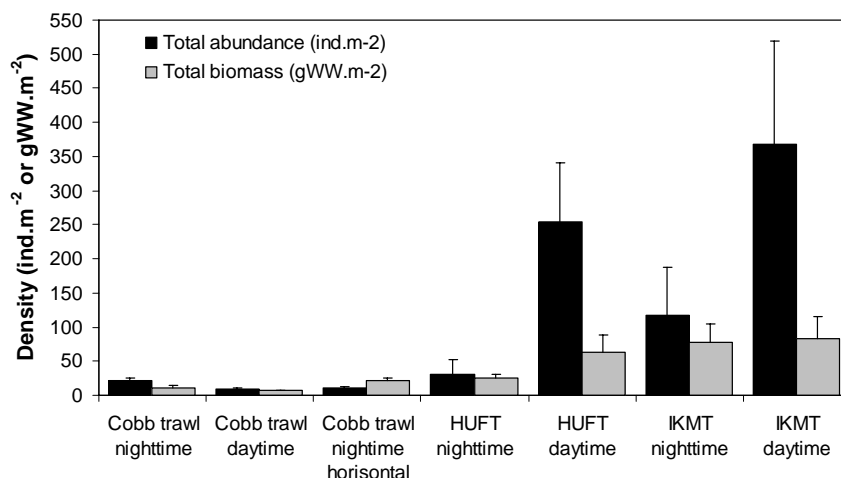
Fig. 2.8 Average values (bars show 1 SD) of total macroplankton/micronekton abundance and biomass during day and nighttime tows of three sampling gears during the MIE-1 in October 2004 off Oahu Island, Hawaii.

2.1.3 Catch Length Frequency Composition

As reported above, the Cobb trawl total catch densities were overall lower than the HUFT and IKMT densities. However, this was also true for almost all size classes in the daytime catches and for sizes < 30 mm and > 70 mm in the nighttime samples (Fig. 2.9). All gears appeared to be able to sample plankton > 1 mm and while the HUFT and IKMT provided comparable total catch size distributions, the Cobb trawls significantly undersampled size classes < 30–40 mm during both day and nighttime series. It should be noted that the closest similarity of the total catch densities between all three gears compared was only observed in the size range of 40 to 60 mm.

Similar trends between gears were observed in the size frequency distribution of total fish (Fig. 2.10) and crustaceans (Fig. 2.11). Although the slope of the total fish curve was similar between the Cobb trawl and the IKMT during nighttime, this was clearly not the case in the daytime samples (Fig. 2.10). It should be noted that the HUFT appeared to sample efficiently for only small-sized fish (< 30–40 mm) during both the day and nighttime series. Although the Cobb trawl overall sampled the largest fish more readily, the overall size range of fish sampled by both the IKMT and Cobb trawls was generally comparable (Fig. 2.10). Similarly to size frequency distributions of total catch, both the HUFT and IKMT showed comparable distributions of crustacean densities with Cobb trawl catches being consistently lower through the entire size range

(Fig. 2.11). The most comparable densities of crustaceans in all three gears were, again, observed in the size range of 20 to 40 mm. Overall, however, it is important to point out that data for both fish and crustaceans appeared to be inadequate for a proper inter-comparison between gears (see section 2.1.4).
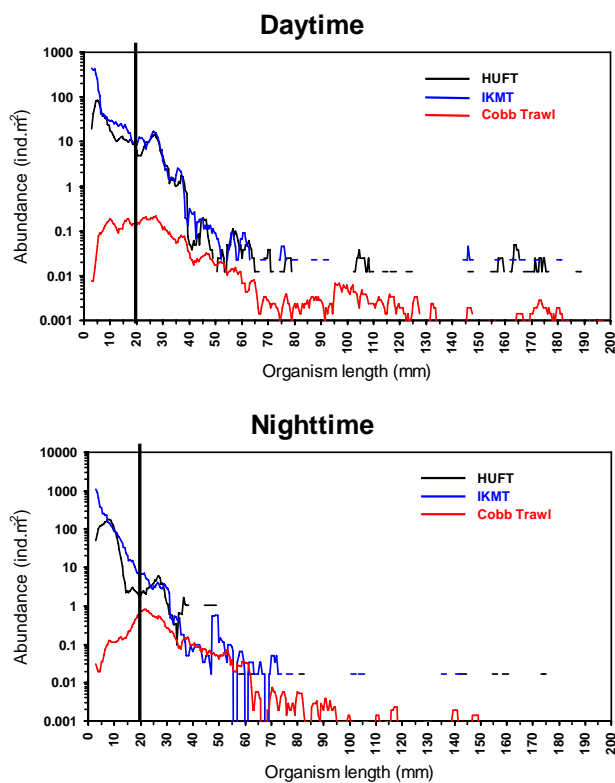
Fig. 2.9 Day and nighttime average length frequency composition of total catch in three sampling gears during the MIE-1 in October 2004 off Oahu Island, Hawaii.

nighttime their contribution was modest, ranging between 8 and 13% of the total fish catch.

It was observed (even during the preliminary visual inspection) that individual gears appear to have different sampling efficiencies, often collecting non-overlapping size groups of plankton and micronekton. This appeared to be relevant for our ability to interpret the data acquired from the multiple acoustic frequencies. Therefore, successful inter-comparisons between gears would require a closer scrutiny of gear types and net mesh sizes prior any inter-calibration experiment and the inter-comparison is perhaps only possible for a particular size range of the sample. Hence, it was decided that from now on we will concentrate only on macroplankton and micronekton fractions of the samples (*e.g.*, on organisms > 20 mm).

Fig. 2.10 Day and nighttime average length frequency composition of fish in three sampling gears during the MIE-1 in October 2004 off Oahu Island, Hawaii.

The Cobb trawl caught substantially larger organisms than either of the other two gears due principally to its large mouth opening and net mesh size (Brodeur *et al.*, 2005). Overall, the total macroplankton/micronekton size fraction (> 20 mm) in Cobb trawls comprised only 1.2–3.9% and 6.8–18.6% of total catch abundance in the HUFT/IKMT during the night and daytime, respectively. The Cobb trawl, however, was a truly micronektonic sampling gear, with organisms > 20 mm constituting, on average, 58–71% of its total catch throughout the diel period. A similar pattern was obvious for total crustaceans where crustaceans > 20 mm comprised on average < 5% of total abundance in the HUFT and IKMT samples and around 40% in Cobb trawl catches. Although overall Cobb trawl samples were dominated by fish > 20 mm (77–90% of total fish counts), only the daytime samples of HUFT and IKMT revealed a high average contribution (*ca.* 65%) of micronektonic fish, while during the

Fig. 2.11 Day and nighttime average length frequency composition of crustacean densities in three sampling gears during the MIE-1 in October 2004 off Oahu Island, Hawaii.

2.1.4 Inter-calibration between Three Sampling Gears Used during the MIE-1

Log-transformed relationships between average macroplankton/micronekton (size range > 20 mm) densities and the organism length, presented in Figure 2.12, had similar slopes for daytime and nighttime samples in both the HUFT and IKMT. In both cases, there were fewer organisms in the size range 20–50 mm at the surface at night than during the day at the deep (*ca.* 550 m) backscattering layer.

This is likely an indication of avoidance of small nets by micronekton in this size range. The Cobb trawls, however, sampled micronekton well and revealed high similarity in micronekton densities at the 550 m backscattering layer during both day and nighttime. However, it was clear that organisms in the size range of 20–50 mm were quite abundant at night in surface tows but not in the deep layer, even during the daytime. It is plausible to suggest that their downward vertical migration does not reach 550 m depth and that they perhaps disperse just above the deep backscattering layer.
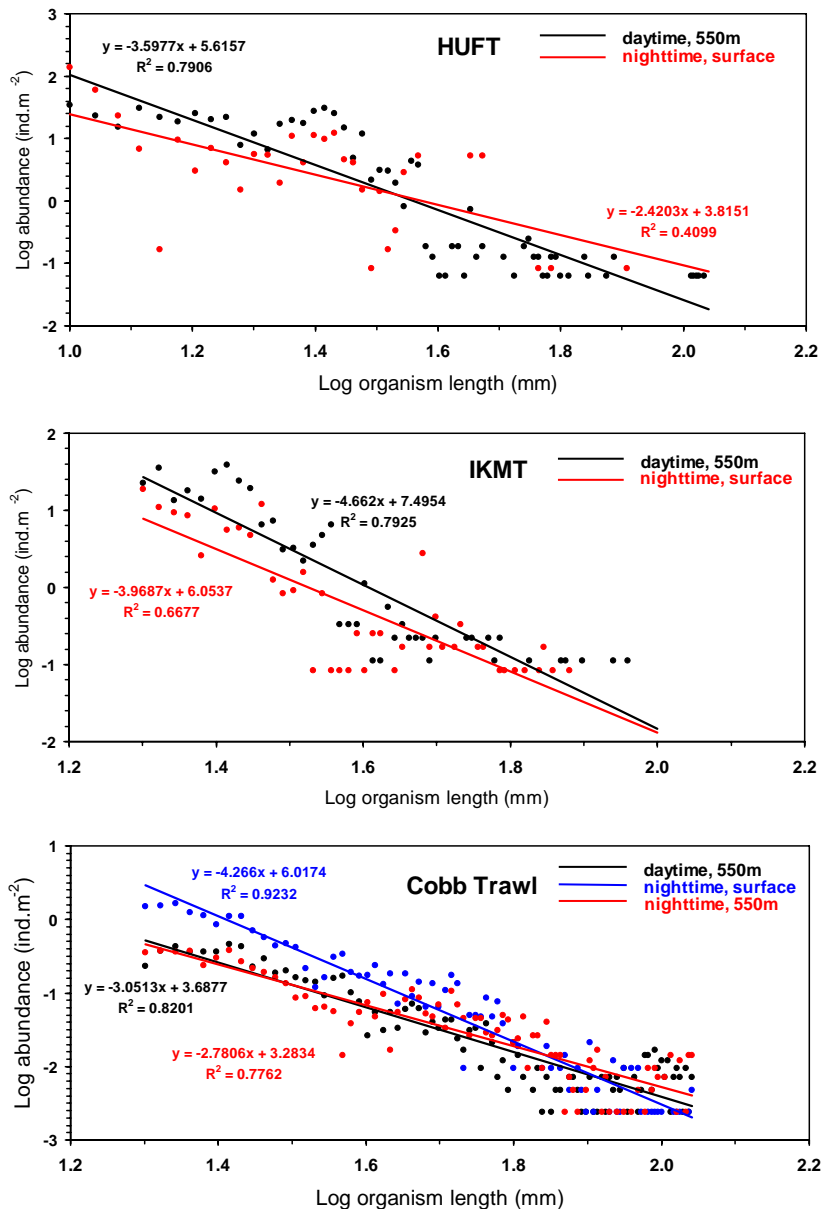
Fig. 2.12 Log-transformed relationships of organisms > 20 mm in total catch of different sampling gears during the MIE-1 in October 2004 off Oahu Island, Hawaii.
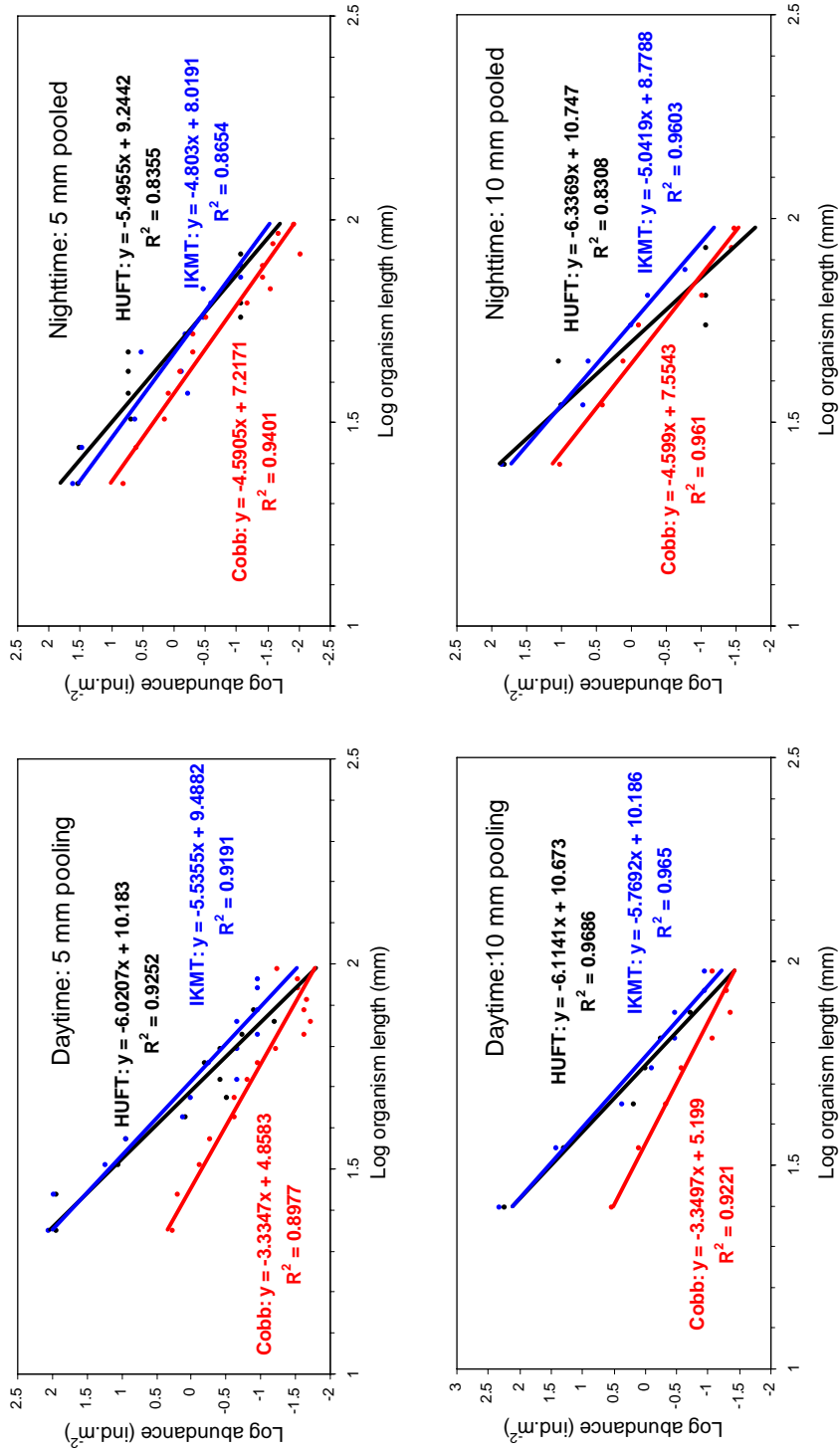
Fig. 2.13 Log-transformed relationships of organisms > 20 mm in total catch pooled into 5 and 10 mm size bins of different sampling gears during the MIE-1 in October 2004 off Oahu Island, Hawaii.

During the night, all three gears showed similar slopes of their density–length relationships, which was encouraging news for the between-gear inter-calibration (Fig. 2.13). This, however, was not the case during the daytime sampling. While the HUFT and IKMT produced very similar results, the Cobb trawl undersampled 20–50 mm sized organisms quite dramatically due to the reason proposed above.

To quantify the differences in densities of the three gears, pair-wise ratios between densities of total catch, fish and crustaceans were calculated (Figs. 2.14–2.16). For the size classes < 20 mm, the ratios of total catch varied widely, sometimes by orders of magnitude, between both the HUFT/IKMT and Cobb trawl densities but were similar to each other (ratio around 1) for the HUFT and IKMT for the size class > 5 mm (Fig. 2.14). A similar pattern was observed for both total fish and crustacean densities although the nighttime sample ratios were inconsistent (Figs. 2.15 and 2.16). The encouraging finding was that in the micronekton size classes, the ratios seem to be reduced to within one or two orders of magnitude. Unfortunately, the ratios were still highly variable at 1 mm size intervals.

Fig. 2.15 Ratios of total fish abundances between different gears during the MIE-1 in October 2004 off Oahu Island, Hawaii. Boxes mark macroplankton/micronekton size fraction (> 20 mm).

Fig. 2.14 Ratios of total catch abundances between different gears during the MIE-1 in October 2004 off Oahu Island, Hawaii. Boxes mark macroplankton/micronekton size fraction (> 20 mm).
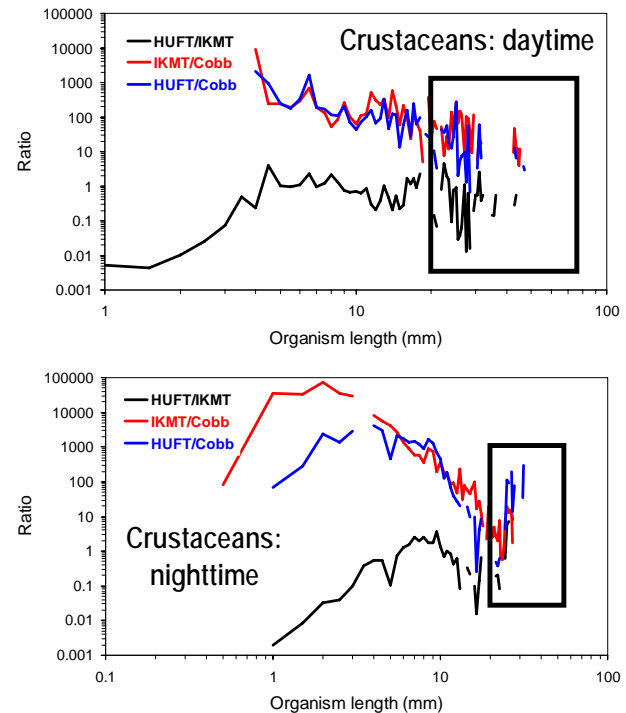
Fig. 2.16 Ratios of total crustacean abundances between different gears during the MIE-1 in October 2004 off Oahu Island, Hawaii. Boxes mark macroplankton/micronekton size fraction (> 20 mm).

An attempt to reconstruct the biomass of the IKMT samples from both the HUFT and Cobb trawl densities using average ratios calculated for 1 mm intervals revealed reasonably good performance of this approach for the size classes > 10 mm and > 20 mm in the day and nighttime samples (Fig. 2.17). However, overall performance of this approach was not encouraging, with calculated values either exceeding the true values by 47% or underestimating them by 15–41% (see Table 2.1). Similarly, poor results were obtained for total crustaceans and fish, either overestimating values by 28–79% or underestimating values by 21–68%. The one exception was when the Cobb trawl made a

reasonable prediction of the daytime IKMT total fish densities.

To reduce the high between-gear ratio variability but stay within narrow size intervals, preferably with uniform ratio ranges, we pooled data into 5 and 10 mm size bins. The reconstructed values were increasingly more consistent between gears during the daytime sampling and less consistent during the nighttime sampling (Fig. 2.17). The deviations from a true IKMT value were always negative (underestimation) and ranged from –2 to –35% and from –11 to –30% for 5 mm and 10 mm size interval treatments (Table 2.2).

Table 2.1 IKMT true and reconstructed mean abundances (ind. m^{-2}) of total crustaceans, fish and catch (> 20 mm) during the MIE-1 in October 2004 off Oahu Island, Hawaii.

Taxonomic division	Sampling time	IKMT: true	IKMT: calculated from HUFT	IKMT: calculated from Cobb trawl
Total crustaceans	daytime	89	47 (–47%)	114 (+28%)
Total crustaceans	nighttime	14	11 (–21%)	25 (+79%)
Total fish	daytime	138	80 (–42%)	132 (–4.3%)
Total fish	nighttime	25	8 (–68%)	43 (+72%)
Total catch	daytime	238	350 (+47%)	161 (–32%)
Total catch	nighttime	82	70 (–15%)	48 (–41%)

(±N%): shows the deviation calculated from true values.

Table 2.2 IKMT true and reconstructed (for 1, 5 and 10 mm size bins) mean total catch abundances (ind. m^{-2}) of macroplankton/micronekton (> 20 mm) during the MIE-1 in October 2004 off Oahu Island, Hawaii.

Size bin (mm)	Sampling time	IKMT: true	IKMT: calculated from HUFT	IKMT: calculated from Cobb trawl
1	daytime	238	350 (+47%)	161 (–32%)
1	nighttime	82	70 (–15%)	48 (–41%)
5	daytime	238	199 (–16%)	164 (–31%)
5	nighttime	82	53 (–35%)	80 (–2%)
10	daytime	238	200 (–16%)	167 (–30%)
10	nighttime	82	73 (–11%)	72 (–12%)

(±N%): shows the deviation calculated from true values.
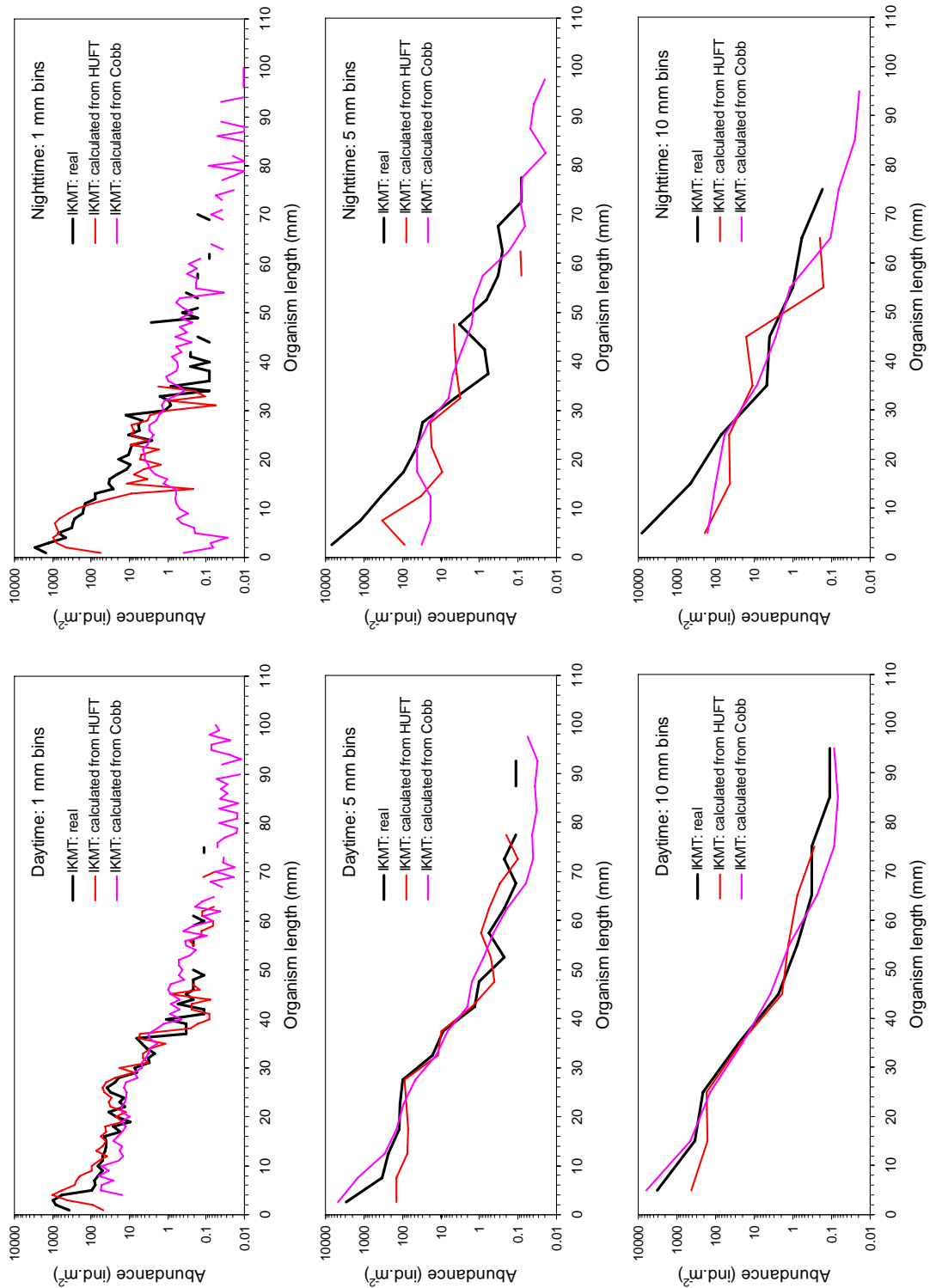
Fig. 2.17   True and calculated total catch abundance in various size bins for the IKMT during the MIE-1 in October 2004 off Oahu Island, Hawaii.

2.1.5 MIE-1 Macroplankton/Micronekton Lessons

- The MIE-1 sampling design appeared to be robust for the purpose of inter-comparison between various sampling gears and could be applied in future experiments. It was noted, however, that if the macronekton and micronekton community is diverse, an adequate number of samples needs to be collected to yield sufficient data for proper statistical analyses of species and taxonomic groups.
- Due to high diversity (too many species, each at low individual density), it appeared to be impractical to inter-compare macroplankton and micronekton densities between different gears at the highest taxonomic levels (*e.g.*, species or genus). Nevertheless, it is possible to inter-compare densities of major taxonomic groups sampled by different gears. In the region off Hawaii, it was further shown that different size groups of the larger taxonomic group could be dominated by different taxa. For example, crustacean organisms < 20 mm were represented mostly by Euphausiacea and Stomatopoda, while specimens > 20 mm were composed largely of Decapoda. This makes the inter-calibration of the results between different gears more promising.
- The macroplankton/micronekton fraction accounted for < 20% and > 60% of total numbers in the HUFT/IKMT and Cobb trawl samples, respectively. Hence, individual sampling gears compared during the MIE-1 clearly sampled different size groups of plankton covering the size range from meso- to mega-plankton. The Cobb trawl, despite its lower catch densities overall, appeared to be the best micronektonic gear, consistently producing a higher species diversity as well as sampling the largest specimens of micronekton compared to both the HUFT and IKMT. The latter gears were fairly comparable, although the HUFT sampled more mesozooplankton and less large fish than the IKMT.
- Using size frequency density data of major micronekton taxonomic groups for inter-gear calibration appeared to be promising. The size bin method was found to be useful in obtaining reliable inter-calibration coefficients between the three gears investigated. The ratios between plankton densities in compared gears are size specific and the 10 mm size bin provided the best (within ±30%) density reconstruction runs between gears. It was only reliable for the catch size fraction > 20 mm.
- Although the between-gears ratio coefficients are size specific, it remains to be shown that they are similar/universal between the same gears in different geographical regions and micronekton compositions.

2.2   Acoustic Characterization of the Mesopelagic Community off the Leeward Coast of Oahu Island, Hawaii

R. Domokos, E.A. Pakhomov, A.V. Suntsov, M.P. Seki and J.J. Polovina

2.2.1   Methodology

Active acoustic data were collected on board the NOAA research ship *Oscar Elton Sette* between October 6 and 13, 2004, on the leeward coast of the island of Oahu, Hawaii (Fig. 2.1). The R/V *Sette* is equipped with a hull-mounted, dual-frequency, split-beam Simrad EK60 echosounder system, operating at 38 and 120 kHz frequencies. Both transducers have 7° beam angles and were set to operate at pulse lengths of 1,024 and 256 ms and transmit powers of 2.0 and 0.5 kW, respectively. The lowest signal threshold, measured as the mean volume backscattering strength, S_v, was set to –75 dB re 1 m^{-1} to exclude backscatter from zooplankton and/or other smaller organisms. These settings allowed for a depth range of >1,500 and 220 m for the 38 and 120 kHz channels, respectively, while maintaining an order of 10 signal-to-noise ratio (10 dB re 1 m^{-1}).

Data were recorded during all trawl operations (17 Cobb, 19 IKMT, and 20 HUFT trawls, each approximately 5 km in length), as well as during 10 crepuscular periods (5 during dawn and 5 during dusk). Crepuscular periods were avoided during trawls as most micronekton undergo diel vertical migration between the shallow scattering layer, SSL, and the deep scattering layer, DSL (*e.g.*, Fig. 2.3). Data collection for trawl operations started and ended approximately 3–4 km before the beginning and after the end of the trawls, resulting in 47 approximately 12-km long "Transects", not counting the 10 Transects recorded during crepuscular transition periods. Before processing the data, each echogram was visually inspected to ascertain that only high quality data would be used for analysis. For the purposes of estimating relative biomass, S_v were integrated over 50-m long by 5-m deep bins for each of the Transects (echograms). For visual scrutiny and for integration, Myriax Echoview® software was used. The integration of S_v resulted in mean nautical area scattering coefficients (NASC), in units of m^2 nmi^{-2} (nmi = nautical miles), which were then exported from Echoview® for further processing. Data only from the upper 1000 and 220 m for the 38 and 120 kHz frequencies were integrated. The resulting NASC were used as a proxy for biomass estimates, as they are proportional to biomass, assuming that the species composition of the scattering layers and the resulting scattering properties of micronekton do not change significantly (MacLennan and Simmonds, 1992). To obtain micronekton density estimates, NASC values from each Transect were normalized vertically to a unit depth, which was arbitrarily set to 100 m.

As the thresholded sonic scattering layers are composed mostly of micronekton undergoing diel migration, daytime and nighttime NASC had to be analyzed separately. Thus, both 38 and 120 kHz bioacoustic records were divided into daytime and nighttime components. Two 3-h windows, one from 05:00 to 08:00 h and another from 17:00 to 20:00 h were deemed sufficient to remove the effects of all crepuscular transition periods.

To compare the acoustic results with those from the net trawls, NASC were taken only for the time periods of the trawls and from a 30 m vertical window centering on the depth of the net, continuously monitored and recorded by a Netmind acoustic system. The extent of autocorrelation of the data was determined using variograms to obtain mean NASC values that are statistically independent from each other. The size of the statistically independent units, *i.e.*, Elementary Sampling Units (ESUs) were determined to be 30-m by 1-km bins in the vertical and horizontal dimensions, respectively. To compare biomass and density of the SSL and DSL during day and nighttime, or between trawls, NASC means from the 38 kHz frequency were calculated for each Transect using only one NASC value from each ESU. The NASC means from each ESU were then tested to ascertain that the assumed

normal distribution for the 95% statistical significance calculations holds. Since sound attenuates faster at higher frequencies, only the 38 kHz frequency could be used for these calculations, as the 120 kHz signals did not penetrate to the depth of the DSL. However, the availability of S_v at two frequencies in the upper 220 m allowed for some primitive scattering layer composition estimates of the SSL, as organisms scatter sound differently at lower and higher frequencies. To compare the relative composition of the SSL, the method of "dB differencing" was used, expressed as δS_v, and defined as 120 kHz S_v – 38 kHz S_v.

2.2.2   Acoustic Results

Acoustic data show that the SSL typically extends down to an average depth of 200 m (170–230 m), while the DSL is located between the depths of 450 and 750 m, less variable in depth range than the SSL. While the DSL is more of a permanent feature, the SSL is prominent only during nighttime (Fig. 2.3). The DSL consists of two prominent layers, day and nighttime, extending from 450–575 m and from 600–750 m depths. Both the SSL and the two prominent layers of the DSL are composed of several thin layers with different acoustic backscatter characteristics. Between the SSL and DSL, at 200–400 m depths, the water column is devoid of organisms except during the dawn and dusk transition times (Fig. 2.3). The scattering layers show evidence of relatively high spatial and/or temporal variability in their density and composition, evidenced by echograms that were recorded within a maximum of 0.5 nmi distance and within a 1-h window from each other.

Using the 38 kHz data from each Transect, daytime DSL was found to have the highest relative biomass (mean NASC: 871 ±73 m^2 nmi^{-2}), followed by nighttime SSL (mean: 722 ±67 m^2 nmi^{-2}), nighttime DSL (mean: 608 ±58 m^2 nmi^{-2}), and daytime SSL (mean: 119 ±17 m^2 nmi^{-2}), all significantly different at the 95% confidence level except the nighttime DSL and SSL values (see graphical representation of statistical significance in Figure 2.18a, indicated by the notches). However, the relative densities of the scattering layers showed a different pattern. Nighttime SSL showed the highest densities (mean: 301 ±21 m^2 nmi^{-2}), followed by daytime DSL (mean: 290 ±42 m^2 nmi^{-2}), although they were not significantly different from each other (Fig. 2.18b).

Nighttime DSL densities were significantly lower with a mean of 203 ±39 m^2 nmi^{-2} while daytime SSL showed the lowest densities at 50 ±6 m^2 nmi^{-2}.

The δS_v of the SSL typically changed from approximately 9 dB during daytime to –2 dB during nights, with 75% of the data points within the range of approximately ±6 dB (Fig. 2.19). Furthermore, nighttime δS_v showed differences between regions of "shallow" and "deep" topography, defined as bottom depths shallower or deeper than approximately 800 m. Regions with shallow topography tended to show lower δS_v values relative to those with deep topography.

Topography seems to affect not only the SSL but also the DSL. The DSL was observed to spread vertically at slopes of topographical features that are shallower than the top vertical extent of the DSL (Fig. 2.3). At topographical regions where the bottom topography was about up to 100–150 m deeper than the bottom of the DSL, the DSL was observed to be thicker and to extend deeper, reaching the bottom in those regions (Fig. 2.20). This feature was typically more prominent from about 15:00 to 06:00 h local time than at other times (Fig. 2.21).

Relative densities calculated for each trawl show significant differences from those calculated for each Transect (Figs. 2.18c and 2.22). Trawl region nighttime SSL densities were significantly higher than those for the DSL both during day and nighttime as well as those for the Transect nighttime SSL. The mean trawl regions nighttime SSL was 518 ±30 m^2 nmi^{-2}, while these values for the daytime and nighttime DSL were 269 ±24 and 176 m^2 nmi^{-2}, respectively. Statistical significance of the difference between daytime and nighttime trawl-region DSL could not be confirmed due to the low number of trawls conducted in the DSL during the night (5 total: 3 Cobb, 1 IKMT and 1 HUFT).

To compare the acoustic micronekton composition results to the net trawl samples, δS_v values were estimated for the nighttime SSL and daytime DSL based on the trawl sample results. From previous dB differencing studies, in combination with the observed species present in the trawl samples and their sizes, the expected δS_v values for the organisms that were observed in significant numbers were as follows: 5 to 15 dB for Euphausiacea, 8 to 15 dB for Mysidacea, Decapoda, and Stomatopoda, –5 to –1 dB for Oegopsida, 5 to 10 dB for Tunicata, and –3 to

0.5 dB for Myctophidae and other fish (Simmonds and MacLennan, 2005). Based on the percent composition of organisms in the nighttime SSL and daytime DSL in the three different types of nets, we would expect δS_v values < 0 and > 0 for the nighttime SSL and daytime DSL Cobb trawl samples (mostly Myctophidae and mostly Euphausiacea for nighttime and daytime, respectively) and > 0 and $\gg 0$ for the nighttime SSL and daytime DSL IKMT and HUFT samples, with the Hokkaido δS_v values somewhat lower than those of the IKMT net. Since the acoustic data showed < 0 δS_v for nighttime SSL, it suggests that the Cobb trawl micronekton composition results match those of the acoustics the best.

Relative densities of nighttime SSL and daytime DSL from only the Cobb trawl samples were consistent with those of the scattering layers, although there was no statistical significance between nighttime SSL and daytime DSL in the acoustic data. Calculating the relative densities for the trawls showed more consistency between the acoustics and Cobb trawl results for these values, as the densities of nighttime SSL become significantly higher than those of daytime DSL (Fig. 2.18 b, c). On the other hand, relative nighttime DSL densities were the highest in the Cobb trawl samples, while those values were the lowest calculated from the acoustics data, both for each Transect and trawl region only, not counting the daytime SSL. Calculating the nighttime DSL densities for the trawl areas – as opposed to the entire nighttime DSL – reduced the nighttime DSL densities, increasing the inconsistency with those of the Cobb trawl results. Interestingly, relative densities from the IKMT and HUFT for nighttime SSL and daytime DSL trawls were more consistent with those of acoustic relative biomasses, not densities, as both IKMT and HUFT results show nighttime SSL densities that are lower than those of the daytime DSL.
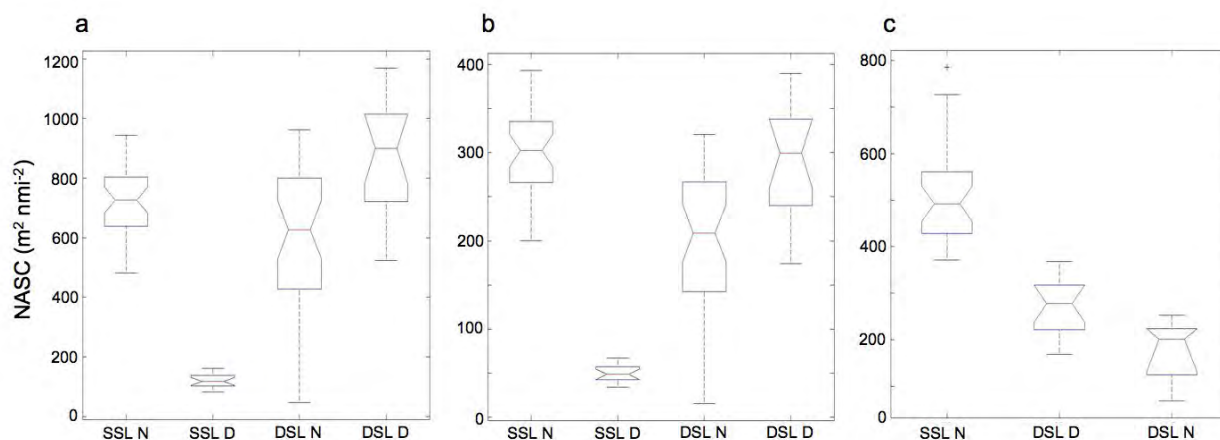
Fig. 2.18   Boxplots of (a) the relative biomass of scattering layers, (b) the relative density of scattering layers, and (c) the relative density of trawl regions. Horizontal lines represent the first, second (median, in red), and third quartiles, with notches showing strong evidence that the medians differ with 95% confidence level. N and D stand for daytime and nighttime, respectively.
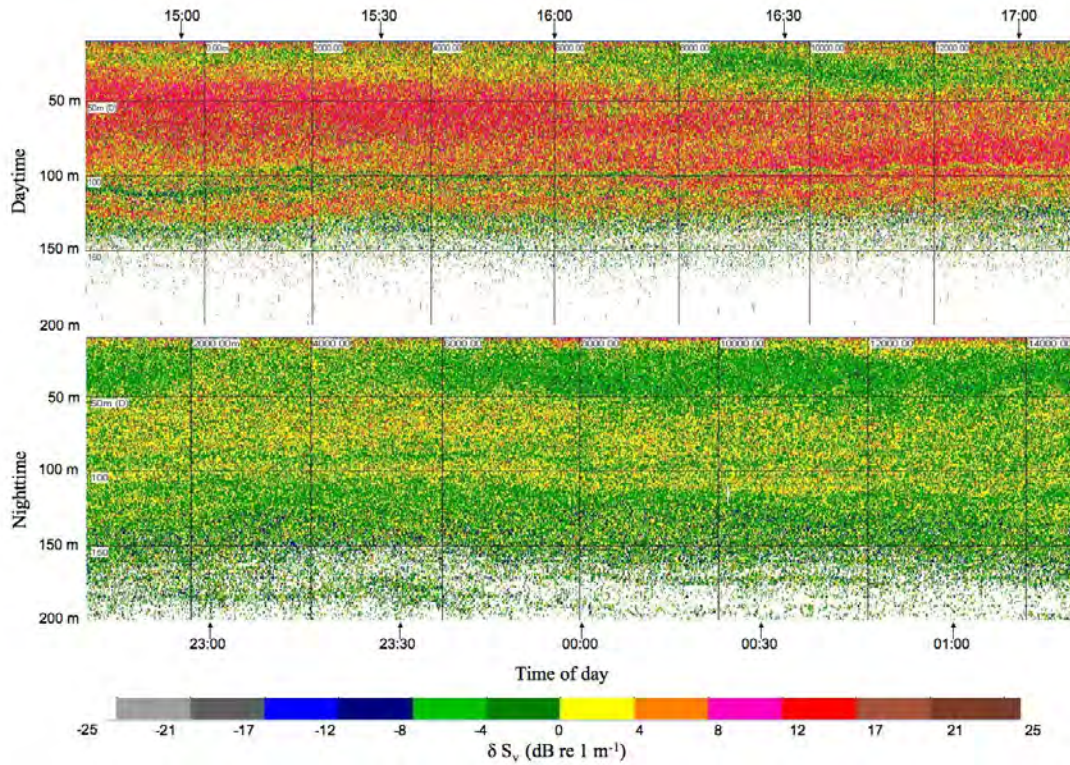
Fig. 2.19   Example of typical δSᵥ values during daytime (upper panel) and nighttime (lower panel).
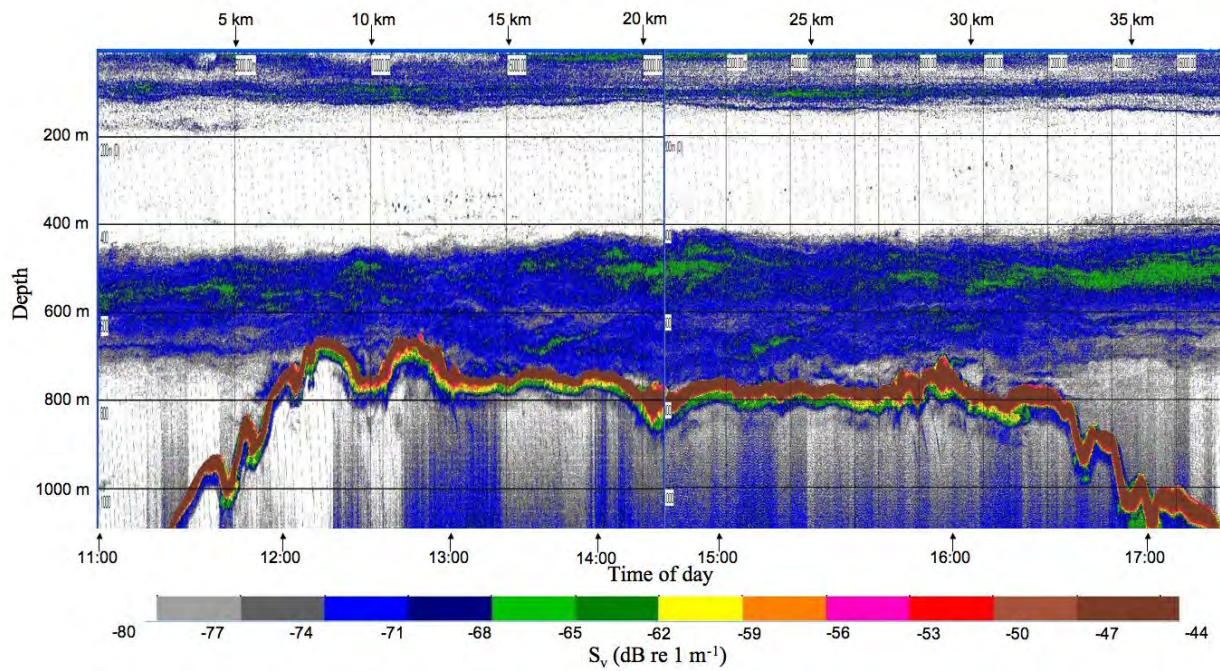
Fig. 2.20   Example illustrating the effects of topography on the deep scattering layer (DSL). Note that the DSL extends deeper in regions with bottom depth less than 800 m than in regions that are deeper.
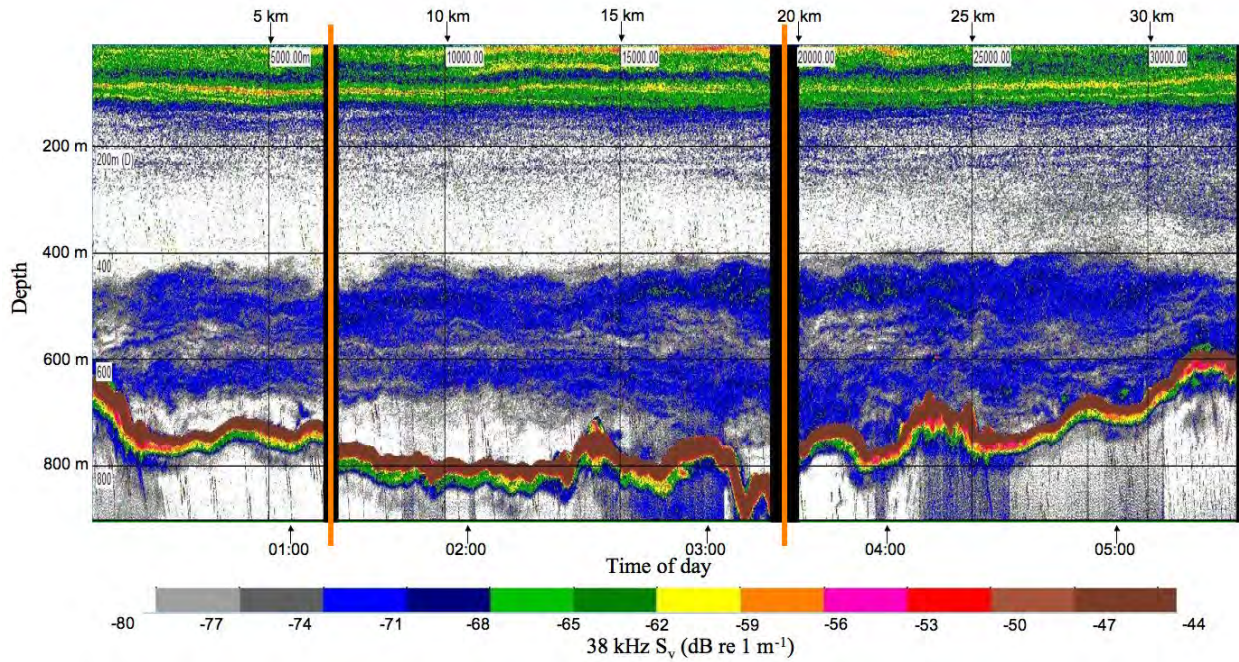
Fig. 2.21   Nighttime echogram recorded passing over the same area three times, each pass separated by the orange vertical lines. The three tracks did not deviate from each other more than ¼ nmi. Note the extension of the DSL to deeper depths after 03:00 h local time and the beginning of the vertical migration from the shallow scattering layer (SSL) from around 05:00 h.
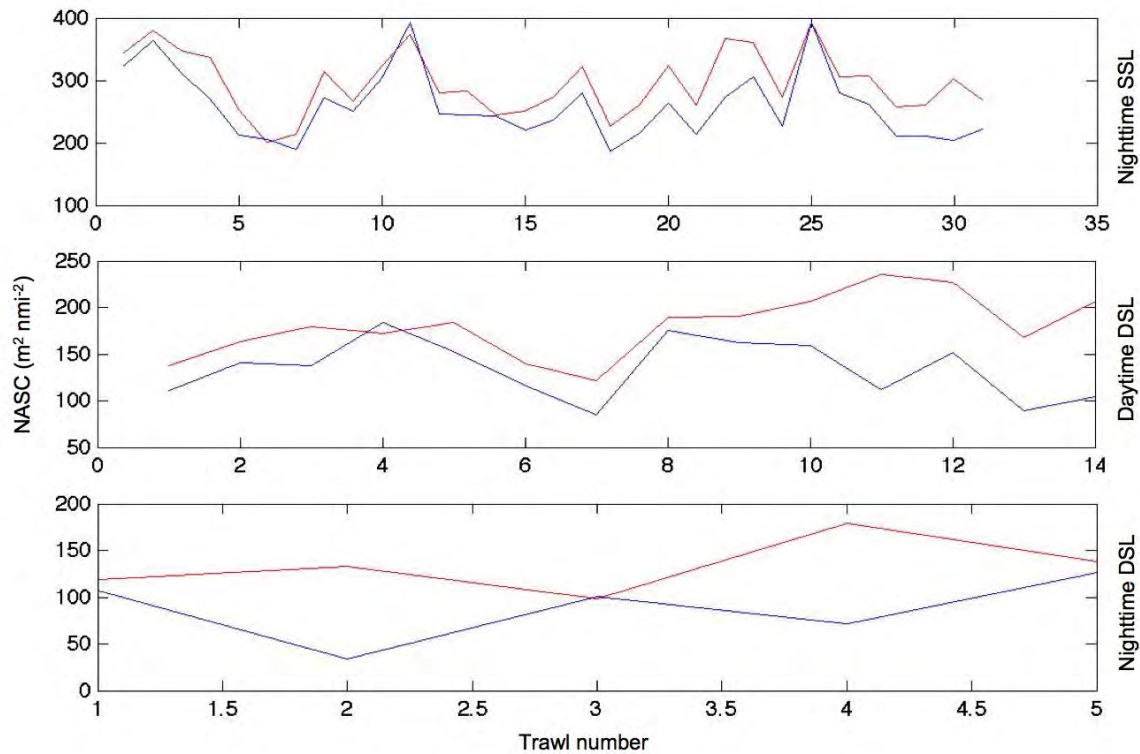
Fig. 2.22   Scattering layer (red) and trawl region (blue) micronekton densities for each trawl in the SSL during nighttime (top), in the DSL during daytime (middle), and in the DSL during nighttime (bottom). All densities are nautical area scattering coefficient (NASC) values normalized to 30 m in vertical extent.

2.2.3   Main Findings

The results of this study provide some basic information on the characteristics of the scattering layers off the leeward coast of Oahu, Hawaii. The DSL is more of a permanent feature with densities comparable to the nighttime SSL during daytime. However, the vertical extent of the SSL is ⅔ of that of the DSL (300 m *vs*. 200 m depth), suggesting that the daytime DSL contains significantly higher biomasses than those of the nighttime SSL. On the other hand, nighttime SSL densities were significantly higher than those of the nighttime DSL, although this was not the case for biomass.

The fact that the DSL is more of a permanent feature than the SSL indicates that organisms were likely to be moving to or from deeper depths than the DSL during the dusk and dawn crepuscular periods. This hypothesis is also supported by the observation that the DSL, especially after 15:00 h, extended deeper in regions with 800–1000 m deep topographies than in areas with deeper depths, implying that organisms that start migrating down from the DSL at that time get trapped by the relatively shallow topography (Fig. 2.21). Differences in δS_v at shallow *versus* deep topographies during nighttime could also indicate that some organisms with stronger backscatter at the higher frequency might be migrating to the SSL from depths deeper than the DSL during nighttime.

However, differences in daytime and nighttime δS_v in the SSL indicate that most migratory organisms scattered more strongly at the 38 kHz frequency than at the 120 kHz (Fig. 2.19). The generally lower nighttime δS_v values, with a mean of –2 dB, indicated that organisms with $\delta S_v < 0$, such as small fish with gas bladders, gelatinous organisms with gas inclusions, and possibly squid (*e.g.,* Goss *et al.*, 1998, 2001; SIMFAMI, 2005; Simmonds and MacLennan, 2005) made up the majority of migratory organisms. As opposed to nighttime, daytime δS_v values with a mean of 9 dB indicate that the daytime SSL was composed mostly of crustaceans, gelatinous organisms without gas inclusions, and possibly fish without gas bladders (*e.g.*, Ressler *et al.*, 2004; Simmonds and MacLennan, 2005).

While the Cobb trawl samples matched the acoustic results the best, there were still inconsistencies between the Cobb trawl samples and acoustics results. Differences between nighttime and daytime SSL δS_v indicate that most of the migratory organisms – based on the dominant organisms found in the trawl samples – were Mysidacea and possibly Oegopsida. This conclusion is inconsistent with any of the 3 trawl sample results, as the percentages of Mysidacea and Oegopsida were lower in the daytime DSL than in either the nighttime DLS or nighttime SSL. Furthermore, nighttime DSL samples showed lower percentages of Euphausiacea than daytime DSL, again contradicting the deduction from the acoustics results that most fish, and possibly many squid, migrated from the DSL to the SSL during the nighttime. These inconsistencies might be due to the possible migration of organisms to and from depths deeper than the DSL and/or the SSL.

It is interesting to note that the ratio of Myctophidae to Euphausiacea increased from the daytime DSL to the nighttime SSL consistently for each gear type. This increase could indicate that the acoustic relative biomass of the daytime DSL might show lower values relative to those obtained during nighttime, with more (less) Myctophidae (Euphausiacea) in the nighttime scattering layer, since Euphausiacea (Myctophidae) scatter lower (higher) at the 38 than at the 120 kHz frequency. This could introduce a low daytime DSL bias into the acoustic biomass and density estimates, with the result that the DSL daytime and nighttime values could possibly be closer to each other than indicated by the acoustic results.

Trawl samples in combination with acoustics can help in estimating the composition of scattering layers. While trawl sampling is a useful tool for obtaining information on the composition of scattering layers, all trawls are inherently biased and can be inaccurate, explaining most, if not all, of the inconsistencies between the acoustic and net trawl results. As evidenced by this study, the composition and biomass obtained by trawl sampling depends on the type of net used. Highly mobile micronekton such as fish and squid can easily evade the mouth opening of the net, especially nets with relatively smaller openings. Others that have fragile bodies, such as salps, disintegrate upon capture in the net, resulting in only small pieces of them remaining in the samples. As the trawl results indicate, the daytime DSL is dominated by Euphausiacea in all three gear types, although increasing from Cobb to HUFT to IKMT. On the other hand, the nighttime SSL is dominated by Myctophidae in the Cobb trawl

samples and their percentage decreases from Cobb to HUFT to IKMT. These results clearly indicate that the three different gear types sample some types of organisms better than others. It is not surprising that the Cobb trawl, with the largest mouth opening of approximately 140 m^2 when fishing, is better at catching micronekton while the smaller nets are most effective at catching the smaller organisms that tend to scatter sound more strongly at higher frequencies.

Inconsistencies between the acoustic and net trawl results also arise from the difficulty in reaching and/or maintaining trawl target depths with the nets, especially while sampling the DSL. This difficulty was encountered even though trawl depths were continuously monitored by the Netmind system. Of all the 14 daytime and 5 nighttime DSL trawl samples, 6 and 2 missed the DSL entirely, sampling either above it (*e.g.*, Fig. 2.23) or below. Sampling of the DSL at inappropriate depths is likely the reason for finding more inconsistencies between the Transect and trawl region DSL acoustic results than

between those of the nighttime SSL (Fig. 2.22) and, consequently, between the DSL acoustic and trawl sample density results than between those from the nighttime SSL.

It is important to note that even trawls that sampled at accurate depths only sampled a small thin layer of the DSL. As stated earlier, the DSL is composed of two prominent layers, each consisting of several smaller layers with different acoustic characteristics, indicating variability in either composition or density of micronekton, or both. Some micronekton were most likely missed entirely by the fact that the nets did not sample the thin layers they form within the scattering layers.   Others   form   small,   tight aggregations that are even more easily missed by the nets. For example, during two consecutive HUFT trawls   sampling   the   SSL   near   dawn,   tightly aggregated   micronekton   were   observed   in   the echograms at 100–150 m depths, with roughly 8 dB δS_v values, and were missed entirely by the nets (Fig. 2.24).
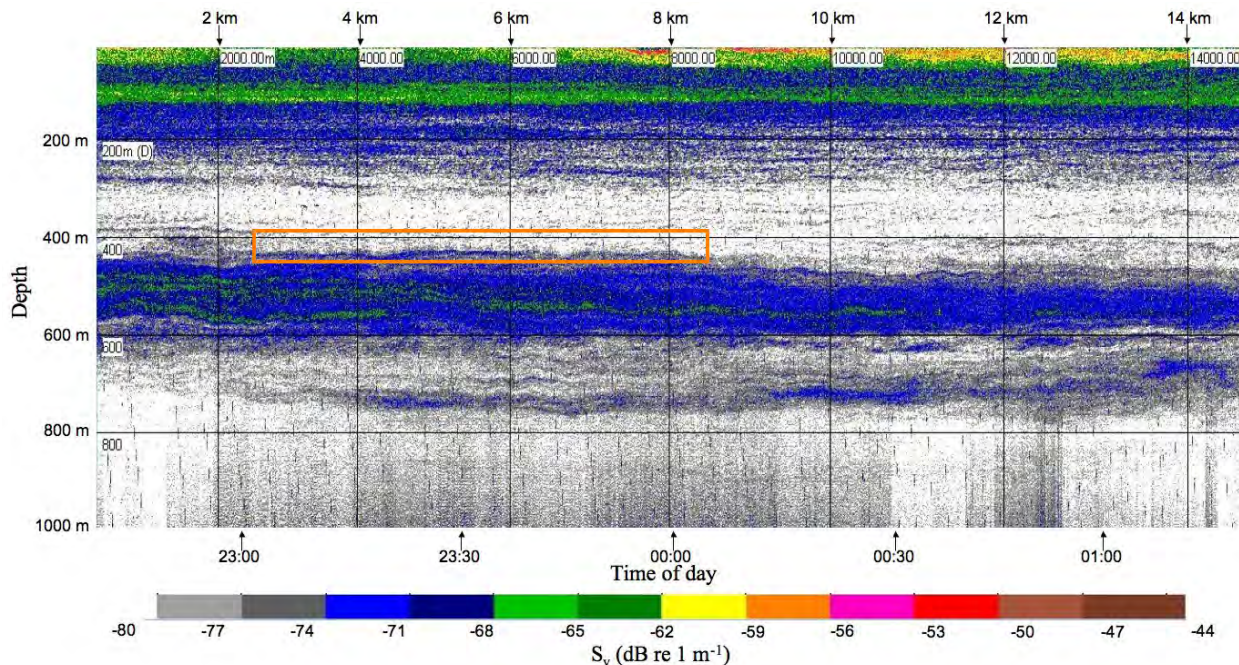
Fig. 2.23   Example illustrating the difficulties encountered to reach and maintain trawl target depths by the nets. The orange box shows the depth of the net for the hour of towing at a depth targeting the deep scattering layer (DSL).
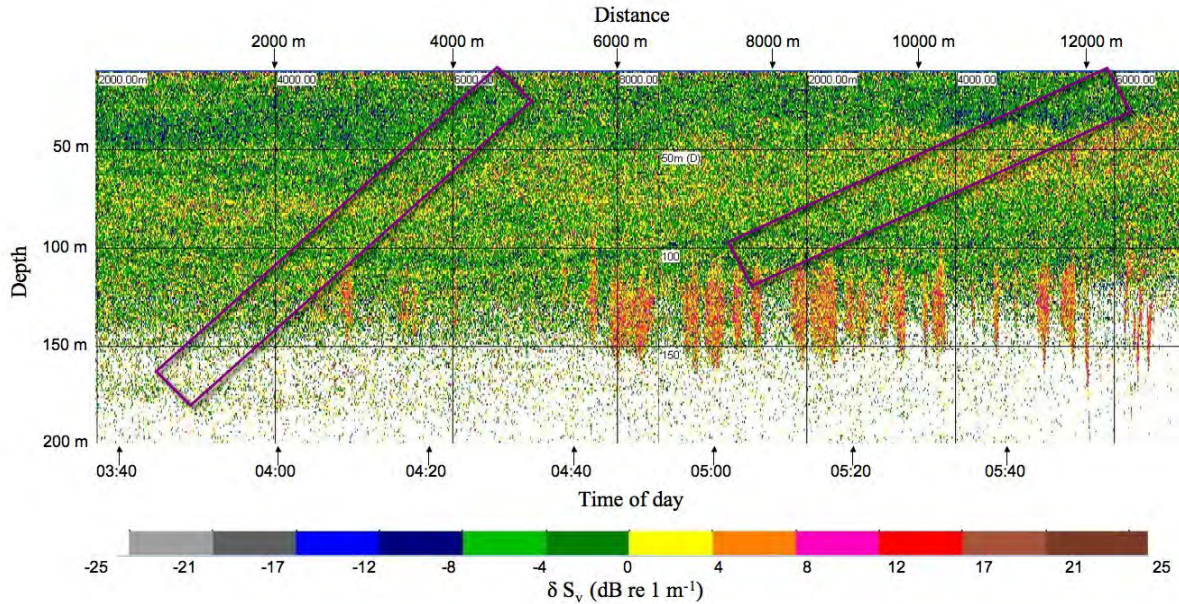
Fig. 2.24 Echogram showing δS_v values recorded during two HUFT trawls, shown by the purple boxes. Note that the tightly aggregated micronekton, with approximately 8 dB δS_v, are missed entirely by the nets.

As this study indicates, micronekton composition and density obtained from trawl data can be highly inaccurate as different types of nets preferentially sample different types of organisms while less efficiently sampling others. Since the acoustic data were targeted at micronekton, the highest consistency between acoustic and Cobb trawl data indicates that of the three nets used in this study, the Cobb trawl sampled micronekton the most effectively. While more efficient and accurate, acoustic data cannot be used without trawl samples to effectively estimate micronekton composition and biomass. Even though trawl samples cannot be used for these estimations, they are very useful for giving information on species compositions and their sizes,

which then can be incorporated into models developed by the Species Identification Methods From Acoustic Multifrequency Information (SIMFAMI) project (SIMFAMI, 2005) for effective micronekton composition estimations. These models are based on the different acoustic characteristics of various types of micronekton at different frequencies and provide more accurate estimates with increasing number of frequencies (Lebourges-Dhaussy and Ballé-Béganton, 2004). While the two frequencies used in this study are clearly not efficient, using 3 to 4 or more frequencies, with the combination of Cobb trawl samples, would enable effective and reliable estimation of micronekton composition and biomass.

2.3   Ichthyoplankton in the Vicinity of Oahu Island, Hawaii

A.V. Suntsov, E.A. Pakhomov, M.P. Seki, R.D. Brodeur, R. Domokos and L.G. Pakhomova

2.3.1   Composition and Abundance of Ichthyoplankton Collected during the MIE-1

Three types of gear used to collect oceanic micronekton during the MIE-1 simultaneously sampled the diverse tropical ichthyoplankton community present in the upper 500 m of the water column during both night and daytime tows. The total ichthyoplankton collection is represented by 5539 larval specimens from 17 orders, 75–78 families and 140–150 species (Table 2.3). Although the assessment and description of an extremely diverse ichthyoplankton assemblage in this area was not part of the original field plan, we use this complementary data to (1) document kinds and abundance of tropical ichthyoplankton in this area and (2) compare the performance of different gears for ichthyoplankton sampling.

Composition and abundance of ichthyoplankton in HUFT samples

Overall, 20 tows performed with the HUFT net yielded 2404 fish larvae (43% of total ichthyoplankton) from 59–60 families and 105–110 species. Almost 90% of larval fishes collected with this net came from the 13 nighttime tows, which showed much higher species diversity compared to daytime collections (95–100 *vs.* 60–65 species). Nighttime oblique HUFT tows were dominated by a common Hawaiian engraulid, *Encrasicholina punctifer*, which alone accounted for 48.6% of all larval specimens. Other numerically abundant species collected at night included *Ceratoscopelus townsendii* (7.5%), *Gempylus serpens* (3.3%), *Bolinichthys* spp. (2.8%), *Vinciguerria nimbaria* (2.8%), *Cubiceps pauciradiatus* (2.7%), *Cyclothone* spp. (2.4%) and *Lampanyctus* sp. (2.1%), with the remaining 83 taxonomic categories contributing to less than 30% of all larvae (Fig. 2.25). The composition of deep horizontal daytime tows was somewhat different largely due to the higher

numbers of larval hatchetfishes (*Sternoptyx* sp., *Argyropelecus* sp.) which are known to occur at deeper levels and thus were never collected during shallow oblique tows at night. Larval hatchetfishes comprised 15.1% of total larval abundance, with the majority formed by *Sternoptyx* spp., and equaling the abundance of *E. punctifer*. Other numerically dominant species included unidentified myctophids (9.6%), *Diaphus* sp. (8.8%), *G. serpens* (6.0%), *C. townsendii* (4.8%) and *Diplophos taenia* (2.8%) (Fig. 2.25). The most species-rich family in both night and daytime tows of the HUFT was the Myctophidae, represented by 14–16 species. Barracudina larvae (Fam. Paralepididae) also showed somewhat elevated species richness (5 species, nighttime tows), but the majority of families were represented by 1–2 species. In general, for both night and daytime tows, the most numerically abundant species were also the most frequently collected.

Composition and abundance of ichthyoplankton in IKMT samples

Nineteen tows with the IKMT yielded 2893 fish larvae (52% of total ichthyoplankton). The total species diversity was slightly lower compared to the HUFT collections, with 95–100 species from 51 families recorded and with nearly 97% of all specimens collected with 12 nighttime oblique tows. Similarly to the HUFT net, both night and daytime IKMT tows were dominated by *E. punctifer*, comprising 66.7% and 51.7% of all larval specimens collected during night and daytime, respectively. Other numerically abundant species collected at night were *Diaphus* spp. (3.6%), *Bolinichthys* spp. (2.4%), *Cyclothone* spp. (2.4%), and *V. nimbaria* (2.1%), with the remaining species contributing less than 18% of total larval abundance (Fig. 2.25). Although deep daytime tows with the IKMT did not collect as many hatchetfish larvae as was observed with the HUFT net, larval sternoptychids (*Sternoptyx* sp. and *Argyropelecus* sp.) still comprised significant numbers (6.9%), equaling larval *Diaphus* sp.

Lanternfish larvae (Fam. Myctophidae) were the most diverse in both nighttime (17–18 species) and daytime (8 species) collections, followed by larval paralepidids (6 species), gempylids (3 species) and muraenid leptocephalii (3 species).

Composition and abundance of ichthyoplankton in Cobb samples

The very large mesh size of the Cobb trawl is generally not appropriate for collecting larval fishes. Nevertheless, 241 larval specimens (4.3% of total ichthyoplankton) from 28–29 families and 50–55 species were found in samples obtained with this gear. Cobb samples primarily contained large postlarvae, with most specimens (91%) collected during nighttime. In addition to the numerically abundant *E. punctifer* (41%), the most frequently collected taxa were large bothid postlarvae (*Bothus* sp., *Engyprosopon* sp., 12.3% of total abundance), larval lizardfishes (Fam. Synodontidae, 7.7%) and a variety of large leptocephalii (Fam. Muraenidae, Ophichthyidae, 7.7%), present in nearly every tow (Fig. 2.25).
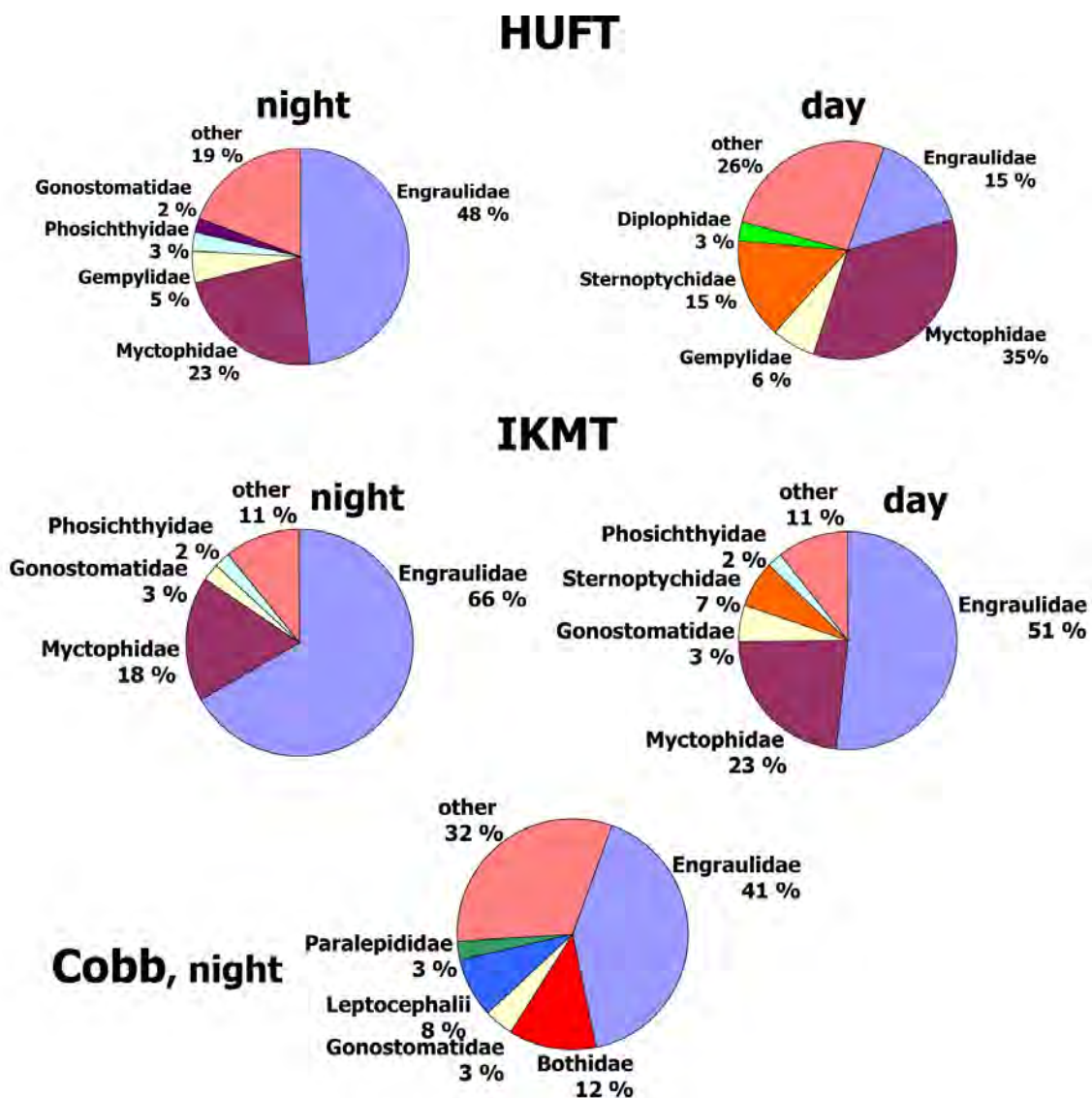
Fig. 2.25   Principal ichthyoplankton groups collected with three different nets during the MIE-1.

Table 2.3 Taxonomic composition and abundance of ichthyoplankton collected during the MIE-1.

Order	Family	Species	HUFT no.	IKMT no.	Cobb no.	Total no.	Frequency (%)	Total (%)
Anguilliformes	Muraenidae	*Uropterygius* sp.	3	–	–	3	3.6	0.1
		Gymnothorax spp.	1	–	4	5	5.5	0.1
		Muraenidae spp.	21	10	3	34	45.5	0.6
	Synaphobranchidae	*Dysomma* sp.	–	1	–	1	1.8	0.0
	Ophichthyidae	*Callechelys luteus*	1	–	–	1	1.8	0.0
		Gorgasia sp.	1	–	–	1	1.8	0.0
		Ophichthyidae spp.	1	–	1	2	3.6	0.0
	Congridae	Congridae spp.	1	–	–	1	1.8	0.0
	Nettastomatidae	*Saurenchelys* sp.	–	1	–	1	1.8	0.0
	Serrivomeridae	*Serrivomer sector*	14	4	1	19	20.0	0.3
	unidentified leptocephalii		12	3	14	29	38.2	0.5
Clupeiformes	Engraulidae	*Encrasicholina punctifer*	1082	1916	90	3088	74.5	55.8
Stomiiformes	Diplophidae	*Diplophos taenia*	19	4	2	25	29.1	0.5
	Gonostomatidae	*Cyclothone* spp.	57	71	1	129	45.5	2.3
		Maurolicine alba	1	–	–	1	1.8	0.0
		Sigmops elongatum	9	7	–	16	14.5	0.3
		Valenciennellus tripunctulatus	1	–	–	1	1.8	0.0
	Sternoptychidae	*Argyropelecus hemigymnus*	1	4	–	5	7.3	0.1
		Argyropelecus sp.	2	–	–	2	1.8	0.0
		Sternoptyx diaphana	2	–	–	2	1.8	0.0
		Sternoptyx sp.	32	4	–	36	12.7	0.6

Table 2.3 Continued.

Order	Family	Species	HUFT no.	IKMT no.	Cobb no.	Total no.	Frequency (%)	Total (%)
Stomiiformes	Phosichthyidae	*Vinciguerria nimbaria*	60	61	2	123	49.1	2.2
		Vinciguerria poweria	4	1	–	5	5.5	0.1
	Astronesthidae	*Astronesthes* spp.	3	2	–	5	9.1	0.1
	Idiacanthidae	*Idiacanthus fasciola*	1	2	–	3	5.5	0.1
	Melanostomiidae	*Eustomias* spp.	3	–	–	3	5.5	0.1
	Melanostomiidae	Melanostomiidae gen. sp.	–	1	–	1	1.8	0.0
	Stomiidae	*Macrostomias pacificus*	1	–	–	1	1.8	0.0
Aulopiformes	Synodontidae	*Synodus* spp.	1	–	15	16	10.9	0.3
		Trachinocephalus myops	1	–	2	3	5.5	0.1
	Notosudidae	*Ahliesaurus brevis*	2	–	–	2	3.6	0.0
		Scopelosaurus sp.	2	1	1	4	7.3	0.1
	Scopelarchidae	*Benthalbella infans*	–	1	–	1	1.8	0.0
		Scopelarchidae spp.	3	1	–	4	7.3	0.1
		Scopelarchus sp.	3	2	–	5	7.3	0.1
	Evermannellidae	*Evermannella indica*	1	3	–	4	7.3	0.1
	Paralepididae	*Lestidiops* sp.	7	11	–	18	10.9	0.3
		Lestrolepis intermedia	23	4	5	32	21.8	0.6
		Magnisudis atlantica	–	1	–	1	1.8	0.0
		Paralepididae spp.	5	7	1	13	16.4	0.2
		Sudia atrox	3	3	–	6	10.9	0.1
		Stemonosudis sp.	1	1	1	3	5.5	0.1
		Uncisudis sp.	1	–	–	1	1.8	0.0
	Giganturidae	*Gigantura indica*	–	3	–	3	3.6	0.1
Myctophiformes	Myctophidae	*Bolinichthys* spp.	65	71	–	136	61.8	2.5
		Ceratoscopelus townsendii	170	25	1	196	43.6	3.5
		Diaphus mollis	31	25	–	56	36.4	1.0
		Diaphus problematicus	25	17	–	42	29.1	0.8
		Diaphus spp.	50	108	–	158	90.9	2.9
		Diogenichthys laternatus	–	1	–	1	1.8	0.0

Table 2.3 Continued.

Order	Family	Species	HUFT no.	IKMT no.	Cobb no.	Total no.	Frequency (%)	Total (%)
Myctophiformes	Myctophidae	*Hygophum proximum*	23	46	–	69	38.2	1.2
		Hygophum reinhardti	5	7	–	12	16.4	0.2
		Lampadena luminosa	25	6	–	31	21.8	0.6
		Lampadena urophaus	2	–	–	2	1.8	0.0
		Lampadena sp.	1	4	–	5	7.3	0.1
		Lampanyctus spp.	49	20	–	69	58.2	1.2
		Myctophum nitidulum	1	–	–	1	1.8	0.0
		Myctophum punctatum	–	1	–	1	1.8	0.0
		Myctophum sp.	5	6	–	11	16.4	0.2
		Notolychnus valdivae	–	1	–	1	1.8	0.0
		Symbolophorus evermani	42	38	2	82	41.8	1.5
		Triphoturus nigrescens	11	5	–	16	29.1	0.3
		Taaningichthys sp.	–	1	–	1	1.8	0.0
		unidentified	56	146	–	202	50.9	3.6
Lampridiformes	Lampridae	*Lampris* sp.	1	–	–	1	1.8	0.0
	Radiicephalidae	*Radiicephalus elongatus*	–	1	–	1	1.8	0.0
Gadiformes	Bregmacerotidae	*Bregmaceros japonicum*	3	6	–	9	12.7	0.2
		Bregmaceros spp.	–	10	–	10	9.1	0.2
Ophidiiformes	Carapidae	*Carapidae* spp.	–	2	–	2	3.6	0.0
	Ophidiidae	*Acanthonus armatus*	1	–	–	1	1.8	0.0
		Brotulotaenia nielseni	1	–	–	1	1.8	0.0
		Ophidiidae spp.	1	–	–	1	1.8	0.0
Lophiiformes	Antennariidae	*Antennarius* sp.	1	–	–	1	1.8	0.0
	Melanocetidae	*Melanocetus* sp.	3	1	–	4	7.3	0.1
	Oneirodidae	*Microlophichthys microlophus*	1	–	–	1	1.8	0.0
	Ceratiidae	*Cryptopsaras couesii*	2	1	–	3	5.5	0.1
	Gigantactiniidae	*Gigantactis* sp.	1	–	–	1	1.8	0.0

Table 2.3 Continued.

Order	Family	Species	HUFT no.	IKMT no.	Cobb no.	Total no.	Frequency (%)	Total (%)
Beloniformes	Oxyporhamphidae	*Oxyporhamphus micropterus*	1	1	2	4	7.3	0.1
Stephanoberyciformes	Melamphaeidae	*Melamphaes* spp.	–	2	–	2	1.8	0.0
Zeiformes	Zeniontidae	*Zenion hololepis*	1	1	–	2	1.8	0.0
Gasterosteiformes	Fistulariidae	*Fistularia* sp.	–	–	2	2	3.6	0.0
Scorpaeniformes	Dactylopteridae	*Dactylopterus orientalis*	–	–	1	1	1.8	0.0
	Scorpaenidae	Scorpaenidae spp.	3	7	3	13	20.0	0.2
		Scorpaenodes sp.	–	2	–	2	3.6	0.0
Perciformes	Percichthyidae	*Howella* spp.	8	7	–	15	21.8	0.3
	Serranidae	Anthiinae sp.	3	1	2	6	7.3	0.1
		Plectranthias sp.	–	1	–	1	1.8	0.0
		Pseudogramma sp.	6	2	–	8	10.9	0.1
		Serranidae spp.	1	–	2	3	5.5	0.1
	Coryphaenidae	*Coryphaena hippurus*	14	–	–	14	14.5	0.3
		Coryphaena sp.	4	2	–	6	10.9	0.1
	Echeneidae	*Echeneis* sp.	–	–	1	1	1.8	0.0
		Phteirichthys lineatus	1	–	–	1	1.8	0.0
	Lutjanidae	Lutjanidae spp.	–	–	8	8	10.9	0.1
	Bramidae	*Brama* sp.	8	5	–	13	18.2	0.2
		Bramidae spp.	2	–	–	2	1.8	0.0
	Caristiidae	*Caristius macropus*	1	–	–	1	1.8	0.0
	Mullidae	Mullidae spp.	–	1	–	1	1.8	0.0
	Cirrhitidae	*cf.* Cirrhitidae	2	3	–	5	9.1	0.1
	Pomacanthidae	*Pomacanthus* sp.	–	–	3	3	5.5	0.1
	Chiasmodontidae	*Chiasmodon* sp.	4	3	–	7	9.1	0.1
		Kali sp.	3	–	–	3	5.5	0.1
		Pseudoscopelus sp.	28	3	–	31	23.6	0.6
	Pomacentridae	Pomacentridae spp.	1	–	–	1	1.8	0.0
	Labridae	Labridae spp.	12	17	2	31	36.4	0.6

Table 2.3 Concluded.

Order	Family	Species	HUFT no.	IKMT no.	Cobb no.	Total no.	Frequency (%)	Total (%)
	Scaridae	Scaridae spp.	2	–	1	3	5.5	0.1
	Pinguipedidae	*Parapercis* spp.	31	23	–	54	47.3	1.0
	Percophidae	Percophidae spp.	1	–	–	1	1.8	0.0
	Ammodytidae	*Ammodytoides pylei*	4	1	–	5	5.5	0.1
	Blenniidae	Blenniidae spp.	–	–	1	1	1.8	0.0
	Callyonimidae	Callyonimidae spp.	13	18	–	31	38.2	0.6
	Gobiidae	Gobiidae spp.	1	3	–	4	7.3	0.1
	Ptereleotridae	*Parioglossus* sp.	1	5	–	6	10.9	0.1
		Ptereleotris sp.	3	–	1	4	3.6	0.1
	Acanthuridae	Acanthuridae spp.	–	–	6	6	9.1	0.1
	Scombolabracidae	*Scombrolabrax heterolepis*	15	2	–	17	7.3	0.3
	Gempylidae	*Diplospinus multistriatus*	–	2	–	2	3.6	0.0
		Gempylus serpens	84	36	9	129	54.5	2.3
		Lepidocybium flavobrunneum	9	–	–	9	10.9	0.2
		Nesiarchus nasutus	20	5	–	25	23.6	0.5
	Scombridae	*Katsuwonus pelamis*	19	3	2	24	21.8	0.4
		Scombridae spp.	5	9	4	18	16.4	0.3
	Istiophoridae	*Makaira* sp.	5	3	–	8	9.1	0.1
	Nomeidae	*Cubiceps pauciradiatus*	63	19	3	85	38.2	1.5
		Cubiceps sp.	–	1	–	1	1.8	0.0
		Psenes cyanophrys	–	–	1	1	1.8	0.0
		unidentified	–	–	1	1	1.8	0.0
Pleuronectiformes	Bothidae	*Bothus pantherinus*	6	2	6	14	23.6	0.3
		Bothus sp.	–	–	10	10	7.3	0.2
	Samaridae	*Engyprosopon* sp.	32	29	18	79	54.5	1.4
		Samariscus sp.	–	–	3	3	3.6	0.1
	Soleidae	*Asserragoges* sp.	–	1	–	1	1.8	0.0
	Cynoglossidae	Cynoglossidae spp.	–	1	–	1	1.8	0.0
Tetraodontiformes	Tetraodontidae	cf. *Sphoeroides* sp.	–	1	–	1	1.8	0.0
		unidentified larvae	6	3	12	21	27.3	0.4

2.3.2 Comparison of Diversity and Abundance between Different Net Types

Ichthyoplankton sampling efficiency was significantly higher for the IKMT net (77.9 ±38.1 ind. m^{-2}) during the nighttime compared to the HUFT net (41.3 ±27.7 ind. m^{-2}). However, during the daytime these two gears showed the opposite trend, with the HUFT catching more larvae, although numbers were an order of magnitude lower for both nets compared to the nighttime abundance (Fig. 2.26a). Nighttime sampling with the HUFT and IKMT showed similar variations in species richness although the number of species collected with each IKMT tow was less variable. However, significantly more species were collected with each HUFT net during daytime (16.5 ±8.3 ind. m^{-2}), compared to the IKMT (7 ±2.5 ind. m^{-2}), whereas Cobb samples consistently contained fewer species compared to the two smaller nets (Fig. 2.26b). Shannon-Weaver diversity, as well as evenness, were significantly higher for the HUFT in both night and daytime collections compared to the IKMT net (Fig. 2.26c, d).

2.3.3 Similarity of Ichthyoplankton Assemblages Sampled by Different Nets

We assessed the overall similarity of the ichthyoplankton assemblages sampled with the three different nets using multivariate analyses, including hierarchical agglomerative cluster analysis and non-metric multi-dimensional scaling (MDS). The resulting groups were examined with a similarity percentage (SIMPER) procedure to identify within-group sample similarity and the species most responsible for group identity. As seen from the cluster dendrogram (Fig. 2.27), the compositions of both night and daytime Cobb samples (group III) were markedly distinct from both the HUFT and IKMT nets. In another large group, composed of all HUFT and IKMT samples, most of the samples
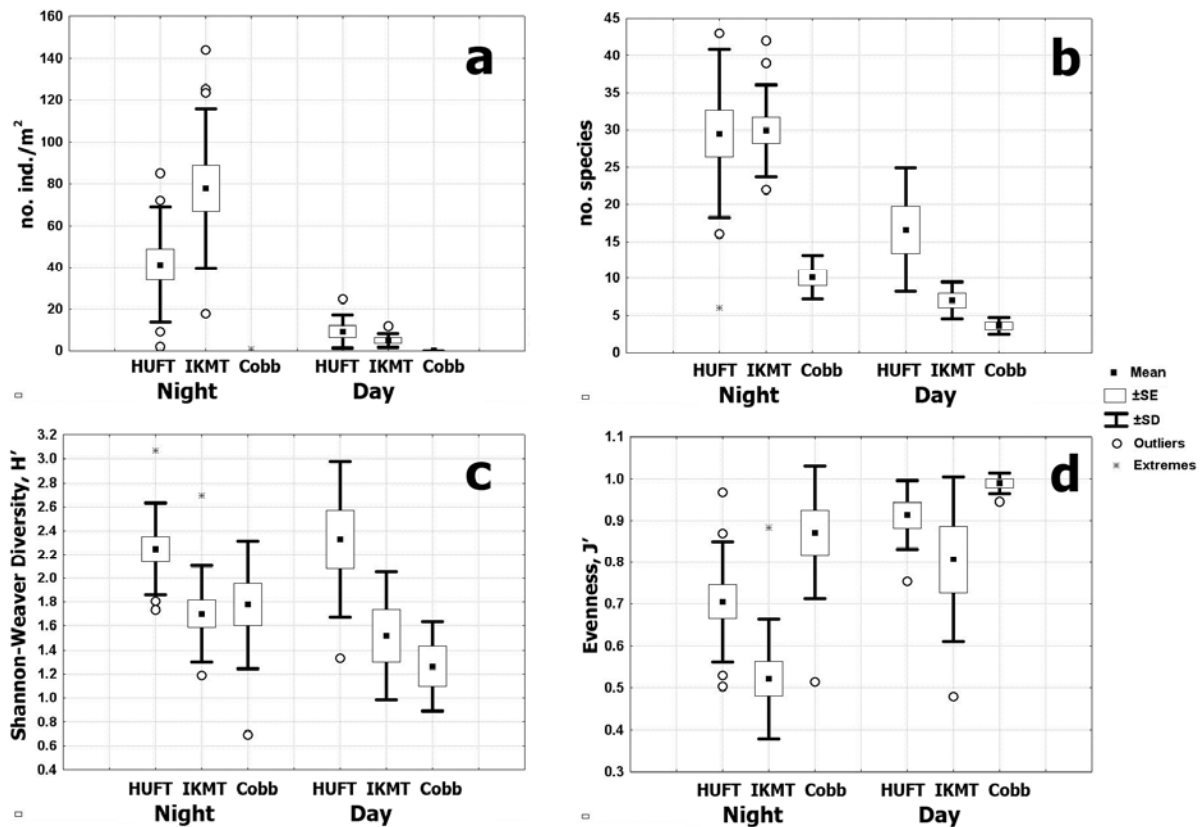
Fig. 2.26 Comparison of total ichthyoplankton densities (a), number of species (b), Shannon-Weaver diversity (c) and evenness (d) between different nets during the MIE-1.

collected at night (group I) were quite distinct in their composition from daytime deep tows (group II). The classification did not show any particular distinction between the HUFT and IKMT tows, both mixed in their respective clusters (deep and shallow tows). SIMPER analysis indicated that Cobb samples were dominated by unidentified leptocephalii, snapper larvae (Fam. Lutjanidae), larval bothids (*Engyprosopon* sp., *Bothus* sp.), *E. punctifer* and lizardfish larvae, which accounted for almost 80% of the average similarity within this group. Top taxa in the group containing shallow nighttime samples taken with the IKMT and HUFT included *E. punctifer*, *Diaphus* spp., *G. serpens*, *V. nimbaria*, and unidentified myctophid larvae, which made up

50% of the total similarity within this group. The group of daytime deep HUFT and IKMT samples was mainly characterized by just 5 taxa – *E. punctifer*, *Diaphus* spp., unidentified myctophids, *Bolinichthys* sp. and *Sternoptyx* sp., which accounted for 92% of the total similarity between the samples of this group. A multi-dimensional scaling plot shows similar groups, with the HUFT and IKMT samples being distinct from Cobb samples along the first, most important ordination axis (Fig. 2.28). Nighttime IKMT and HUFT samples show similar scores on both axes, and daytime tows for both of these nets are primarily separated along the second ordination axis.
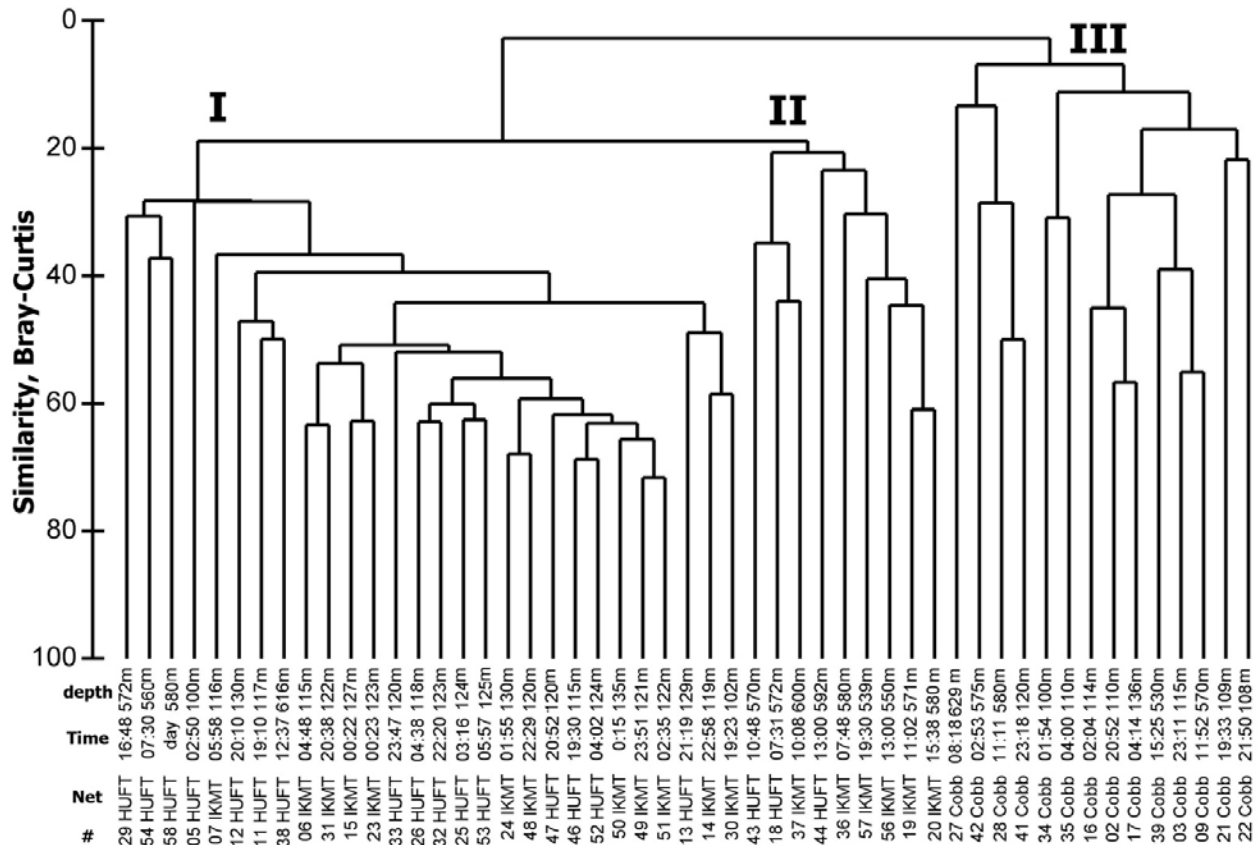
Fig. 2.27   Dendrogram of cluster analysis for samples collected with different nets during the MIE-1. Roman letters designate groups discussed in text. Tows 4, 10 and 45 are excluded as potential outliers.
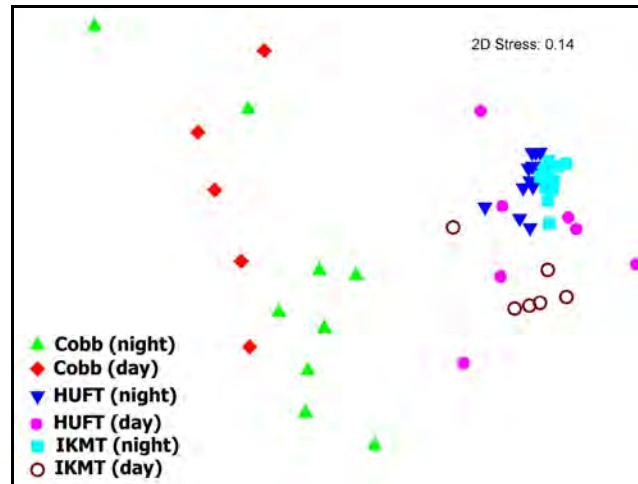
Fig. 2.28 Non-metric multi-dimensional scaling plot for samples collected with different nets during the MIE-1.

2.3.4 Summary

- Inter-comparison of the three types of gear used in the MIE-1 for collection of ichthyoplankton is essentially limited to the HUFT and IKMT because the large mesh size of the Cobb trawl is not designed to retain fish larvae, and its catches were limited to large-sized postlarvae and juveniles.
- Nighttime sampling efficiency of the IKMT was significantly higher than that of the HUFT in terms of larval abundance, but both nets caught a similar number of species.

- Daytime sampling efficiency of the HUFT was significantly higher than that of the IKMT in terms of overall larval abundance and species richness. These differences could probably be attributed to a lesser stability of the IKMT at deeper layers and greater variability in its mouth opening when towed at greater depths (as opposed to the rigid frame of the HUFT).
- Shallow oblique tows performed at night and deep horizontal daytime tows of the HUFT and IKMT sampled somewhat different ichthyo-plankton assemblages, described in two types of the multivariate analysis.

2.4 References

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3   Second Micronekton Inter-calibration Experiment, MIE-2

3.1   Macrozooplankton and Micronekton off Hokkaido Island, Japan: Composition and Gear Inter-calibration

O. Yamamura and H. Yasuma

3.1.1   Background of the MIE-2

The second micronekton inter-calibration experiment (MIE-2) was carried out in the coastal area off southeastern Hokkaido Island, Japan, during September 23–October 3, 2005. Comparative tows were made at four stations situated over the upper continental slope with bottom depths of approximately 500 m (Fig. 3.1). This area is strongly influenced by the coastal branch of the Oyashio Current (Kono *et al.*, 2004). The R/V *Hokko-Maru* of the Hokkaido National Fisheries Research

Institute (HNFRI; Fig. 3.2) was used as the sampling platform during the experiment. The participating team included: Orio Yamamura (HNFRI; lead scientist), Hiroya Sugisaki (Tohoku National Fisheries Research Institute), Kazuhiro Sadayasu (Hokkaido University (HU)), Shin-suke Abe (HU) and Ryu-ichi Matsukura (HU). Since the cruise overlapped with the PICES Fourteenth Annual Meeting held September 29–October 9, 2005 in Vladivostok, Russia, no scientists from countries other than Japan were able to participate in the cruise.
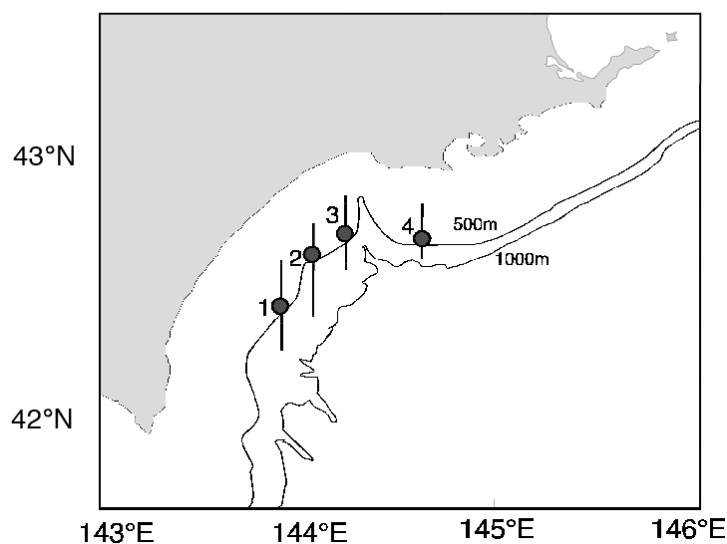
Fig. 3.1   Chart showing four stations of the MIE-2 occupied southeast of Hokkaido Island during September 25–October 3, 2005. Vertical lines show the track of the vessel along which backscattering of the echosounder was recorded.

Fig. 3.2   MIE-2 sampling platform: R/V *Hokko-Maru*.

Table 3.1   Summary of sampling gears tested during the MIE-2. Number of tows made during the MIE-2 is also shown.

	MOCNESS-1 (MOC-1)	MOCNESS-10 (MOC-10)	Framed Midwater Trawl (coarse) (FMT-C)	Framed Midwater Trawl (fine) (FMT-F)	Matsuda-Oozeki-Hu-Trawl (MOHT)	Otter Trawl (OT)
Mouth opening (m^2)	1.4	14	4	4	5	*ca.* 900
Mesh size (mm)	0.33	4	9	3	1.6	9*
Towing speed (kt)	1.6–2.1	1.3–2.0	1.6–3.0	1.0–3.0	3.0–5.0	2.6–3.0
Towing angle (deg)	42–55	41–47	N/A	N/A	8	–
# of tows (Day, Night)	4, 3	4, 4	3, 3	4, 4	4, 4	2.0

* Mesh size of the cod-end liner
N/A: not available

The sampling gears compared in the experiment were the MOCNESS-1 (MOC-1), MOCNESS-10 (MOC-10) (Wiebe *et al.*, 1985), Matsuda-Oozeki-Hu Trawl (MOHT) (Oozeki *et al.*, 2004), Hokkaido University Framed Midwater Trawl[1] (FMT) (Itaya *et al.*, 2001), and a midwater otter trawl (OT) with Multisampler (multiple cod-ends with acoustically operating opening/closing device, SIMRAD Inc.). In addition, the FMT was equipped with nets of two different mesh sizes (fine: 3 mm (FMT-F) and coarse: 9 mm (FMT-C)). Specifications and photographs of the sampling gears are shown in Table 3.1 and Figure 3.3. The samples collected by the MOCNESS-1 were used only for comparison of euphausiid catch efficiency.

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[1] Expressed as HUFT in previous sections.

Fig. 3.3 Sampling gears tested during the MIE-2. Upper left: MOCNESS-10, upper right: MOHT, lower left: FMT (= HUFT, with fine mesh net), lower right: otter trawl (OT) + Multisampler.

3.1.2 Sampling

At each of the four stations, every sampling gear was towed obliquely to a depth of 300 m, and then the nets were retrieved to the surface. The MOCNESS and OT with Multi-sampler sampled down to 400 m but only the samples taken in the top 300 m layer were used for the inter-comparison. The nets were towed during daytime and nighttime, with the exception of the OT, which was towed during daytime only. The sequence of sampling is presented in Figure 3.4. Net depth was monitored using SCANMAR net depth sensors attached to each net. It was impossible to attach a sensor to the MOHT, consequently a SBT data logger (Rigosha Co., Tokyo) was used to record the time–depth data of the MOHT. Net depth and wing distance sensors (SCANMAR Inc.) were attached to the OT to monitor the mouth opening of the net. At each station, the OT was deployed to a depth of approximately 400 m, and was then towed obliquely to a depth of 300 m with the #1 cod-end opened. After that, the OT was towed obliquely to the surface with the #2 cod-end opened. For the inter-comparison, only the sample collected by the #2 cod-end was used. Although it was planned to sample with the OT at four stations, it was towed only at three stations due to a winch malfunction. Furthermore, the sample taken at Station 4 was in too poor of a condition to be reliably identified, perhaps due to the prolonged sampling time due to the winch problems. Therefore, for inter-comparison only OT samples from Stations 1 and 2 were used. All tows were commenced at least 1 h after sunrise or before sunset to avoid sampling during twilight conditions. Hydrographic observations were carried out in the

entire water column at each station using an SBE-9 plus Conductivity Temperature Depth (CTD) sensor (Sea-Bird Electronics Inc.). Backscattering from the scattering layers was recorded using an EK60 echosounder (SIMRAD Inc.) with 38, 70, 120 and 200 kHz transducers.

3.1.3   Sample and Data Processing

Immediately after the nets were retrieved, micronekton, including fish, squids and shrimps, were picked out and fixed in a 10% formalin seawater solution. Then, after large jellyfish were removed, the total weight of the rest of the sample (zooplankton, mainly euphausiids) was weighed to the nearest 1 g. If the remaining sample exceeded 1 kg in mass, only a subsample of approximately 500 g was preserved in a 10% formalin seawater solution. In the laboratory, micronekton were identified, counted, measured and weighed to the nearest 1 mm and 0.1 g, respectively. From each tow, up to 150 *Diaphus theta* were randomly sampled and

Fig. 3.4   Schedule of sampling operations during the MIE-2. Note that the Hokkaido University Framed Midwater Trawl (FMT) was towed only one time each during daytime and nighttime on the second day. T-3 was cancelled due to a winch mulfunction.

measured to the nearest 0.01 mm using an electronic caliper. In addition, up to 100 individuals of *Euphausia pacifica* were randomly sampled from each sample, and their total lengths measured to the nearest 0.01 mm using an electronic caliper.

Species diversity of the catch of each net was assessed using Simpson's diversity index:

$$D = 1 - \sum_{i=1}^{s} p_i^2 \;,$$

where p_i is the fraction of the i-th species in the total biomass of samples collected by each net. This index ranges from 0 to 1, with 0 representing the least diverse community.

3.1.4 Catch Composition and Diversity

In total, 26,387 individuals and 26.97 kg of micronekton were collected during the MIE-2. Myctophid fishes were most important, contributing 72.9% and 88.5% to the total number and mass (hereafter %N and %W), respectively. Myctophids were followed by non-myctophid fishes (12.3%N and 4.2%W), crustaceans (decapods and mysids; 9.9%N and 2.0%W) and cephalopods (4.9%N and 5.2%W). Among the myctophids, *Diaphus theta* accounted for 59.6%N and 66.8%W.

Catch compositions by major taxonomic groups are shown for different fishing gears in Figure 3.5. By abundance, crustaceans were most important in the MOCNESS-10, whereas myctophids highly dominated (>90%) both the MOHT and OT catches. Myctophids were always more prominent gravimetrically with the exception of the MOCNESS-10 samples, where they contributed < 50% to total catch.

Overall, at least 8 families, 15 genera and 24 species of mesopelagic fish were collected during the MIE-2. Of these, myctophids, and gonostomatids were the most taxonomically diverse groups, represented by 10 and 6 species, respectively. Micronektonic crustaceans included decapods and mysids. While the former included 7 species, the latter was

represented by 2 species (*Gnatophausia zoea* and *Eucopia* sp.). Cephalopods were the least diverse group and were represented only by 5 species.

The Simpson's diversity indices showed small differences between the same sampling gears using both abundance and biomass (Fig. 3.6). One exception was the FMT with coarse mesh size (FMT-C), where *D. theta* gravimetrically dominated (76%) the catches, while accounting for only 38% numerically. The samples collected by the MOCNESS-10 showed the highest diversity, while the MOHT collections had the lowest.
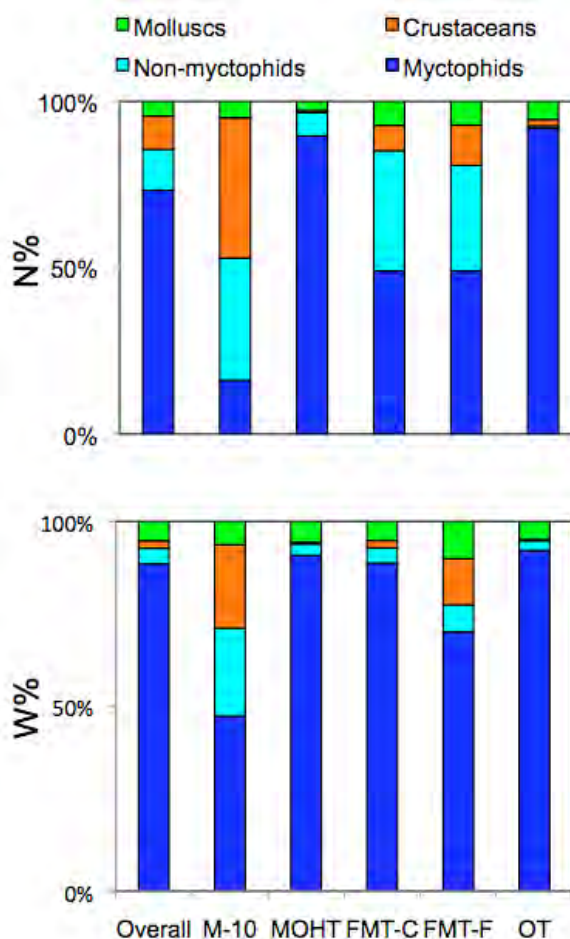
Fig. 3.5 Numerical (upper) and gravimetric (lower) composition of micronekton collected during the MIE-2 southeast of Hokkaido Island in September–October 2005.
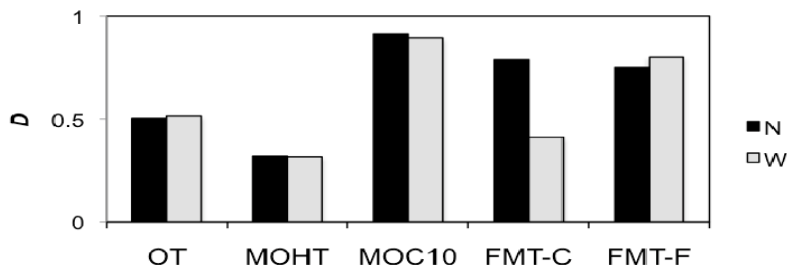
Fig. 3.6   Simpson's diversity index (D) of different sampling gear catches during the MIE-2, southeast of Hokkaido Island in September–October 2005, calculated on a numerical (N, abundance) and gravimetric (W, wet mass) basis. The index was calculated by summing up data from all sampling stations.
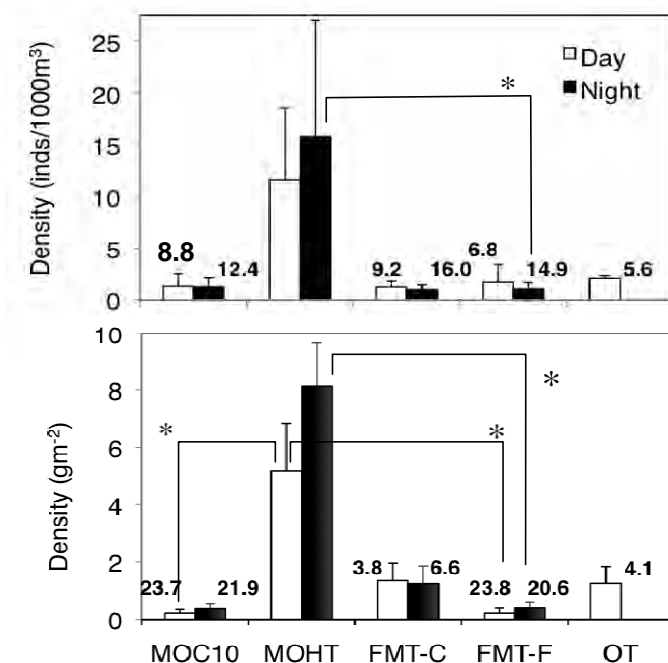
Fig. 3.7   Numerical (upper) and gravimetric (lower) density (±1 S.E.) estimated by different sampling gears used for *Diaphus theta* during the MIE-2, southeast of Hokkaido Island in September–October 2005. No nighttime sampling was made for the otter trawl (OT). Numbers above the bars indicate ratios to the value of the MOHT; *: $P < 0.05$ (See Tables 3.1–3.2 and 3.3–3.4).

3.1.5   Sampling Efficiency of Micronekton

Since *Diaphus theta* dominated the catch both by number and weight, sampling efficiencies of gears for fish were examined using this species only (Fig. 3.7, Table 3.2). Among the five gears tested, the MOHT showed extremely high sampling efficiency in terms of both abundance and biomass. On average, its efficiency was 6.6–12.2 times higher than the other gears by number, and 5.1–23.2 times by biomass.   For the calculation, day/nighttime differences were not considered since the number of tows and the differences by time of day were limited.

Generally, the higher ratio in the gravimetric comparison indicated that the MOHT caught larger fish than other nets. MOHT fine mesh net catches during nighttime showed statistically significant differences (Mann-Whitney's *U*-test; $P < 0.05$) in numerical density from the FMT catches. In comparison, the MOHT showed statistically significant higher values in 3 out of 5 pairs in both daytime and nighttime (Table 3.3).   The nets other than the MOHT showed rather smaller differences between each other (Fig. 3.8) with no significant differences in density estimates among the nets (Tables 3.3 and 3.4).
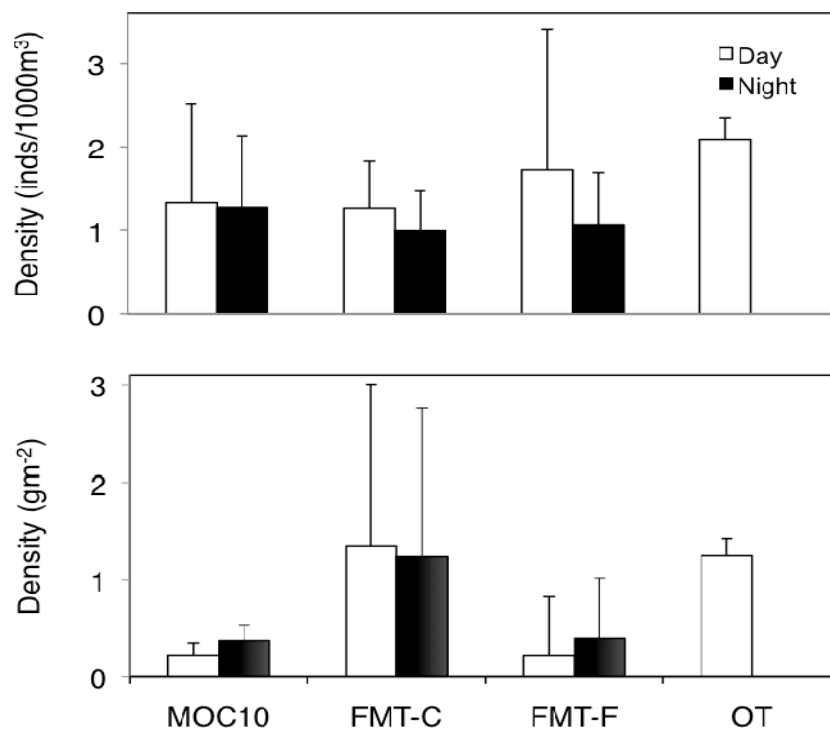
Fig. 3.8 Numerical (upper) and gravimetric (lower) density (±1 S.E.) estimated by different sampling gears used for *Diaphus theta* during the MIE-2, southeast of Hokkaido Island in September–October 2005. Data for the MOHT were excluded for detailed viewing.

Table 3.2 Numerical and gravimetric density estimates by different sampling gears used for *Diaphus theta* during the MIE-2.

	Density in number (N/1000m³)					Density in weight (wwt g/m²)				
	MOC-10	**MOHT**	**FMT-C**	**FMT-F**	**OT**	**MOC-10**	**MOHT**	**FMT-C**	**FMT-F**	**OT**
1D	5.5	32.0	n.d.	6.8	n.d.	0.5	2.9	n.d.	0.7	n.d.
2D	0.4	9.5	0.2	0	1.8	0.4	10.1	0.2	0	0.7
3D	0	3.1	1.4	0.1	2.3	0	3.7	1.5	0.1	1.8
4D	0	2.0	2.2	0.1	n.d.	0	4.0	2.3	0.1	n.d.
1N	4.2	48.9	n.d.	2.9	n.d.	0.3	9.5	n.d.	0.1	n.d.
2N	0.3	10.0	1.3	0.6	n.d.	0.0	10.8	1.5	0.7	n.d.
3N	0.8	3.7	1.6	0.7	n.d.	0.8	3.8	2.2	0.7	n.d.
4N	0.2	0.8	0.1	0	n.d.	0.3	8.3	0.1	0	n.d.
Average	1.4	13.7	1.1	1.4	2.1	0.3	6.7	1.3	0.3	1.3

n.d.: no data.

Table 3.3   Comparison of catch efficiency of different fishing gears for gravimetric densities of *Diaphus theta* in daytime (upper) and nighttime (lower) during the MIE-2.

Day

	MOC	MOHT	FMT-C	FMT-F	OT
MOC		*	NS	NS	NS
MOHT	0.03		NS	*	NS
FMT-C	0.21	0.11		NS	NS
FMT-F	0.88	0.03	0.11		NS
OT	0.10	0.13	1.00	0.27	

Night

	MOC	MOHT	FMT-C	FMT-F
MOC		NS	NS	NS
MOHT	0.06		NS	*
FMT-C	0.63	0.23		NS
FMT-F	0.89	0.03	0.40	

P-values in Mann-Whitney's *U*-test are shown in lower triangle; *: *P* < 0.05.

Table 3.4   Comparison of catch efficiency of different fishing gears for numerical densities of *Diaphus theta* in daytime (upper) and nighttime (lower) during the MIE-2.

Day

	MOC	MOHT	FMT-C	FMT-F	OT
MOC		NS	NS	NS	NS
MOHT	0.11		NS	NS	NS
FMT-C	0.59	0.11		NS	NS
FMT-F	0.88	0.11	0.40		NS
OT	0.48	0.27	0.40	0.53	

Night

	MOC	MOHT	FMT-C	FMT-F
MOC		NS	NS	NS
MOHT	0.11		NS	*
FMT-C	1.00	0.11		NS
FMT-F	0.34	0.03	0.40	

P-values in Mann-Whitney's *U*-test are shown in lower triangle; NS: no significance; *: *P* < 0.05.

The linear relationships between catches of different sampling gears (the OT was excluded due to the small sample size) are shown in Figures 3.9 and 3.10. Using abundance data, three net pairs (MOHT/MOC-10; FMT-F/MOC-10 and FMT-F/MOHT) showed significant correlations (Fig. 3.9).   The poor correlations with FMT-C were likely due to the absence of this net sampling at Station 1, where numerous small-sized (< 25 mm) *D. theta* were caught by the other gears.   Therefore, the linear relationships presented in Figure 3.9 would be useful for small-sized (< 25 mm) micronekton.   When comparing gears using the gravimetric data (Fig. 3.10), none of gear pairs showed significant correlation, suggesting that no other sampling gear was comparable with the MOHT.
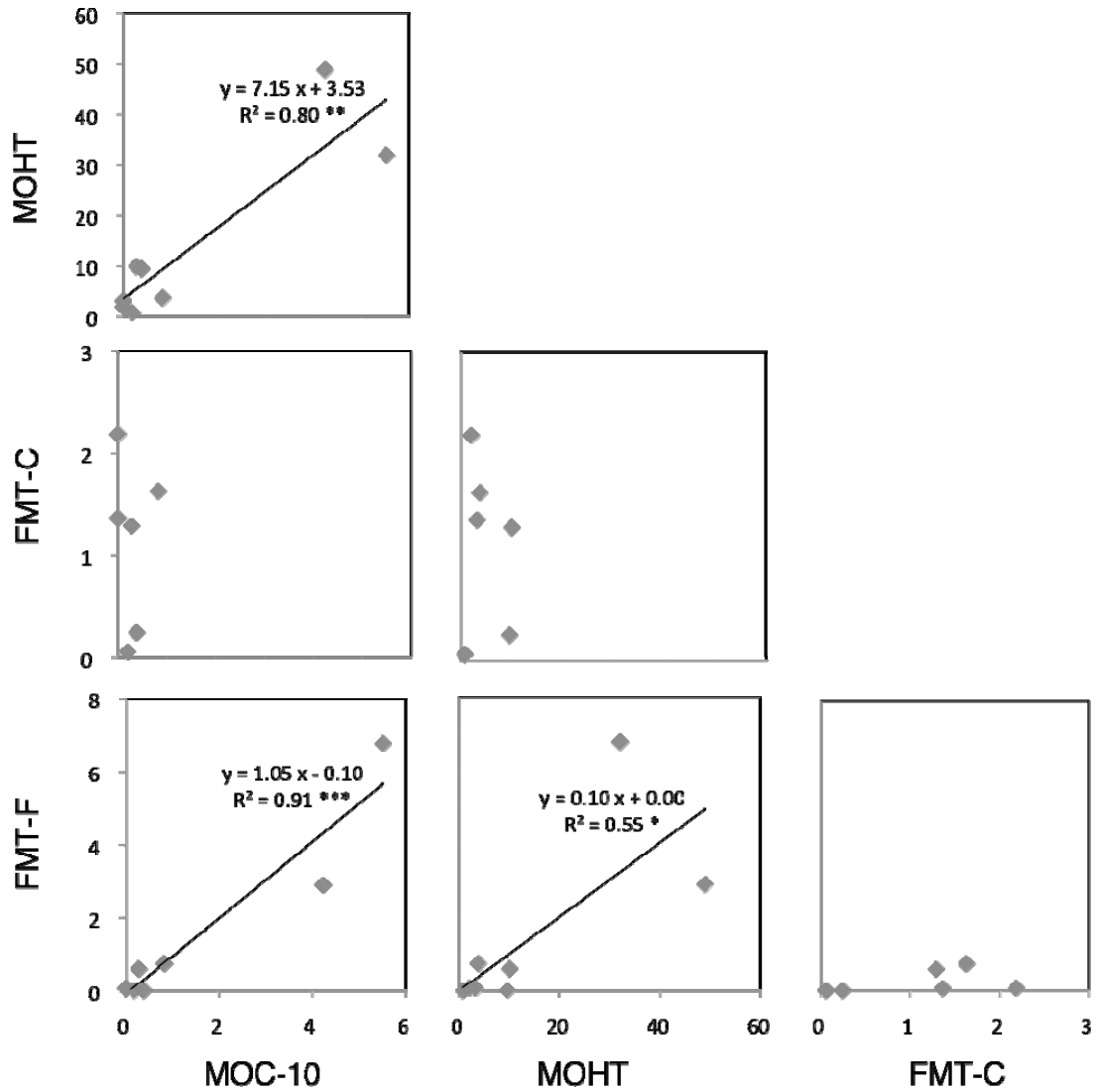
Fig. 3.9   Scatter plots for *Diaphus theta* showing relationships of numerical density estimates (N/1000 m^3) between different sampling gears used during the MIE-2. One diamond shows the density estimate at one station by two different gears; *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.
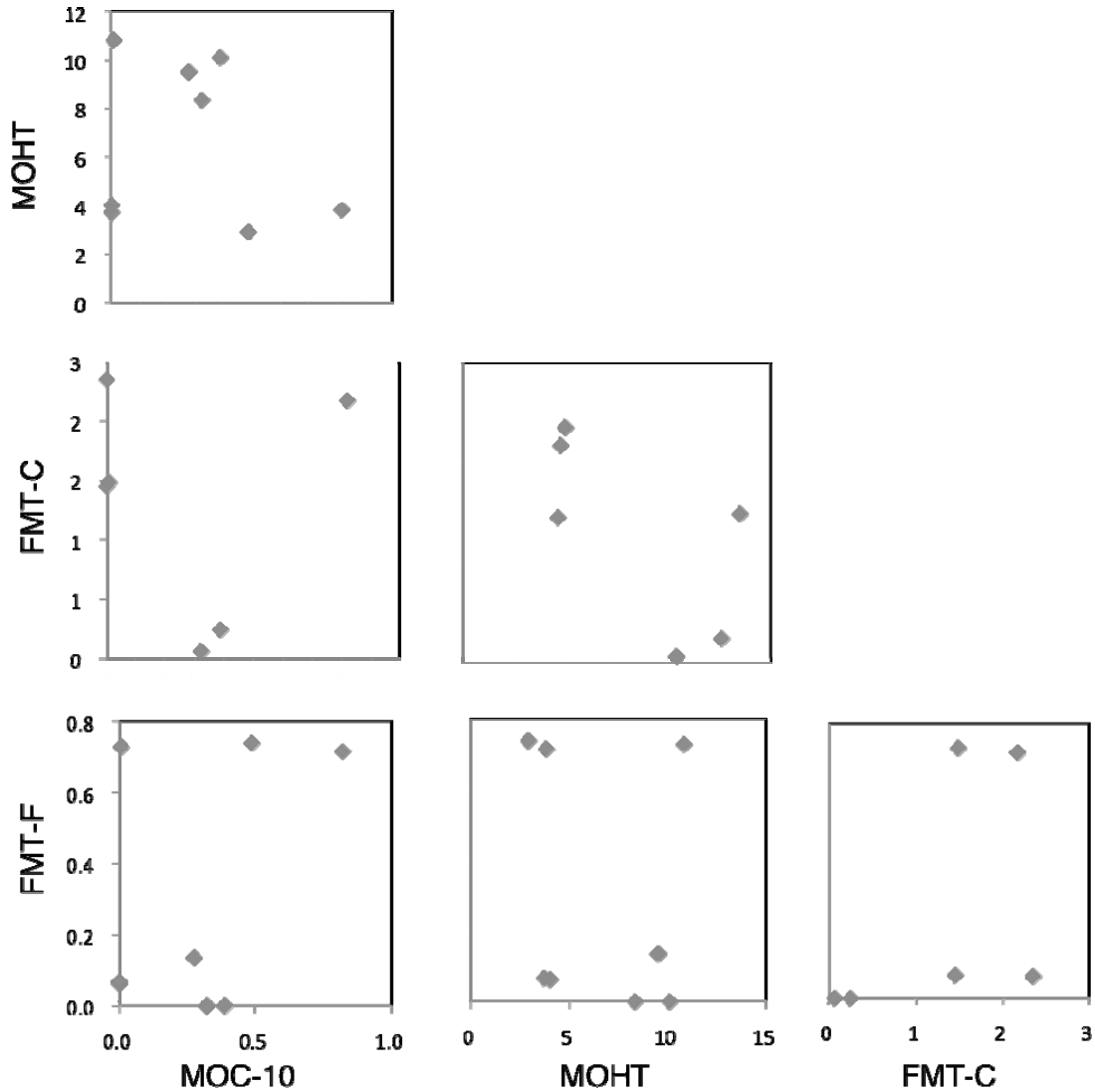
Fig. 3.10   Scatter plots for *Diaphus theta* showing relationships of gravimetric density estimates (wwt g m^{-2}) between different sampling gears used during the MIE-2. One diamond shows the density estimate at one station by two different gears.

3.1.6   Sampling Efficiency of Euphausiids

Sampling efficiency of euphausiids was compared between the MOCNESS-1, MOCNESS-10, MOHT and FMT-F, with a fine mesh net. The mesh size in the cod-ends of the OT and FMT with their coarse meshed net (9 mm) was insufficient to retain euphausiids. The biomass of euphausiids caught at four stations by different gears is presented in Table 3.5. Some data are missing due to the loss of a cod-end at a sampling station (MOCNESS-1) or loss of on-board measurement data of the total amount of zooplankton samples (MOCNESS-10 and MOHT). The ratio of maximum to minimum density at each station ranged from 1.7– 57.3 whereas coefficient of variation ranged between 29% and 123%, suggesting that estimates vary significantly by sampling gear. On average, the MOHT produced 3.9–5.1 times higher euphausiid catches compared to the other sampling gears.

Table 3.5   Comparison of euphausiid biomass (wwt g m^{-2}) estimated by different sampling gears at each station (daytime/nighttime) during the MIE-2.

Stn.	MOC-1	MOC-10	MOHT	FMT-F	% C.V.	Min/Max
1D	1.7	1.7	2.8	1.7	29	1.7
2D	22.1	12.1	15.5	6.0	48	3.7
3D	7.0	5.1	29.2	0.5	123	57.3
4D	29.9	n.d.	37.7	6.2	67	6.1
1N	10.3	27.4	n.d.	21.3	44	2.7
2N	n.d.	7.8	192.0	58.3	111	24.5
3N	26.6	0.8	20.3	3.3	99	32.9
4N	24.1	52.5	248.7	64.4	105	10.3
Average	17.4	15.3	78.0	20.2	–	–

Red and blue values indicate maximum and minimum estimates at a given station, respectively.
n.d.: no data.

Density estimates by different sampling gears are plotted for comparison in Figure 3.11. The MOCNESS-1 showed no clear relationship with any other sampling gear. The MOCNESS-10 showed weak positive relationships with the MOHT and FMT-F, but these were not statistically significant ($P = 0.07$ and 0.09, respectively). The comparison of the MOHT and the FMT-F showed a strong linear relationship ($y = 0.28x - 1.98$, $P < 0.001$). These results likely indicate that the estimate by the MOHT is most reliable whereas the estimate by the FMT is conservative, perhaps due to low filtering efficiency of the fine-meshed net. However, the estimate by the latter may be used for inter-comparison between the FMT and MOHT. It should be noted that each gear was towed at the highest ship speed possible in this experiment (see Table 3.1). Thus it appears that the superiority in catching more organisms by the MOHT was partly due to the higher ship speed allowed by this gear, which is an additional advantage of this net over other gears.

3.1.7   Size Distribution of Samples

Following the sampling efficiency inter-comparison, comparisons of size distribution were made for *Diaphus theta*, which represented approximately 60% and 67% of the total number and biomass, respectively, of the overall collection. Length frequency distributions in different tows were combined by weighting with catch number of each tow (Fig. 3.12). Comparison between daytime and nighttime was possible only for the MOHT. Two distinct modes occurred at 20 mm and 60 mm SL.

There was no significant difference between daytime and nighttime samples ($P > 0.05$). The MOCNESS-10 and FMT-F showed a distinct mode at 18–20 mm SL. Fish larger than 40 mm SL also occurred in samples, but their densities were low. The OT and FMT caught only > 48 mm SL fish.

The size frequency distribution of *Euphausia pacifica*, the most commonly occurring and dominant species among crustaceans at all stations, is shown in Figure 3.13. There were no diel differences in all samples collected using the MOCNESS-1 and MOCNESS-10. However, samples collected using the MOHT and FMT showed significant differences. Generally, nighttime collections were represented by larger euphausiids ($P < 0.001$, t-test; Table 3.6). Euphausiid body sizes also differed by sampling gear. During nighttime, samples collected using the MOHT and FMT showed larger euphausiid body length than those taken by the MOCNESS-1 and MOCNESS-10. Alternatively, during daytime *E. pacifica* taken by the MOCNESS had significantly larger body size than those taken by the MOHT and FMT, although the differences in mean TL were < 1 mm.

It should be noted that day/nighttime differences in euphausiid body length were found in the high-speed towing nets, *e.g.*, the MOHT and FMT. This suggests that large *E. pacifica* may potentially avoid such nets even at the highest towing speed, but they are likely evasive only when they are able to visually sense the nets well in advance. Furthermore, these nets successfully collected many small-sized *E. pacifica* during daytime when compared with the

MOCNESS. It is possible that the MOHT and FMT appear to be efficient in sampling near-surface layers where small-sized euphausiids concentrate by keeping a vertical towing angle to their mouths, due to their depressors and the heavy weights at the bottom (Bollens *et al.*, 1992). During the nighttime, small-sized *E. pacifica* were lacking in the size frequency distributions. We also have no explanation for the skewed size frequency distribution, but one possible reason for this may be an increased predation pressure from mesopelagic and pelagic fishes during the nighttime near the surface.
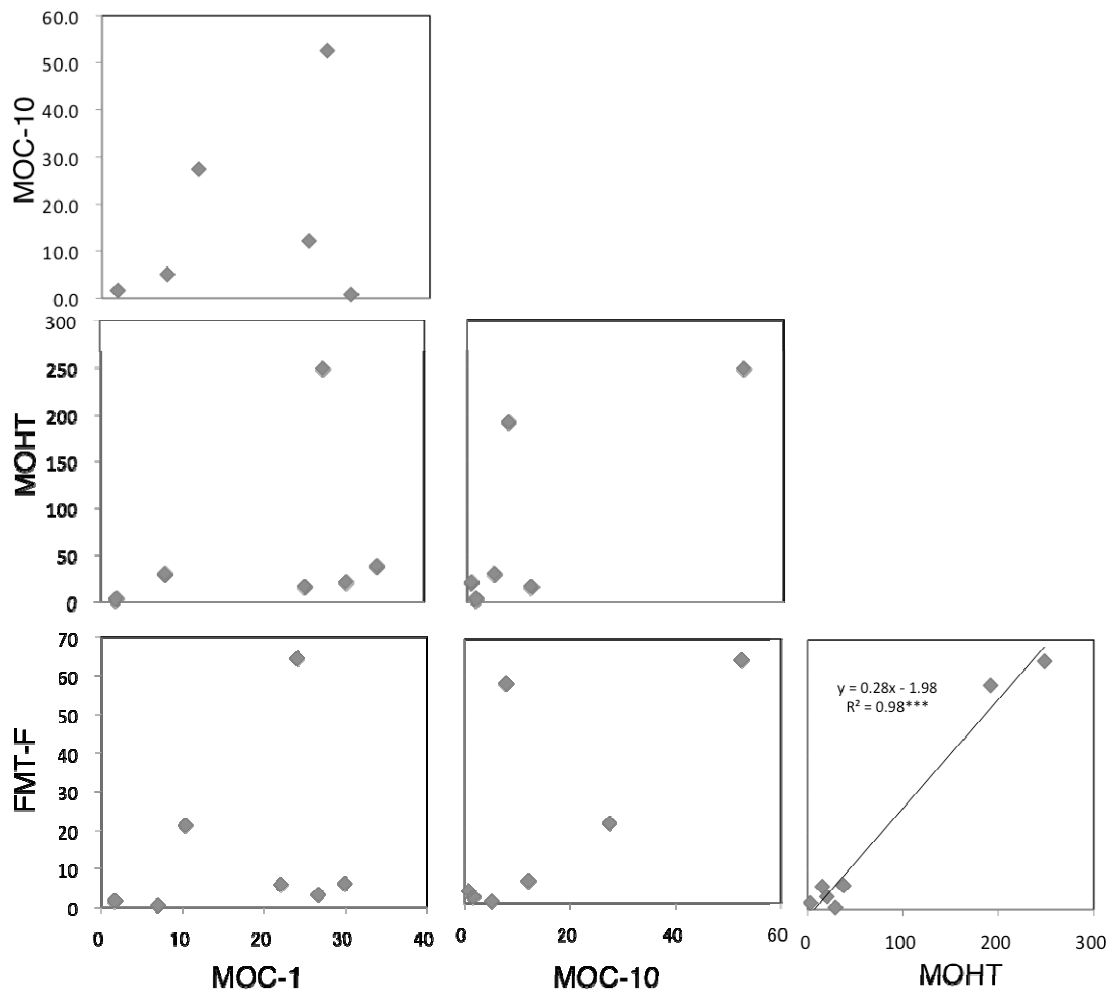
Fig. 3.11 Scatter plots for *Diaphus theta* showing relationships of density estimates (wwt g m^{-2}) between different sampling gears used during the MIE-2. One diamond shows the density estimate at one station by two different gears. Note that significant regression was found only between the MOHT and FMT-F.
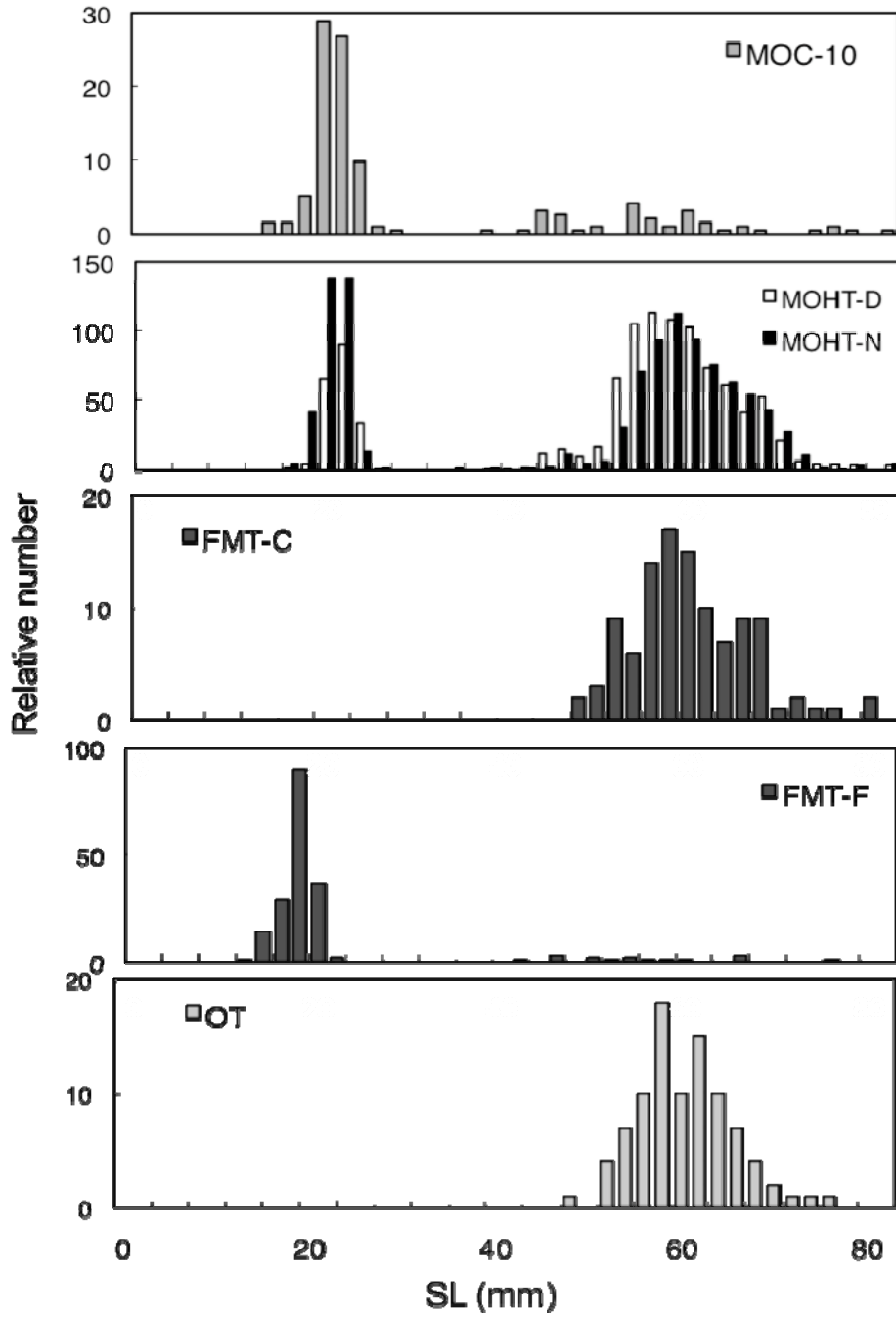
Fig. 3.12 Body length frequency distributions of *Diaphus theta* sampled by different gears during the MIE-2. Numbers were weighted by catch number of different tows.
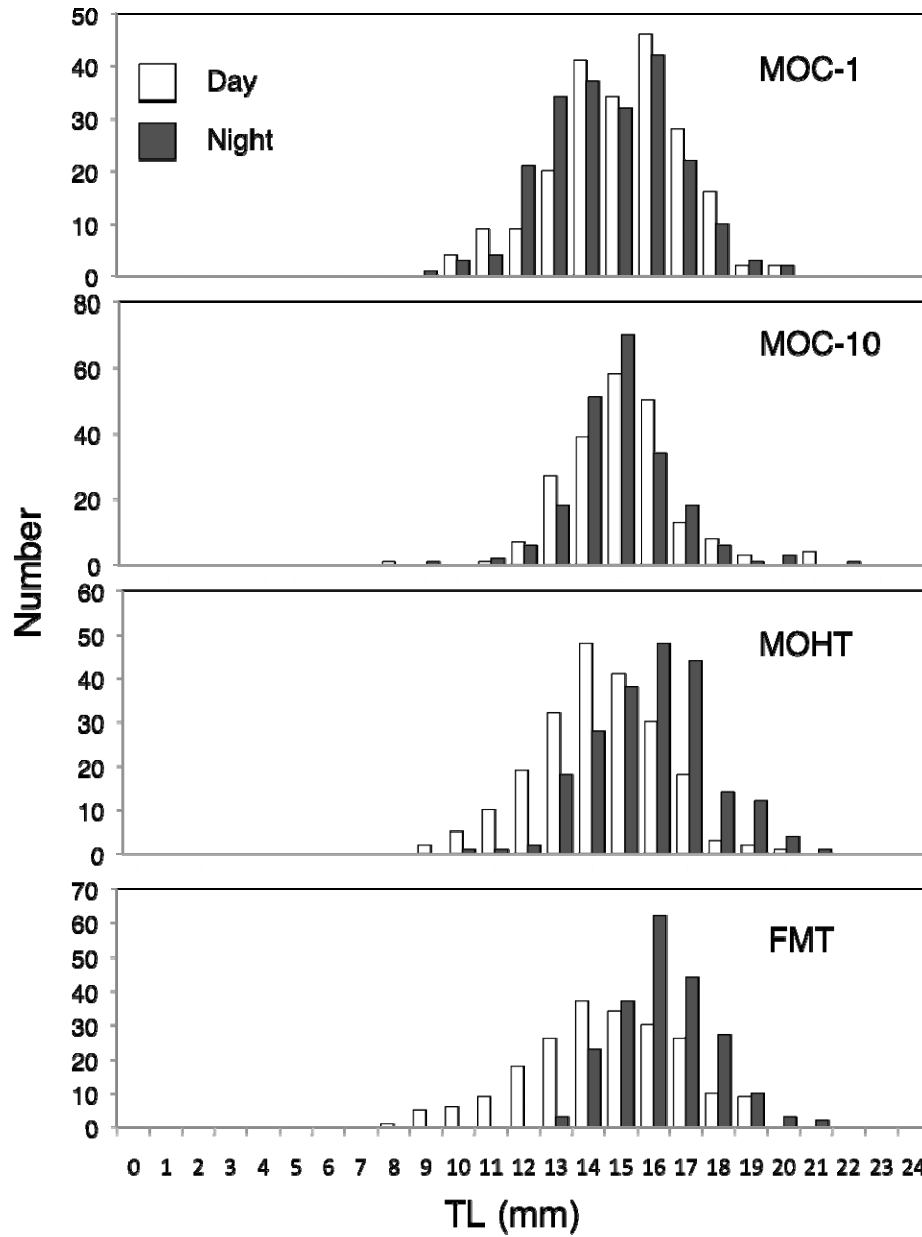
Fig. 3.13 Length frequency distribution of *Euphausia pacifica* collected by different sampling gears during the MIE-2.

Table 3.6 Average body length (TL, mm) of *Euphausia pacifica* collected by different sampling gears during the MIE-2.

	Daytime		Nighttime	
	Mean	**SD**	**Mean**	**SD**
MOC-1	15.5	2.0	15.2	2.0
MOC-10	15.6	1.7	15.5	1.6
MOHT	14.7	1.9	16.3***	1.8
FMT	15.1	2.3	16.8***	1.5

***: $P < 0.001$ in daytime *vs.* nighttime comparison.

3.2   Comparison between Acoustic Estimates

H. Yasuma and O. Yamamura

3.2.1   Data Collection and Analyses

A Simrad EK-60 echosounder system with 38, 70, 120, and 200 kHz full-mounted transducers was operated at a pulse length of 1.024 ms. Day and nighttime acoustic data were collected along five transect lines (Fig. 3.1; see also Fig. 3.17), which were set from shelf edge (about 150 m depth) to the end of the continental shelf slope (800–1000 depth). Data were also recorded during all trawl operations and used in comparative analyses with the trawl data.

Raw data of the mean volume backscattering strength, S_v, obtained at 38 and 120 kHz were used with the 2-frequency S_v method (Miyashita *et al.*, 1997; Kang *et al.*, 2002). This method uses the difference of S_v values (ΔS_v) between 38 and 120 kHz to identify the echo of a given target from raw echograms. We defined ΔS_v as $\Delta S_v = S_{v\ at120kHz} - S_{v\ at38kHz}$. The value of ΔS_v can be directly transformed to the difference of acoustic target strength, TS ($\Delta S_v = \Delta TS = TS_{at120kHz} - TS_{at38kHz}$) (Kang *et al.*, 2002), and the values of ΔTS of *Diaphus theta* were referenced to models based on the swimbladder shape and theoretical TS models developed by Yasuma *et al.* (2008). We assumed the ΔTS range of mature adult fish (> 60 mm in standard length) as –4 to 2 dB, and the range of immature fish (< 60 mm) as < –4 dB (Yasuma *et al.*, 2008). In addition, the ΔTS range of the other major component in the mesopelagic layer, the euphausiid *Euphausia pacifica*, was assumed to be 2 to 16 dB (Miyashita *et al.*, 1997). Echoview® Ver. 3.1 (Myriax) software was used for all echo scrutiny and integration.

3.2.2   Day and Nighttime Echograms and Vertical Fish Density

Typical raw echograms during day and nighttime are shown in Figure 3.14. The higher S_v on the sea bottom in shallow areas (circles in the figure) were assumed to be the echo from walleye pollock, *Theragra chalcogramma* (Miyashita *et al.*, 2004) and excluded in the following analyses. The DSL consisted of two prominent layers in daytime (Fig. 3.14, left panels). One was located between the depth of 250–300 m and higher levels of S_v were detected at 38 kHz. The other was located within the depth of 100–200 m and higher levels of S_v were detected at 120 kHz. The S_v levels in both DSLs were relatively low (< –65 dB) at both frequencies. At night, these DSLs were difficult to identify because both of them moved to the surface layer and only a weak scattering extended vertically (Fig. 3.14, right panels).

Echos from both size classes of *D. theta* and *E. pacifica* were extracted using each ΔS_v range and re-sampled at 120 kHz (Fig. 3.15). These echograms showed that the upper DSL in the raw echogram in daytime (Fig. 3.14) consisted of *E. pacifica*, and the lower DSL consisted mostly of immature *D. theta*, which agreed with the results obtained by the sampling gears (Fig. 3.11). The echograms that were re-sampled at night revealed the distribution of both sizes (or species), which showed that most individuals of *D. theta* were distributed in the surface layer (< 100 m), although some immature fishes remained within the mesopelagic layer (Fig. 3.15).

Using the above echograms, the vertical distribution of fish density was estimated by dividing linear values of S_v by linear values of fish TS. The length distribution obtained by the MOHT net (Fig. 3.11) was applied to the TS–length equation of *D. theta* at 120 kHz (TS = 19.5 log L – 73.5) (Yasuma *et al.*, 2008) and –55.0 and –58.2 dB were estimated for adult and immature fish, respectively. An example (line 1) of vertical distribution of fish density (ind. m^{-3}) between 0 and 400 m averaged every 20 m is shown in Figure 3.16. Values are integrated for every 200 m layer and shown on the figure as fish ind. m^{-2}. The main habitat of both size classes was below the depth of 200 m in daytime, but it was above the depth of 200 m at night. Total fish number

(ind. m^{-2}) in the upper layer (> 200 m) increased about twofold at night (Fig. 3.16) due to the upward migration. These patterns were similar among all transect lines.

3.2.3   Horizontal Distribution and Biomass

Horizontal distribution and biomass of *D. theta* were estimated separately in the 0–200 m and 200–400 m layers, bearing in mind the prominent change of day/nighttime fish distribution between the surface and mesopelagic layer (Fig. 3.16) which implied significant diel changes of biomass in these layers. Mean area scattering strength, SA, at 120 kHz was obtained at 0.1 nm intervals from re-sampled echograms (*e.g.*, Fig. 3.15) for adult and immature fish in each layer. Fish density (ind. m^{-2}) in each nm was estimated by dividing the linear values of S_A by the linear values of fish TS (Yasuma *et al.*, 2008). Estimated fish density was multiplied by the mean wet weight (g) of a fish at the nearest sampling point

to obtain the distribution of weight density (g m^{-2}). Total biomass in the survey area and its coefficient of variance, C.V., were estimated by cluster analysis. Details of these processes can be found in Williamson (1982).

The horizontal distribution of biomass (g m^{-2}) and total biomass of *D. theta* are shown in Figure 3.17 and Table 3.7. Fish were mostly distributed in the mesopelagic layer (200–400 m depth) during daytime. Similar levels of density (about 10 g m^{-2}) extended toward the offshore area, with enhanced densities observed near the shelf edge. At nighttime, the majority of fish had moved to the upper layer (< 200 m depth) of the water column and fish density in this layer reached about an order of magnitude greater than that during daytime (Fig. 3.17; Table 3.7). The total estimated biomass of *D. theta* within the MIE-2 survey area (18,800 km^2) was estimated to be 30,443 and 47,447 t during the day and nighttime, respectively.
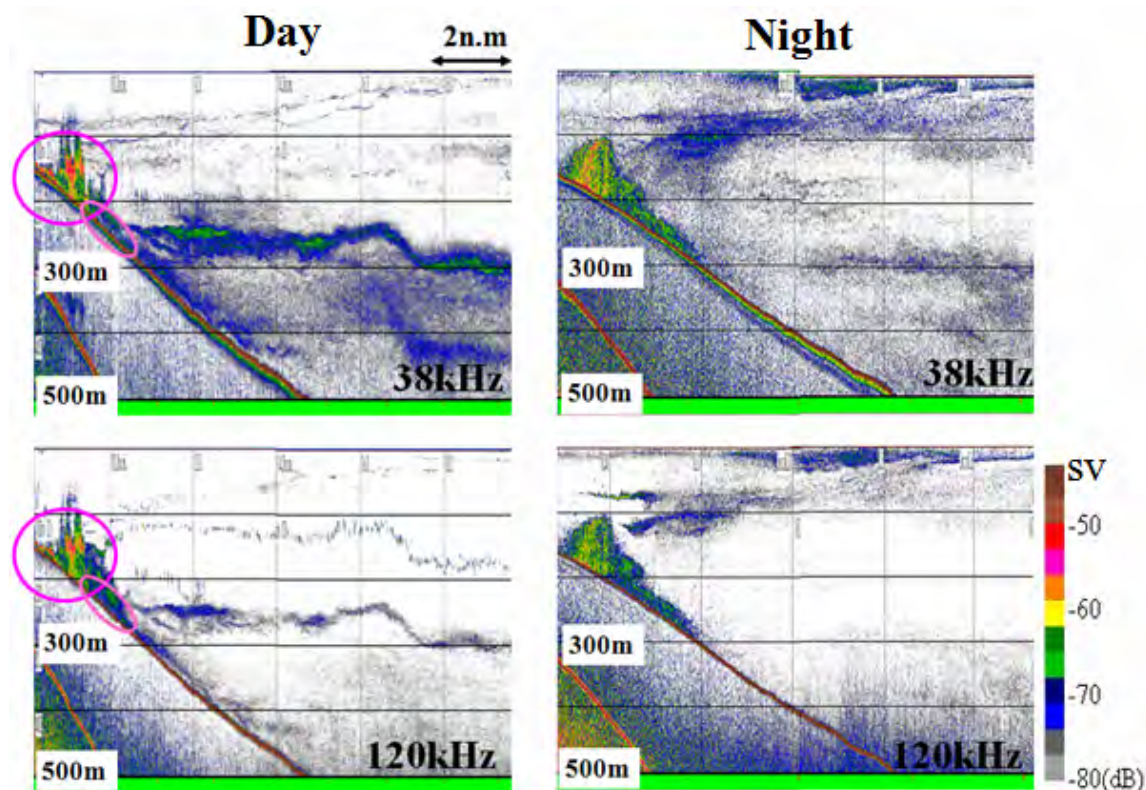
Fig. 3.14   Typical raw echograms (Line 1) obtained during daytime (left) and nighttime (right). Circles in the left panels denote echos from walleye pollock.
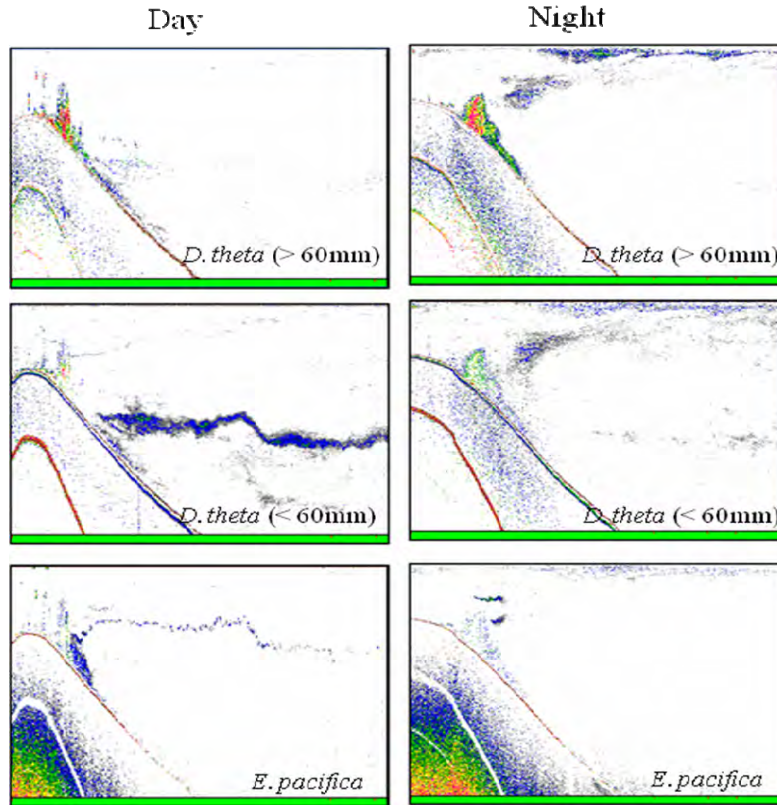
Fig. 3.15 Echograms at 120 kHz after re-sampling with ΔS_v. Upper panels are adult *Diaphus theta* (-4 dB $< \Delta S_v < 2$ dB), middle panels are immature *Diaphus theta* ($\Delta S_v < -4$ dB), and lower panels are *Euphausia pacifica* (2 dB $< \Delta S_v < 16$ dB).
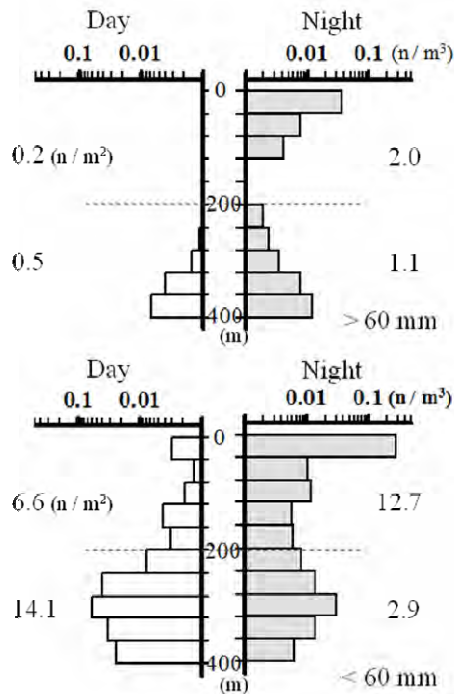
Fig. 3.16 An example (line 1) of vertical distribution of adult (upper panel) and immature (lower panel) fish density (ind. m^{-3}) between 0 and 400 m depth averaged every 20 m. Each value is integrated over every 200 m layer and is shown on the figure as fish number per m^2.
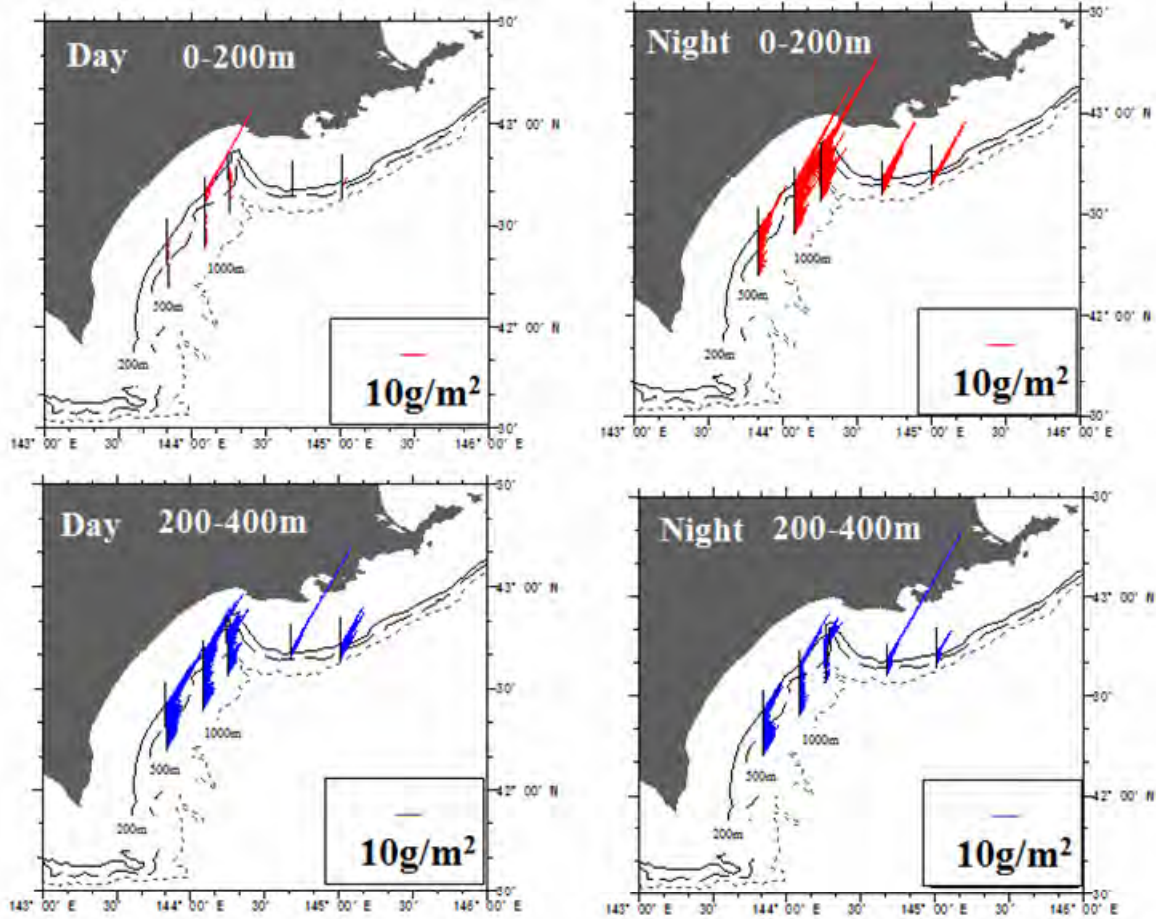
Fig. 3.17   Horizontal distribution of *Diaphus theta* (g m^{-2}) along five acoustic transects. Estimated biomass of each layer and time is given in Table 3.7.

Table 3.7   Average density and biomass of *Diaphus theta* measured during the MIE-2 survey.

	Layer (m)	Average Density (g m^{-2})	Biomass (t)	C.V.
Day	0–200	2.5	4631.5	1.9
	200–400	13.7	25,812.1	0.5
			Total (day) 30,443.6	
Night	0–200	16.1	30,332.1	0.8
	200–400	9.1	17,115.3	0.8
			Total (night) 47,447.4	

Survey area = 18,800 km^2,
C.V.: coefficient of variance of estimated biomass.

3.2.4   Comparative Results between Acoustic and Three Sampling Gears

A simple comparative analysis of fish density estimates was carried out between the acoustic and MOCNESS-10, MOHT, and FMT gears. The track of each oblique tow was estimated using the data from the SCANMAR net depth sensor and/or SBT data logger, and the area of acoustic estimation was determined so that the oblique track was covered (Fig. 3.18). For the sampling gears, fish density was estimated simply by dividing the numerical catch by the volume of water filtered. Both the acoustic and gear estimates were standardized to fish number per 1000 m^3.

Estimated fish density by MOCNESS and acoustics is compared in Table 3.8. In daytime, the MOCNESS did not catch *D. theta* except in two samples at Station 2 and the fish density in all layers at other sampling points were estimated to be zero. Nevertheless, fish echo signals were detected almost continuously during the acoustic observations. Even in the two nets which caught some fish, estimated densities were tens or hundreds of times lower than that of the acoustic densities. On the other hand, most nets in the MOCNESS caught fish at night, although the estimated densities were still lower than those obtained using acoustics. Estimates of fish density by the MOHT and acoustics are shown in Table 3.9. Both the day and nighttime samples caught by the MOHT included *D. theta* in all samples. The fish densities estimated by the MOHT were much higher than those estimated by the MOCNESS, and they were relatively close to the acoustic estimates, except at Station 4. Estimated fish density by the FMT and acoustics is presented in Table 3.10. Estimated fish density by the FMT showed low values compared to the MOHT (except for the daytime samples at Station 1). It should be noted that the differences in fish density estimates between FMT and acoustic varied widely among sampling points.

Fig. 3.18   Scheme of comparative analyses between the acoustic data and sampling gears. The track of each oblique tow was estimated using the record obtained by the SCAMMER net depth sensor and SBT data logger attached to each gear.

Table 3.8 Fish density (ind. 1000 m^{-3}) estimated by MOCNESS and acoustics during the MIE-2. A ratio of the MOCNESS estimate to acoustic estimate (MOCNESS/acoustics) is also presented.

Stn.	Depth (m)	Day			Night		
		MOCNESS	Acoustics	MOC./Acou.	MOCNESS	Acoustics	MOC./Acou.
1	0–100	0	6.7	–	12.0	19.4	6.2×10^{-1}
	100–200	0	2.1	–	0.2	5.7	3.5×10^{-2}
	200–300	0	28.6	–	0	9.6	–
2	0–100	0	2.7	–	0.3	27.7	9.7×10^{-3}
	100–200	0.3	90.3	2.8×10^{-3}	0.6	47.5	1.2×10^{-2}
	200–300	0.9	35.4	2.5×10^{-2}	0	5.6	–
3	0–100	0	2.5	–	1.7	16.3	1.0×10^{-1}
	100–200	0	5.3	–	0.5	15.1	3.6×10^{-2}
	200–300	0	24.0	–	0.2	9.7	2.3×10^{-2}
4	0–100	0	1.0	–	0.3	7.8	4.4×10^{-2}
	100–200	0	113.0	–	0	21.0	–
	200–300	0	120.0	–	0.2	8.8	2.6×10^{-2}

Table 3.9 Fish density (ind. 1000 m^{-3}) estimated by MOHT and acoustics data during the MIE-2. A ratio of the MOHT estimate to the acoustic estimate (MOHT/acoustics) is also presented.

Stn.	Day			Night		
	MOHT	Acoustics	MOHT/Acoustics	MOHT	Acoustics	MOHT/Acoustics
1	32.0	115.7	2.8×10^{-1}	48.8	107.4	4.5×10^{-1}
2	9.5	46.2	2.1×10^{-1}	10.0	23.3	4.3×10^{-1}
3	3.1	10.0	3.1×10^{-1}	3.7	40.1	9.2×10^{-2}
4	2.0	79.8	2.5×10^{-2}	0.8	29.3	2.7×10^{-2}

Table 3.10 Fish density (ind.1000 m^{-3}) estimated by FTM and acoustics during the MIE-2. A ratio of the FMT estimate to the acoustic estimate (FMT/acoustics) is also presented.

Stn.	Day			Night		
	FMT	Acoustics	FMT/Acoustics	FMT	Acoustics	FMT/Acoustics
1	6.8	19.9	3.4×10^{-1}	2.9	29.5	9.8×10^{-2}
2	0.2	81.3	3.0×10^{-3}	1.3	172.1	7.5×10^{-3}
3	1.4	25.1	5.5×10^{-2}	1.6	9.3	1.7×10^{-1}
4	2.2	300.0	7.3×10^{-3}	0.1	188.3	3.1×10^{-4}

3.3 Summary of Results from the MIE-2

- The MOCNESS-10 and FMT with a fine mesh (FMT-F) appeared to be inefficient in quantitatively sampling the medium to large-sized micronekton (> 50 mm BL), perhaps because of low ship speed during towing (MOCNESS-10) and poor filtering capability of the netting (FMT);
- The FMT with coarse mesh (FMT-C) and the OT lack the ability to efficiently catch small-sized (< 25 mm) micronekton due to large mesh size in their cod-ends (9 mm);
- The samples collected by the MOHT appeared to represent the most robust density and size distribution of micronektonic fishes among all gears compared during the MIE-2;

- The sampling superiority of the MOHT was also evident in macroplanktonic crustaceans (euphausiids), as it sampled 3.9 to 5.1 times more of these compared to the other gears. It appears that the superiority of the MOHT was partly due to its ability to work reliably at higher towing speed, which is its greatest advantage over the other gears. Nevertheless, the MOHT still appeared to underestimate micronekton (fish) biomass when compared with the estimates using an echosounder with multiple frequency transducers, by a factor of 2.2 to 10.8. Additional field surveys using the MOHT and acoustics to obtain more reliable correcting factors are clearly required.

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4   Third Micronekton Inter-calibration Experiment, MIE-3

4.1   Macrozooplankton and Micronekton in the eastern Bering Sea: Composition and Gear Inter-calibration

O. Yamamura, A.V. Suntsov and H. Yasuma

4.1.1   Background and Methodology

During the previous micronekton inter-calibration experiments, the following gears were tested: IKMT, FMT (= HUFT), Cobb trawl, MOCNESS-1 and MOCNESS-10, MOHT and a midwater otter trawl (OT) with Multi-sampler), and the superiority of MOHT over the other gears was shown. However, no direct comparison has been made between the MOHT and the IKMT. The latter gear has been used widely in previous (historical) micronekton studies, so the direct comparison between these gears is critical in order to utilize and standardize archived micronekton data.

The third micronekton inter-calibration experiment (MIE-3) was carried out in the eastern Bering Sea during September 21–22, 2007. The experiment was run during the Ocean Carrying Capacity program cruise on board the R/V *Oscar Dyson* (Fig. 4.1), conducted by the Auke Bay Laboratory, NOAA, National Marine Fisheries Service of the USA (Dr. Jim Murphy, Chief Scientist). Scientists participating in the MIE-3 were: Orio Yamamura (Hokkaido National Fisheries Research Institute, FRA Japan), Hiroki Yasuma (Center for Field Science, Hokkaido University) and Andrei Suntsov (Northwest Fisheries Science Center, NOAA NMFS). Initially, a total of three days had been allocated during the cruise for the MIE-3.   However, due to rough weather conditions, this time slot was shortened to only 24 h. The sampling gears tested during the MIE-3 included a 6-foot Isaacs-Kidd midwater trawl (IKMT; Isaacs and Kidd, 1953) and a Matsuda-Oozeki-Hu trawl (MOHT; Oozeki *et al.*, 2004).   In addition, backscattering from the scattering layers was recorded using a Simrad EK-60 echosounder with 15, 38, 70, 120 and 200 kHz transducers. Initially, it was planned to sample the shelf edge in the eastern Bering Sea, targeting micronekton, but the sampling

position was shifted to a site near St. Paul Island, with a bottom depth of 70 m.   This area is well known as a nursery ground for age-0 walleye pollock (Ciannelli *et al.*, 2004).

Sampling was conducted in both day and nighttime during which two gears were towed sequentially with triplicate samples collected in each time interval. Locations and time of sampling are summarized in Table 4.1. The gear was deployed from the ship and lowered to 65 m depth. The position of the gear was monitored by a SCANMAR sensor.   Nets were targeted at depths with dense scattering layers (*e.g.*, 22–23 m and 65–75 m) during the daytime and nighttime, respectively.   Once the net arrived to a target depth, it was towed horizontally for 15 minutes during nighttime, and 30 minutes during daytime.   The tow duration was extended during daytime because the scattering layers representing juvenile walleye pollock adhered to the sea bottom as time elapsed from sunrise.   The ship speed during towing was fixed at 3 kt for both gears following discussion at the MIE workshop (W9) on "*Micronekton sampling gear inter-calibration experiment*" (Fifteenth PICES Annual Meeting, October 13, 2006, Yokohama, Japan; see Appendix 3) although the maximum towing speed for the MOHT is about 5 kt.

Age-0 walleye pollock collected by both gears were measured immediately after every haul, for length frequency distribution, whereas euphausiids *Euphausia pacifica* were measured in the laboratory. From each tow, up to 200 fish were measured to the nearest 1 mm and up to 100 euphausiids were measured to the nearest 0.01 mm using an electronic caliper. Data were separated into day and nighttime periods combining all tows within time periods.

Fig. 4.1   MIE-3 sampling platform: NOAA research vessel *Oscar Dyson*.

**Table 4.1**   Summary of net operations during the MIE-3. Time (GMT).

	Position set		**Position ended**				
	Lat (N)	**Long (W)**	**Lat (N)**	**Long (W)**	**Time set**	**Time ended**	**Wire out (m)**
MOHT-1N	57.30.00	168.48.40	57.30.03	168.44.28	7:44	7:59	80
IKMT-1N	57.29.90	168.41.36	57.29.88	168.41.59	9:13	9:28	80
MOHT-2N	57.30.04	168.26.23	57.30.08	168.37.05	9:51	10:04	80
IKMT-2N	57.30.23	168.34.84	57.30.27	168.33.94	10:26	10:36	80
MOHT-3N	57.30.38	168.31.97	57.30.44	168.31.04	10:55	11:05	N/A
IKMT-3N	57.30.58	168.17.10	57.30.64	168.27.90	11:27	11:37	85
MOHT-1D	57.30.03	168.47.91	57.30.05	168.47.13	6:40	6:50	180
IKMT-1D	57.30.49	168.44.26	57.30.58	168.43.32	20:14	20:25	180
MOHT-2D	57.30.88	168.39.90	57.30.95	168.39.22	21:07	21:17	180
IKMT-2D	57.31.28	168.36.04	57.31.37	168.35.20	21:54	22:04	185
MOHT-3D	57.31.73	168.31.81	57.31.88	168.30.45	22:41	22:57	180
IKMT-3D	57.32.17	168.27.06	57.32.30	168.25.54	23:30	23:46	180–185

4.1.2   Sampling Efficiency

A total of 3499 age-0 walleye pollock were collected during 12 hauls.   Other species sampled included agonids *Podothecus asipenserinus* (15 individuals), capelin *Mallotus villosus* (6 individuals) and Greenland halibut *Reinhardtius hippoglossoides* (6 individuals).   Thus, walleye pollock comprised > 99% of the total number of fish collected, offering a good opportunity for gear inter-comparison.

The density (*i.e.*, sampling efficiency) of age-0 walleye pollock estimated by both sampling gears differed substantially between day and nighttime. Nighttime densities of the MOHT and IKMT were 24.5- and 10.6-fold higher than values during daytime (Fig. 4.2). This remarkable difference may be attributable mainly to the fact that juvenile pollock were distributed and perhaps dispersed closer to the sea bottom during daytime.   Therefore, the difference could be due to lower fish densities rather

than to net avoidance, although the latter cannot be entirely excluded (see later discussion). The inter-gear difference was less conspicuous, but the MOHT during nighttime showed 2.0 to 2.3 times higher densities compared to the IKMT catches in terms of both abundance and biomass (Figs. 4.2 and 4.3). It should be noted that the ratio between sampling efficiencies of the IKMT and MOHT would be even larger if the latter gear were towed at higher speed. Furthermore, the fact that the biomass ratio was higher than the numerical ratio between gears indicated that the MOHT sampled larger fish than the IKMT (see section 4.1.3).
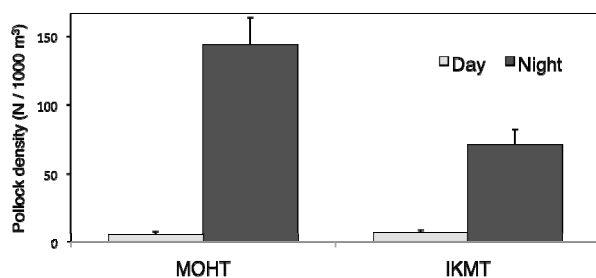
Fig. 4.2 Numerical density of age-0 walleye pollock near St. Paul Island, eastern Bering Sea, estimated by different sampling gears during the MIE-3 in September 2007; error bars: ±1 S.E.
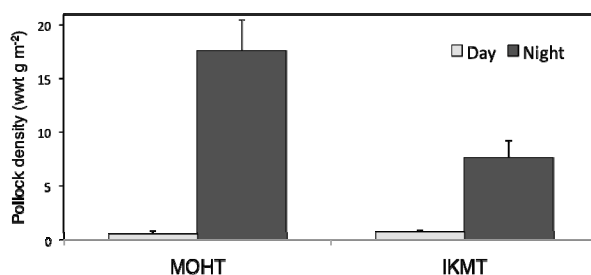
Fig. 4.3 Gravimetric density of age-0 walleye pollock near St. Paul Island, eastern Bering Sea, estimated by different sampling gears during the MIE-3 in September 2007; error bars: ±1 S.E.

Fig. 4.4 Gravimetric density of *Euphausi pacifica* near St. Paul Island, eastern Bering Sea, estimated by different sampling gears during the MIE-3 in September 2007; error bars: ±1 S.E.

The zooplankton sampled during the MIE-3 were dominated by the euphausiid *Euphausia pacifica* which comprised > 99% of the biomass. Similar to juvenile walleye pollock, euphausiid density estimates were significantly higher during nighttime than daytime (16.1 and 4.9 times for the MOHT and IKMT, respectively). Also, the inter-gear difference showed that the MOHT had almost 2-fold higher densities of euphausiids than the IKMT (Fig. 4.4).

4.1.3   Size Distribution of Samples

Age-0 walleye pollock showed single modal length frequency distributions and both gears sampled significantly larger fish during nighttime (Fig. 4.5, Table 4.2). This suggests that visual avoidance of nets by walleye pollock could be a contributing factor to the day/nighttime differences in catches (see section 4.1.2). The MOHT sampled fish slightly larger in size, but a significant difference was found only among daytime samples.

Both gears sampled euphausiids of larger body sizes during daytime (Fig. 4.6, Table 4.3). However, no inter-gear difference was found in mean body length of euphausiids (Table 4.3).

Table 4.2   Mean body length (FL, mm) of walleye pollock collected near St. Paul Island, eastern Bering Sea, during the MIE-3. Significant level in a *t*-test is also shown.

N.S.: no significance; *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.
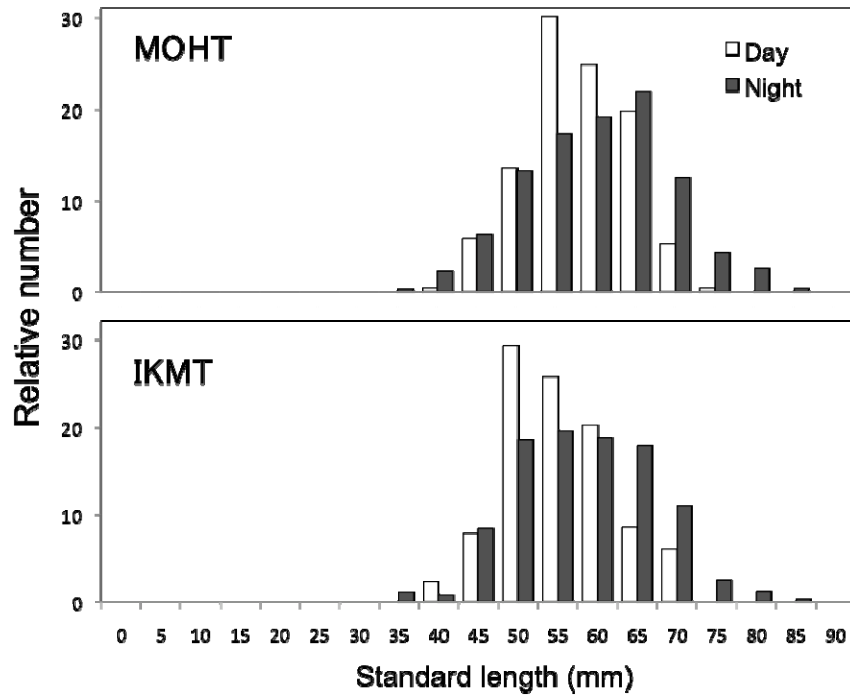
Fig. 4.5   Length frequency distribution of walleye pollock collected by different sampling gears near St. Paul Island, eastern Bering Sea, during the MIE-3 in September 2007.
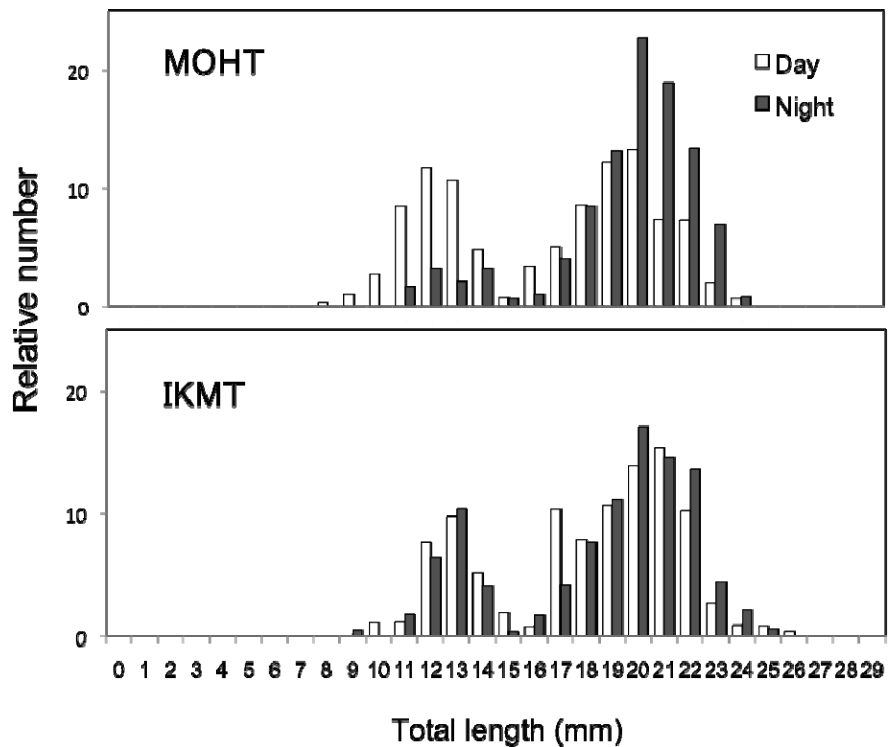
Fig. 4.6   Length frequency distribution of *Euphausia pacifica* collected by different sampling gears near St. Paul Island, eastern Bering Sea, during the MIE-3 in September 2007.

Table 4.3   Mean total length (TL, mm) of *Euphausia pacifica* collected near St. Paul Island, eastern Bering Sea, during the MIE-3. Significant level in a *t*-test is also shown.

N.S.: no significance; ***: *P* < 0.001.

4.1.4   Comparison with Acoustic Data

Backscattering data were collected throughout the MIE-3 experimental sampling, and were processed and analyzed using Echoview® software (Myriax Software Ltd.). For the purpose of comparison between the density estimates based on acoustics and net sampling, each net tow track was depth approximated by a strip on the echogram using the starting and ending tow-points.

The fish and zooplankton species composition collected during the MIE-3 was virtually monospecific with walleye pollock and *Euphausia pacifica* accounting for > 99% in terms of both number and wet weight. As a consequence, backscattering from walleye pollock and *E. pacifica* was easily extracted from the echogram by using the S_v difference method (Kang *et al.*, 2002) between the backscatter of the 38 and 120 kHz transducers. The S_v representing both species were converted to fish density using the species individual target strengths. For walleye pollock, Sadayasu *et al.* (2006) obtained the following regression model by considering swimbladder morphology, tilt angle and body length: TS = 20 log (FL) – 68.3 (FL < 5cm), TS = 24.6 log (FL) – 71.5 (FL < 5cm). For *E. pacifica*, the TS value from Amakasu (2004) was applied. In the calculation of TS for both species, the average body lengths from the nighttime samples of the MOHT, *e.g.*, 57 mm FL and 20 mm TL for walleye pollock and *E. pacifica*, respectively, were used. Numerical density was converted to mass by using an average body weight.

Overall, estimates by nets and acoustics were far more concordant during nighttime. The estimates for walleye pollock by the MOHT and echosounder showed consistent values with the average ratio for three tows being 1.1, while the IKMT showed a ratio of 2.3 (Table 4.4). The difference in the acoustic/net ratio between the MOHT and the IKMT was comparable to the difference in density estimated from both gears (2.0 times). These results suggest a high degree of accuracy of both the MOHT and acoustic estimates during nighttime. The daytime estimates, however, showed significant discrepancies between the acoustic estimates and the densities obtained using nets. Daytime net estimates were consistently lower than acoustic estimates.

The acoustic/net ratios were more variable for *E. pacifica* than for walleye pollock (Table 4.5). On average, daytime acoustic estimates were 3.1 and 3.5 times higher compared with those estimated using the MOHT and IKMT, respectively. This result was rather confusing because euphausiids are generally less evasive from nets compared to walleye pollock, thus the density estimate by the nets was expected to be more consistent with the acoustic measurements. The inconsistency between density estimates by acoustics and nets can be attributable to: (1) underestimation by the nets, (2) overestimation by acoustics, and/or (3) the patchy nature of the euphausiid distribution. We cannot draw conclusions as to which factors were more important. However, the fact that density estimates of *E. pacifica* were more variable compared to walleye pollock densities (C.V. of acoustic estimate during nighttime for walleye pollock and *E. pacifica*; 0.39 and 0.98, respectively) suggests that natural patchiness could account for the majority of the inconsistency between density estimates using acoustics and net sampling.

Table 4.4   Daytime/nighttime comparison of walleye pollock densities estimated by acoustic and net sampling (ind. m^{-3}) during the MIE-3.

		Acoustic	Net	Acoustic/Net	Average
MOHT	Nighttime	0.11	0.10	1.1	1.1
		0.17	0.17	1.0	
		0.17	0.16	1.1	
	Daytime	0.42	0.01	43.3	54.7
		0.28	0.01	49.8	
		0.08	0.001	71.0	
IKMT	Nighttime	0.18	0.08	2.2	2.3
		0.26	0.08	3.1	
		0.08	0.05	1.8	
	Daytime	0.21	0.01	18.8	30.7
		0.26	0.01	51.5	
		0.09	0.004	21.8	

Table 4.5   Daytime/nighttime comparison of *Euphasia pacifica* densities estimated by acoustic and net sampling (ind. m^{-3}) during the MIE-3.

		Acoustic	Net	Acoustic/Net	Average
MOHT	Nighttime	8.9	21.6	0.4	3.1
		13.0	7.9	1.6	
		88.4	12.4	7.1	
	Daytime	17.2	2.1	8.1	9.2
		9.1	2.4	3.8	
		27.4	1.8	15.6	
IKMT	Nighttime	18.1	9.9	1.8	3.5
		25.7	7.7	3.3	
		29.6	5.6	5.3	
	Daytime	58.3	6.9	8.4	119.7
		1.6	2.6	0.6	
		58.3	0.2	350.2	

In conclusion, the comparison between density estimates for age-0 walleye pollock (*ca*. 70 mm FL) using the MOHT and acoustics showed a high degree of agreement suggesting that the MOHT is the more reliable sampling gear for micronekton compared to the IKMT.

4.2   Summary of MIE-3 Results

- The sampling efficiency of the MOHT and IKMT nets for micronekton was compared. Both gears showed an extreme day/nighttime difference which seemed to be not only attributable mainly to diurnal variation in the distribution pattern but at least partially to the net avoidance of age-0 walleye Pollock, rather than the sampling characteristics of the gears;

- The MOHT showed a 2.0- to 2.3-fold higher sampling efficiency in both abundance and biomass compared to the IKMT. This ratio could have been even higher if the MOHT had been towed at higher speed;

- Both gears showed significant day/nighttime differences in the average size of fish sampled, whereas no, or slight, inter-gear differences were found;

- The MOHT showed a 1.8 times higher sampling efficiency for euphausiids than the IKMT. Both gears showed a significant day/nighttime difference in body size of euphausiids sampled, whereas no inter-gear difference was found;

- Both gears were easy to operate, and showed stable behaviors in the water and relatively constant catches for both micronekton and macroplankton (euphausiids). However, the MOHT showed a better ability to sample both groups effectively, even at 55% (3 knots) of its maximum towing speed (5.5 knots);

- When density estimates obtained by the acoustics and different nets were compared, the nighttime MOHT densities appeared to be in close concordance (0.9- to 1.1-fold) with the acoustic estimates.

4.3   References

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5   Overview and Recommendations

1. Results of three MIEs point out that the Matsuda-Oozeki-Hu Trawl (MOHT) gear was among the most reliable and cost effective micronekton gears examined. It provided high quality, quantitative micronekton samples. It is now available commercially and development of a closing/opening mechanism for this net is presently underway. Equipping the MOHT with an opening/closing mechanism on the cod-end could put this gear in a position to become the standard micronekton gear worldwide, and in the North Pacific, in particular. As a consequence, the MIE-AP strongly supports further work in this direction.

2. Models were developed to predict backscattering volume to allow for comparisons between acoustic and net data. However, preliminary results indicated that the compatibility was low, which suggests that there are problems associated with both sampling techniques, as discussed on several occasions. The closest results were obtained between the MOHT and acoustics. The Advisory Panel felt that further research in improving acoustic estimates should be continued. In addition, acoustic data collected during all experiments still require some degree of work and clean-up.

3. A new system, J-QUEST (Sugisaki and Sawada, 2007), was shown to quantify the epipelagic micronekton and nekton but appeared to be inefficient in detecting the mesopelagic fishes, and myctophids in particular. There is good potential for adopting this system for mesopelagic work but more work is required to determine which light spectrum myctophids are less sensitive to.

4. The Advisory Panel, after a brief review of ICES and PICES inter-calibration experiments, concluded that their inter-comparison is generally impossible. This is due to: first, mainly incomparable sampling gears that have been used during the ICES and PICES experiments, and second, the concentration mainly on mesozooplankton in the ICES experiment.

Appendix 1

PICES Advisory Panel on *Micronekton Sampling Inter-calibration Experiment*

Terms of reference

1. Develop a proposal for a micronekton sampling inter-calibration experiment, arising from the work of PICES WG 14 on Effective Sampling of Micronekton. Advise on appropriate locations as well as identify micronekton sampling gears and other quantifying technologies for inclusion in the inter-calibration experiment;
2. Facilitate the experiment by identifying and securing commitments for resources (personnel and ships) to ensure success of the experiment; provide technical advice in development of sampling protocols and experimental design;
3. Oversee post-survey analysis of samples and data; provide guidance in preparation of results for final report and publication(s).

Membership

CANADA

Evgeny Pakhomov (MIE-AP Co-Chairman)
Department of Earth and Ocean Sciences
6339 Stores Rd.
University of British Columbia
Vancouver, BC, V6T 1Z4
Canada
E-mail: epakhomov@eos.ubc.ca

JAPAN

Kazushi Miyashita
Laboratory of Marine Ecosystem Change Analysis
Hokkaido University
3-1-1 Minato-cho
Hakodate, Hokkaido 041-8611
Japan
E-mail: miyashi@fish.hokudai.ac.jp

Orio Yamamura (MIE-AP Co-Chairman)
Hokkaido National Fisheries Research Institute
Fisheries Research Agency
116 Katsurakoi
Kushiro, Hokkaido 085-0802
Japan
E-mail: orioy@affrc.go.jp

PEOPLE'S REPUBLIC OF CHINA

Xianyong Zhao
Yellow Sea Fisheries Research Institute
Chinese Academy of Fishery Science
106 Nanjing Rd.
Qingdao, Shandong 266071
People's Republic of China
E-mail: zhaoxy@ysfri.ac.cn

REPUBLIC OF KOREA

Won-Duk Yoon
National Fisheries R&D Institute
Ministry for Food, Agriculture, Forestry and Fisheries
408-1 Shirang-ri, Kijang-up, Kijang-gun
Busan 619-705
Republic of Korea
E-mail: wdyoon@nfrdi.go.kr

RUSSIA

Galina V. Belova
Laboratory of Pelagic Resources
Pacific Research Institute of Fisheries and
    Oceanography (TINRO-Center)
4 Shevchenko Alley
Vladivostok, Primorsky Kray 690950
Russia
E-mail: belova@tinro.ru

Oleg A. Ivanov
Pacific Research Institute of Fisheries and
    Oceanography (TINRO-Center)
4 Shevchenko Alley
Vladivostok, Primorsky Kray 690950
Russia
E-mail: oliv@tinro.ru

Vadim F. Savinykh
Pacific Research Institute of Fisheries and
    Oceanography (TINRO-Center)
4 Shevchenko Alley
Vladivostok, Primorsky Kray 690950
Russia
E-mail: savinykh@tinro.ru

UNITED STATES OF AMERICA

Richard D. Brodeur
Hatfield Marine Science Center
National Marine Fisheries Service, NOAA
2030 SE Marine Science Dr.
Newport, OR 97365
U.S.A.
E-mail: Rick.Brodeur@noaa.gov

Michael P. Seki
Pacific Islands Fisheries Science Center
National Marine Fisheries Service, NOAA
2570 Dole St.
Honolulu, HI 96822-2396
U.S.A.
E-mail: Michael.Seki@noaa.gov

Appendix 2

List of fish species collected during the MIE-1 cruise onboard the R/V *Oscar Elton Sette* off Hawaii, October 6–13, 2004.

Taxa	Cobb Trawl	HUFT	IKMT
Acanthuridae gen. sp.	*	–	–
Apogonidae spp.	*	–	–
Argyropelecus aculeatus	*	–	–
Argyropelecus affinis	*	*	*
Argyropelecus hemigymnus	*	*	*
Argyropelecus sladeni	*	–	–
Astronesthes bilobata	*	*	*
Astronesthes cyanea	*	*	–
Astronesthes indica	*	*	–
Astronesthes splendidus	*	–	*
Astronesthes trifibulata	*	*	*
Astronesthes spp.	–	–	*
Bathophilus kingi	*	–	–
Bathophilus pawnei	*	–	–
Bathophilus spp.	*	–	–
Benthodesmus spp.	*	–	–
Benthosema subobitale	*	*	*
Blenniidae gen. sp.	*	–	–
Bolinichthys distofax	*	–	*
Bolinichthys longipes	*	*	*
Bothus spp.	*	–	–
Bregmaceros atlanticus	*	–	–
Bregmaceros maclellandi	*	*	*
Bregmaceros nectabanus	–	*	–
Bregmaceros spp.	*	–	*
Brotulotaenia spp.	*	–	–
Centrobranchus andrea	–	*	–
Centrobranchus choerocephalus	*	*	*
Centrobtranchus andrea	–	–	*
Ceratoscopelus spp.	*	*	–
Ceratoscopelus warmingii	*	*	*
Chauliodus sloani	*	*	*
Chauliodus spp.	–	*	–
Coccorella atlantica	*	–	–
Coryphaens spp.	–	*	–
Cubiceps pauciradiatus	*	–	–
Cubiceps spp.	*	–	–
Cyclothone alba	*	*	–
Cyclothone pseudopallida	*	–	–
Cyclothone spp.	*	*	*
Danaphos spp.	*	–	–
Danaphos oculatus	*	*	*
Diaphus adenomus	*	–	–

Taxa	Cobb Trawl	HUFT	IKMT
Diaphus andersoni	*	*	–
Diaphus brachicephalus	*	–	–
Diaphus chrysorhynchus	*	–	–
Diaphus effulgens	–	–	*
Diaphus fragilis	*	*	*
Diaphus fulgens	–	–	*
Diaphus jenseni	*	–	–
Diaphus lucidus	*	*	*
Diaphus mollis	*	*	*
Diaphus percpicillatus	*	–	*
Diaphus phillipsi	–	–	*
Diaphus problematicus	*	*	–
Diaphus richardsoni	*	*	–
Diaphus schmidti	*	*	*
Diaphus spp.	*	*	*
Diaphus suborbitalis	*	*	*
Diogenichthys atlanticum	*	*	*
Diplophos taenia	*	*	*
Echeneidae gen. sp.	–	*	–
Echiostoma barbatum	*	–	–
Encrasicholina punctifer	*	*	*
Engyprosopon spp.	*	*	*
Eustomias sp. 1	*	*	–
Eustomias sp. 2	*	–	–
Fistularia cornuta	*	–	–
Gempylus serpens	*	*	*
Gobiidae gen. sp.	–	–	*
Gonostoma atlanticum	*	*	*
Howella spp.	–	–	*
Hygophum proximum	*	*	*
Hygophum reinhardti	*	–	*
Ichthyococcus intermedium	*	–	–
Ichthyococcus irregularis	*	–	–
Idiacanthus antrostomus	–	–	*
Idiacanthus fasciola	*	*	*
Labridae spp.	*	*	–
Lampadena luminosa	*	*	*
Lampanyctus nigrum	–	–	*
Lampanyctus nobilis	*	*	*
Lampanyctus spp.	*	*	*
Lampanyctus steinbecki	–	*	*
Lampanyctus tenuiformes	–	–	*
Leptocephalus Type I	*	*	–
Leptocephalus Type II	*	–	–
Leptocephalus Type III	*	–	–
Leptostomias spp.	*	–	–
Lestidiops spp.	–	–	*
Lestrolepis luetkeni	*	–	–
Lobianchia gemellari	*	–	–
Lutjaniade gen. sp.	*	–	–
Macrostomias pacificus	*	–	–

Taxa	Cobb Trawl	HUFT	IKMT
Malacosteidae gen. sp.	*	–	–
Malacosteus niger	*	*	–
Melamphaes longivelis	*	–	*
Melanostomias tentaculatus	*	*	–
Melanostomiidae gen. sp.	*	–	–
Mullidae spp.	*	–	–
Myctophidae unidentified	*	*	*
Myctophum asperum	*	–	*
Myctophum aurolineatum	*	–	–
Myctophum nitidulum	*	–	–
Myctophum obtusirostre	*	–	–
Myctophum orientale	–	–	*
Myctophum spinosum	*	–	–
Nannobrachium nigrum	*	–	*
Nannobrachium regale	–	–	*
Naso spp.	*	–	–
Nemichthys spp.	*	–	–
Nesiarchus nasutus	*	–	*
Notolychnus valdivae	*	*	*
Opisthopoctus soleatus	*	*	*
Paralepididae gen. sp.	*	–	–
Photonectes albipennis	–	*	–
Photostomias guerneri	*	–	–
Pomacanthidae spp.	*	–	–
Rhinecanthus spp.	*	–	–
Rhynchohyalus natalensis	*	–	–
Scombridae gen. sp.	*	*	–
Scopelarchidae gen. sp.	–	–	*
Scopeloberyx opisthopteryx	*	–	–
Scopelogadus misolepis	*	–	–
Scopelosaurus hoedti	*	–	–
Scorpaenidae gen sp.	*	–	*
Serrivomer spp.	*	*	*
Sigmops spp.	*	–	–
Sigmops elongatum	*	*	*
Sternoptyx diaphana	*	*	–
Sternoptyx spp.	*	*	*
Sygmops elongatum	*	–	–
Symbolophorus evermani	*	*	*
Synodontidae gen. sp.	*	–	–
Taaningichthys minimus	*	–	–
Thysanactis dentex	*	–	–
Triphoturus nigrescens	*	*	*
Tysanactis dentex	*	–	–
Valenciennellus spp.	*	–	–
Valenciennellus tripunctulatus	*	*	*
Vinciguerria spp.	*	*	–
Vinciguerria nimbaria	*	*	*
Vinciguerria poweria	*	–	–
Zanclus cornutus	*	–	*
Total number of taxa	123	61	65

* presence in samples

Appendix 3

MIE-AP Annual Reports

PICES Twelfth Annual Meeting
October 9–18, 2003
Seoul, Republic of Korea

2003 Report of the Advisory Panel on *Micronekton Sampling Gear Intercalibration Experiment*

Background

While a number of gears are presently being used to sample micronekton in the North Pacific and other parts of the world's oceans, there has been little effort expended in comparing the relative sampling efficiency and selectivity of these gears. At the recommendation of PICES WG 14 on *Effective sampling of micronekton*, a new PICES field effort to evaluate the efficacy of sampling gears and procedures employed by different agencies to sample micronekton in the North Pacific was launched, and the Advisory Panel on *Micronekton sampling gear intercalibration experiment* (MIE-AP) was established at PICES XI to oversee the field program. The first MIE-AP meeting/workshop was convened from 09:00 – 12:15 hours on October 11, 2003, in conjunction with PICES XII.

Workshop summary

This workshop was the first gathering of the MIE-AP members (see *MIE-AP Endnotes 1* for attendance). After short introductions of the participants, a review of the status of the related WG 14 activities (Dr. Richard D. Brodeur), and the project background (Dr. Michael P. Seki), the discussion turned to the goals, objectives, and status of the intercalibration experiment (*MIE-AP Endnote 2*).

The MIE-AP is currently planning to conduct the experiment in two phases: the first cruise in Central North Pacific waters off Hawaii just prior to PICES XIII in Honolulu, and the second cruise in waters of the Bering Sea (or possibly Gulf of Alaska) during the summer of 2005. The Hawaii cruise will serve two purposes: (1) to compare the performance of different types of sampling gears in an oligotrophic subtropical gyre to see how the choice of gear affects our perspective of the micronekton community; and (2) to use the relatively benign sea conditions of the subtropics

to evaluate and refine protocols, logistics, and sampling designs. The northern (Bering Sea) leg will sample a much more productive regime and a faunal community of great interest to many in the PICES member countries. Upon completion, an unprecedented attempt to compare the performance of gears within and between the contrasting environments will highlight the MIE-AP effort.

A commitment for a 10-day shiptime aboard the NOAA ship *Oscar Elton Sette* has been acquired in the first two weeks of October 2004 to support the first leg of the experiment, and a short presentation was made on the facilities and capabilities of the research vessel for the initial phase of the experiment. For the northern cruise in 2005, several scenarios involving other platforms were discussed, including: ships involved with the multinational NPAFC's BASIS project in the Bering Sea, Hokkaido University's R/V *Oshoro Maru*, Japan Fisheries Agency's R/V *Kaiyo Maru*, and Hokkaido National Fisheries Research Institute's "new" *Hokko Maru* scheduled for operation in 2005.

Micronekton gears currently in use by PICES member countries were identified for the experiment. Smaller single warp gear-types included the Methot (5 m^2) net, RMT 8+1, fixed frame 4 m^2 beam trawl, and Isaacs-Kidd midwater trawls (IKMT) (1.8 and 3 m varieties). All of these gears can be accommodated on the *Sette* and will be rigged for monitoring depth and temperature in real-time during operations.

For "larger" dual warp stern trawls, considered were the "Stauffer" modified Cobb trawl and the OSU 100 m^2 rope trawl. Russian scientists generally use large commercial pelagic trawls equipped with a small mesh codend liner, but shipping such a large net out of Russia may be problematic. It was decided that inquiries will be made about the availability of a net with similar

specifications in the United States for possible use. *Sette*'s Netmind mensuration system will be used for monitoring the stern trawl nets performances in the water.

A number of sampling protocols were addressed. Some of the highlights follow:
- to minimize some of the biases associated with diel sampling time, the order of operations conducted would be rotated from night to night;
- net mesh sizes would be standardized to 1 cm for all gears codends;
- tows will be conducted in a horizontal fashion at a depth to be determined in the field;
- many of the gear are designed to perform optimal at specific towing speeds and will be deployed accordingly;
- tow durations will be determined in the field; concern was expressed over the effect of tow duration on animal damage *vs*. reduction of within tow variability of catch.

Assessment of micronekton resources during the surveys will also use acoustic technologies. Specifically, MIE-AP members conducting acoustic assessments employ the Simrad EK60 equipped with two frequencies (38 and 120 kHz). Other gear-types suggested for consideration included visual methods (*e.g.*, video plankton recorders or cameras to monitor net extrusion), prototype lift nets (*e.g.*, Ocean Friendly design), and concurrent neuston nets. Traditional bongo and ring nets while generally macroplankton nets were also considered for inclusion in the experiment.

An unsuccessful attempt to obtain funding to support the experiment was made to the North Pacific Research Board (NPRB) at last year's request for proposals (RFP). A revised proposal will again be submitted to the current $3 million RFP by December 5, 2003.

Action items were identified for MIE-AP members in the weeks to come including the determination of the number of participants from each country for the cruises (particularly for inclusion in the NPRB proposal), consideration of specimen disposition and preservation requirements, and consideration to sample set replication for ensuring statistical analysis.

It was also recommended that a 1-day workshop be convened at PICES XIII, immediately after the *Sette* cruise, to review preliminary data and findings from the cruise, and discuss the goals, objectives, and status of the inter-calibration experiment and the future field program.

MIE-AP Endnote 1

<div align="center">

Participation list

</div>

Members:

Richard D. Brodeur (U.S.A.)
Kazushi Miyashita (Japan)
Vadim F. Savinykh (Russia)
Michael P. Seki (Co-Chairman, U.S.A.)
Won Duk Yoon (Korea)

Observers:

Koh Kawaguchi (Japan)
Vladimir I. Radchenko (Russia)
Orio Yamamura (Japan)

MIE-AP Endnote 2

<div align="center">

Workshop Agenda

</div>

1. Welcome and introductions
2. Status and review of the WG 14 final report
3. Background and Terms of Reference for the Advisory Panel on *Micronekton sampling gear intercalibration experiment*
4. Discussion of experiment logistics, including proposed platform(s), cruise dates, location (region) of survey, participants sampling gears to be included, experiment logistics, protocols, and analysis
5. Status of financial support status including discussion of scenarios in the absence of funding
6. Summary wrap-up and report write-up

PICES Twelfth Annual Meeting Workshop Summary

Workshop W4 (MIE-AP)
Planning a micronekton sampling gear intercalibration experiment

Co-Convenors: Michael P. Seki (U.S.A.) and Evgeny Pakhomov (Canada)

Background

While a number of gears are presently being used to sample micronekton in the North Pacific and other parts of the world's oceans, there has been little effort expended in comparing the relative sampling efficiency and selectivity of these gears. At the recommendation of PICES Working Group 14 on *Effective sampling of micronekton*, a new PICES field effort to evaluate the efficacy of sampling gear and procedures employed by different agencies to sample micronekton in the North Pacific was launched, the *Micronekton sampling gear Intercalibration Experiment* (MIE). This ½-day workshop of the MIE-Advisory Panel (MIE-AP) overseeing the field program was convened to discuss the goals, objectives, and status of the experiment, and begin the formal organization and planning process for the experiment. No formal presentations were scheduled or made at the workshop, other than a short presentation on the facilities and capabilities of the research vessel for the initial phase of the experiment.

PICES Thirteenth Annual Meeting
October 14–24, 2004
Honolulu, U.S.A.

2004 Report of the Advisory Panel on *Micronekton Sampling Inter-calibration Experiment*

The meeting/workshop of the Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) was held from 09:00-15:30 hours on October 14, 2004, and brought together the Advisory Panel members and the participants on the first MIE cruise conducted off Hawaii (*MIE-AP Endnote 1*). After the opening of the meeting by Dr. Michael P. Seki, MIE-AP Co-Chairman, and short introductions by attendees, a background overview of MIE-AP and review of the project to date ensued. The discussion then focused on the activities, preliminary results, lessons learned from the cruise and next steps (*MIE-AP Endnote 2*).

Meeting/workshop summary

The MIE-AP was established at PICES XI (2002) to evaluate the efficacy of sampling gears and the procedures employed by different investigators to sample micronekton in the North Pacific and other parts of the world's oceans (*MIE-AP Endnote 3*). An initial field effort involved an 8-day (October 6–13, 2004) research cruise in Hawaiian waters just prior to PICES XIII, herein referred to as MIE-I. This cruise served two purposes: (1) to compare the performances of different types of sampling gears in an oligotrophic subtropical gyre area to see how the choice of gear affects our perspective of the micronekton community; and (2) to use the relatively benign weather and sea conditions to evaluate and refine the protocols, logistics and design of the sampling. The workshop reviewed preliminary data and findings from the cruise, and the MIE-AP meeting that followed discussed the goals, objectives and status of the future field program.

MIE-I was conducted aboard the NOAA ship *Oscar Elton Sette* in Central North Pacific waters off the west side of Oahu Island. Participants on the cruise included: Michael P. Seki (Chief Scientist), Richard D. Brodeur, Daniel Curran, Reka Domokos and Donald Hawn (U.S.A.);

Douglas Yelland, Evgeny Pakhomov and Larissa Pakhomova (Canada); Masayuki Abe and Hiroki Yasuma (Japan); and Andrei Suntsov (Russia).

Three gear-types were employed in the comparison: a dual trawl warp 140 m^2 Stauffer modified Cobb trawl, the single warp 1.8 m Isaacs-Kidd mid-water trawl, and the single warp 2 m variety of Hokkaido University's Rectangular Frame trawl. During all tows, acoustic backscatter was monitored and data recorded with a Simrad EK-60 echosounder equipped with 38 kHz and 120 kHz transducers. For daytime tows, trawls were dropped to the target depth (550 m) and towed horizontally for 1 hour (contamination by animals in the catch on the ascent and descent to depth was assumed to be minimal). For nighttime tows, trawls were dropped to the desired depth as defined by acoustic scattering (*ca*. 120 m), and retrieved obliquely through the water column for a 1-hour duration, and the tow ending with the net at the surface. Since only a fraction of the sound scattering layer (SSL) was observed to migrate to shallow waters at night, a series of trawls were also conducted at depth (*ca*. 550 m) during the night, to acquire information of the non-migrants and composition of the SSL with respect to acoustic measurements. The real-time net depths during the tows were monitored with a Northstar NETMIND net mensuration system.

A variety of topics were addressed during discussion, and some of the highlights and recommendations follow.

Lessons learned from MIE-I
- The Panel deemed that it was important to note that MIE-I was accomplished without financial support; all support for the successful execution of the cruise was furnished by the participating agencies.
- The cruise was fortunate to have had specialists for each faunal group among the participating scientific field party. When

planning future cruises, having this expertise is strongly recommended and needs to be considered at the planning stages.

- The leads for various aspects of the cruise data (*e.g.*, biological specimen detailed processing – species identification and measurements for faunal groups) were identified. These include fishes (Suntsov), crustaceans (Pakhomov), cephalopods (Seki), and acoustics (Yelland).

- Preliminary analysis from MIE-I indicated that individual gears sampled different, often non-overlapping, size groups of plankton and micronekton. It points out that successful inter-comparison during future cruises requires a closer scrutiny of gear-types and net mesh sizes prior the experiment.

- The Panel agreed that "what one defines as micronekton may not be the same definition as someone else". MIE-I planning encouraged participants to bring their micronekton sampling gear which resulted in a range of mesh sizes and abilities to sample. On the positive side, the ability of the cumulative gears to sample the full range from mesozooplankton to micronekton enhanced the ability to interpret the data acquired from the multiple acoustic frequencies.

- The Panel suggested the adoption of a "standard" sampling gear (*e.g.*, RMT 1+8 or a 3-m IKMT) and mesh sizes to allow and guide comparisons for future efforts. For higher acoustic frequencies, a towed transducer to access the deeper depths was recommended.

Plans for MIE-II

- Based on the success and preliminary findings of the first cruise, MIE-AP recommended conducting a second experiment within the subarctic North Pacific using a larger variety of micronektonic sampling gears. This cruise is tentatively planned for the summer of 2005 or 2006, depending on ship time availability, in the Bering Sea (or possibly the Gulf of Alaska or the western North Pacific). This leg will sample a much more productive regime and a faunal community of great interest to many in the PICES member countries. Upon completion, an unprecedented attempt should be made to compare the performance of gears within and between the contrasting environments. This will highlight the MIE-AP effort.

- Dr. Orio Yamamura has requested shiptime aboard the Japan Fisheries Agency research ship *Kaiyo Maru* for conducting MIE-II during the summer of 2005. A decision is expected by the end of the current calendar year on whether the ship time will be awarded.

- The Panel suggested exploring the possibility of joining one of the BASIS cruises to the Bering Sea to accommodate the MIE-II sampling.

- The Panel also recommended pursuing shiptime aboard the NOAA ships *Oscar Dyson* or *Miller Freeman* or Hokkaido University research vessel *Oshoro Maru*. Since most of the sailing schedules for these ships are already set for 2005, any cruise aboard these ships would target the summer of 2006.

- The Advisory Panel discussed using large opening/closing type nets such as the RMT1+8 and the 4 m^2 MOCNESS, or some other similar gear so that vertically stratified tows can be made during MIE-II.

Publications

- A brief report on MIE-AP activities will be published in the next issue of PICES Press (January 2005).

- A data report containing the detailed processed results from MIE-I will be prepared and a draft completed in time for review at PICES XIV (Vladivostok, Russia). Dr. Seki will take the lead in compiling the information from all contributors. The targeted outlet will be the PICES Scientific Report Series.

- Several formal publications will evolve from MIE-I, but until the detailed processing is completed, a timetable for primary products is very difficult to assemble and will be deferred until better assessment of processing requirements can be accomplished. This will be revisited at PICES XIV.

Proposals

- Another attempt will be made at obtaining financial support for MIE activities from the North Pacific Research Board through the 2004-05 request for proposals process. Dr. Pakhomov will take the lead in preparing the proposal package seeking support for MIE-II either in the summer of 2005 or 2006, depending on platform availability.

MIE-AP membership
- Dr. Pakhomov to continue as Co-Chairman, while Dr. Seki to step down as Co-Chairman but remain a MIE-AP member. The Panel will seek a new Co-Chairman who has expertise working in the subarctic Pacific and/or Bering Sea, the most likely regions to conduct the MIE-II cruise.
- Dr. Yamamura to joint MIE-AP as a member and possibly as Co-Chairman to replace Dr. Seki.
- Nomination of additional members to be requested from all PICES member countries.

MIE-AP Endnote 1

Participation List

Members

Richard D. Brodeur (U.S.A.)
Kazushi Miyashita (Japan)
Evgeny A. Pakhomov (Canada, Co-Chairman)
Vadim Savinykh (Russia)
Michael P. Seki (U.S.A., Co-Chairman)

Observers

Masayuki Abe (Japan)
Reka Domokos (U.S.A.)
R. Ian Perry (Science Board Chairman)
Andrei Suntsov (Russia)
Hiroki Yasuma (Japan)
Douglas Yelland (Canada)

MIE-AP Endnote 2

Workshop Agenda

1. Welcome and introductions
2. Background and Terms of Reference for the Advisory Panel on *Micronekton sampling inter-calibration experiment*
3. Review of cruise activities, sampling, and status of the data and analysis
4. Discussion on the second MIE-AP cruise logistics, including possible platform(s), dates, participants, region of experiment, sampling gears, sampling protocols, sample analysis and disposition
5. Status of financial support status including discussion of scenarios in the absence of funding
6. Summary wrap-up and report write-up

MIE-AP Endnote 3

Terms of Reference for Advisory Panel on
Micronekton sampling inter-calibration experiment

1. Develop a proposal for a micronekton sampling inter-calibration experiment, arising from the work of PICES WG 14 on *Effective sampling of micronekton*. Advise on appropriate locations as well as identify micronekton sampling gears and other quantifying technologies for inclusion in the inter-calibration experiment.
2. Facilitate the experiment by identifying and securing commitments for resources (personnel and ships) to ensure success of the experiment; provide technical advice in development of sampling protocols and experimental design.
3. Oversee post-survey analysis of samples and data; provide guidance in preparation of results for final report and publication(s).

PICES Thirteenth Annual Meeting Workshop

Workshop and Advisory Panel Meeting W1 (MIE-AP)
Micronekton Sampling Gear Inter-calibration Experiment

Co-Convenors: Michael P. Seki (U.S.A.) and Evgeny Pakhomov (Canada)

The PICES Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) was established to evaluate the efficacy of a variety of sampling gears and the procedures employed by different investigators to sample micronekton in the North Pacific and other parts of the world ocean. An initial field effort will involve a 10-day (October 4–13, 2004) research cruise in Hawaiian waters just prior to the PICES Thirteenth Annual Meeting in Honolulu. The Hawaii cruise will serve two purposes: (1) to compare the performance of different types of sampling gears in an oligotrophic subtropical gyre to see how the choice of gear affects our perspective of the micronekton community; and (2) to use the relatively benign sea conditions of the subtropics to evaluate and refine protocols, logistics, and sampling designs. The morning workshop will review preliminary data and findings from the cruise, while the afternoon meeting of the MIE-Advisory Panel will discuss the goals, objectives, and status of the experiment and the future field program.

PICES Fourteenth Annual Meeting
September 29–October 9, 2005
Vladivostok, Russia

2005 Report of the Advisory Panel on *Micronekton Sampling Inter-calibration Experiment*

The Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) has been focusing on fieldwork and did not convene meetings or workshops in 2005.

Membership changes

Since PICES XIII, several changes in membership have occurred to the Advisory Panel. New members include Drs. Alexei Baitalyuk and Oleg Ivanov of the Pacific Fisheries Research Center (TINRO-Center) representing Russia, and Dr. Orio Yamamura of the Hokkaido National Fisheries Research Institute representing Japan. Dr. Yamamura has also been appointed to co-chair MIE-AP replacing Dr. Michael Seki, who stepped down as Co-Chairman but remains as a member of the Panel.

Inter-sessional report, March 2005

Dr. Michael Seki summarized the activities and plans of MIE-AP in March 2005, prior to the inter-sessional Science Board/Governing Council meeting After the successful completion of the initial MIE-1 in Hawaiian waters just prior to PICES XIII, the Panel began plans to conduct the experiment (MIE-2) in waters of the Bering Sea (possibly in conjunction with a BASIS cruise), Gulf of Alaska, or the temperate waters of the western Pacific. A second attempt to obtain funding from the North Pacific Research Board through the 2004–05 request for proposals was not successful. Nevertheless, Dr. Yamamura offered two cruises in 2005 (July 5–11 and September 27-October 3) aboard the Hokkaido University research ship, *Hokko Maru,* to conduct MIE-2 in waters of the western Pacific off Kushiro, Japan. The R/V *Hokko Maru* is a state-of-the art 200' stern trawler (905t) equipped with a MOCNESS-10 (enabling discrete depth sampling) and capabilities to deploy other mid-water sampling gear including stern trawls equipped with a MULTI-SAMPLER (an opening-closing multiple codend system). Transit time to sampling sites

would be minimal at just 30 minutes after departure from Kushiro. At that time (March 2005), no firm decisions have been made with regard to proceeding with MIE-2. As for MIE-1, processing of samples collected on the cruise continues.

Status Report at PICES XIV

Drs. Evgeny Pakhomov and Orio Yamamura (MIE-AP Co-Chairmen) provided an update of activities and plans for the period from the inter-sessional report until PICES XIV.

MIE-1 cruise

In 2005, samples collected during the MIE-1 cruise in Hawaiian waters have been transported to the University of British Columbia, where detailed analysis of the sample size-structure has been carried out. Presently, the catch size-structure analysis is in its final stage, and Dr. Pakhomov is going to present the findings at the BIO Committee meeting in Vladivostok.

MIE-2 cruise

Just prior to PICES XIV, the second MIE cruise (MIE-2) took place. The cruise, provisionally scheduled for September 27 to October 3, on board R/V *Hokko Maru* was extended by 2 days and was conducted between September 25 and October 3, 2005. Dr. Yamamura served as the Chief Scientist. The cruise started and ended at Kushiro. The experiment was conducted in the Doto area where the cold Oyashio current prevails. This area represents a relatively simple and stable species composition of micronekton, which makes it fairly easy to compare sampling efficiency of different gears. Since the areas where nets have to be deployed are just 1–2 h sail from the port of Kushiro, it was possible to split the cruise into two legs to accommodate those who can participate in either the first or second half of the cruise only.

The nets deployed in the experiment include MOCNESS-10, 10 ft IKMT, HUFT (Hokkaido University Frame Trawl), MOHT, and mid-water otter trawling net with a mouth opening of *ca*. 30 × 30 m and opening/closing multiple codends. The R/V *Hokko Maru* is equipped with a Simrad EK-60 echosounder that can monitor and record backscattering from micronekton.

MIE-3 cruise

Plans for the 2006 (MIE-3) cruise in the Bering Sea are proposed to coincide with the 2006 NPAFC BASIS program activities in this area. A formal letter has been sent to NPAFC representatives to determine if there is any interest in doing a joint cruise to the Bering Sea in 2006 using one of the BASIS project vessels.

The initial response is promising. Dr. Richard Brodeur is planning to meet with NPAFC representatives at the joint NPAFC/PICES Symposium in November 2005 to discuss the MIE-3 cruise proposal. Attempts will be made to obtain financial support for MIE-3 from the North Pacific Research Board during 2006. So far, no financial support has been obtained for these experiments.

MIE Workshop and Topic Session at PICES XV

As the dates of the MIE-2 cruise overlap, in part, with PICES XIV, there will be no MIE workshop and business meeting this year. At the next PICES Annual Meeting in Yokohama, MIE-AP would like to convene a 1-day BIO Workshop on "*Synthesis of MIE-AP sampling inter-calibration experiments*" (*MIE-AP Endnote 1*) and a 1-day BIO Topic Session on "*Micronekton biology: Advances in epi- and meso-pelagic ecosystem research*" (*MIE-AP Endnote 2*).

MIE-AP Endnote 1

Proposal for a 1-day BIO (MIE-AP) Workshop at PICES XV on
"*Synthesis of MIE-AP sampling inter-calibration experiments*"

The Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) was established to evaluate efficiency of a variety of sampling gears and procedures employed by different investigators to sample micronekton in the North Pacific and other parts of the world ocean. Two MIE-AP gear inter-calibration experiments were conducted in 2004 (MIE-1 cruise on board of R/V *Oscar Elton Sette*, in Hawaiian waters) and in 2005 (MIE-2 on board of R/V *Hokko Maru*, in the Oyashio region). The proposed workshop will review and synthesize findings from these two successful sampling experiments.

Recommended convenors: Evgeny Pakhomov (Canada) and Orio Yamamura (Japan).

MIE-AP Endnote 2

Proposal for a 1-day BIO (MIE-AP) Topic Session at PICES XV on
"*Micronekton biology: Advances in epi- and meso-pelagic ecosystem research*"

Micronekton is an important component of epi- and meso-pelagic ecosystems linking meso-zooplankton and higher trophic levels. Due to their intermediacy and mobility, quantitative sampling of micronekton has long been regarded as virtually impossible. Recent advances in acoustic devices and efforts in standardizing sampling gear have made the sampling of micronekton more precise. In the PICES area, various ongoing projects such as BASIS (NPAFC), US-GLOBEC and DEEP (Japan FRA) are studying micronekton. The session will synthesize new knowledge on micronekton biology including distribution, life history and vertical migrations, relationships with commercial species and its functional role in the North Pacific boundary current and open ocean ecosystems. Presentations on quantitative sampling are also welcome.

Recommended convenors: Evgeny Pakhomov (Canada) and Orio Yamamura (Japan).

PICES Fifteenth Annual Meeting
October 13–22, 2006
Yokohama, Japan

2006 Report of the Advisory Panel on *Micronekton Sampling Gear Inter-calibration Experiment*

The PICES Advisory Panel on *Micronekton sampling inter-calibration experiment* (hereafter MIE-AP) was established to evaluate efficacy of sampling gears and the procedures employed by different investigators to sample micronekton in the North Pacific and other parts of the world's oceans.

MIE-AP met on the morning of October 13, 2006. After brief introductions of the participants (*MIE-AP Endnote 1*), a total 4 presentations were made on the results and data processing from the two field experiments organized by the Panel in 2004 and 2005, followed by questions and brief discussions on future activities (*MIE-AP Endnote 2*).

MIE-AP workshop (Agenda Items 2 and 3)

The workshop (W9) reviewed data and results from the MIE-1 cruise (off the west side of Oahu Island, Hawaii, October 6–13, 2004) and the MIE-2 cruise (in Oyashio waters off Japan, September 27–October 3, 2005). Sample processing and analysis was discussed, as were other sampling gears to be compared, and plans for the MIE-3 experiment. The summary of the workshop can be found in the *Session Summaries* chapter of this Annual Report.

MIE-AP future activities (Agenda Item 4)

Further data analysis

Although substantial progress has been achieved in the analysis of the MIE-1 and MIE-2 data, further analyses are required. In particular:
- The size-structure approach used by Dr. Evgeny Pakhomov for the MIE-1 data could be applied to the MIE-2 data sets.
- An inter-comparison between the MIE-1 and MIE-2 data should be attempted.
- The acoustic data need to be analyzed and compared in the light of gear densities. At first, this should be done separately for each cruise.

Other sampling gears to be tested

- The results of the MIE-2 experiment revealed that the MOHT gear is among the most reliable and cost-effective micronekton gear developed to date, providing high quality and quantity micronekton samples. The development of a closing/opening mechanism could put this gear in the position to become a standard micronekton gear in the North Pacific and elsewhere in the world.
- It has been noted that the RMT-8 gear, as well as Russian micronekton sampling gear, should be included in future experiments to allow comparisons.
- Dr. Hiroya Sugisaki presented some preliminary results on the development a novel technology (a combination of acoustic and high resolution video imaging) to quantify deep-sea micronekton. MIE-AP felt that this technology could be beneficial and encouraged Dr. Sugisaki to describe the preliminary results of trials during the next PICES Annual Meeting.

Possibility of the MIE-3 experiment

MIE-AP felt strongly that a third experiment (MIE-3) is required to complete the geographical coverage, and to include gear types that were missed during the first two inter-comparisons. The major problem at the moment is the availability of ship time, and in this regard MIE-AP suggests pursuing three options:
- MIE-AP should work towards establishing a joint NPAFC-PICES research activity on micronekton sampling and conduct MIE-3 in the Bering Sea. Initial and encouraging contacts have already been made and will be followed in the forthcoming year.
- Dr. Orio Yamamura will apply for ship time (likely for R/V *Hokko-Maru*) to carry out the MIE-3 experiment off Japan.

- The possibility of obtaining ship time for the MIE-3 experiment either in the Bering or Okhotsk Sea should be negotiated with the Russian Delegation.

In the light that the Panel activities will largely be concentrated in the northern Pacific seas, MIE-AP felt strongly that the membership of the Advisory Panel should be increased, particularly from Russia and the United States.

Proposal of workshop/session at PICES XVI

MIE-AP proposed to convene a workshop at PICES XVI on "*Lessons learned during MIE-1 and MIE-2: Reconciling acoustics and trawl data*" with the objectives of (a) finalizing MIE-1 and MIE-2 analyses, (b) presenting and discussing acoustic data sets from both cruises, (c) comparing ICES and PICES inter-calibration experiments, and (d) discussing recent developments in the field of micronekton quantitative techniques (*MIE-AP Endnote 3*). Travel funds from PICES are requested for two invited speakers.

MIE-AP Endnote 1

Participation list

Members

Richard D. Brodeur (U.S.A.)
Kazushi Miyashita (Japan)
Evgeny A. Pakhomov (Canada, Co-Chairman)
Orio Yamamura (Japan, Co-Chairman)

Observers

Yoshioki Oozeki (Japan)
Larissa Pakhomova (Canada)
Hiroya Sugisaki (Japan)
Andrei V. Suntsov (Russia)
Hiroki Yasuma (Japan)

MIE-AP Endnote 2

MIE-AP meeting agenda

1. Welcome and introductions
2. MIE-1 results and data processing:
   - E.A. Pakhomov, M.P. Seki, A.V. Suntsov, R.D. Brodeur and K.R. Owen. *Comparison of three sampling gears during the first Micronekton Intercalibration Experiment (MIE-1): Size composition of selected taxonomic groups and total macroplankton and micronekton*
   - A.V. Suntsov, M.P. Seki, E.A. Pakhomov and R.D. Brodeur. *Diversity and abundance of Hawaiian ichthyoplankton: Comparison of three types of midwater net*s

3. Discussion on MIE-2 results and data processing:
   - O. Yamamura, H. Sugizaki, S. Abe, K. Sadayasu, R.-I. Matsukura, K. Miyashita, A. Hino and T. Tokai. *Inter-calibration of micronekton sampling gear during the 2005 MIE-2 cruise*
   - H. Yasuma, K. Miyashita and O. Yamamura. *Acoustic identification and density estimate of a lanternfish,* Diaphus theta*, off Hokkaido, Japan*
4. Discussion on future MIE-AP activities:
   a. further data analysis
   b. other sampling gears to be tested
   c. possibility of the MIE-3 experiment
   d. workshop/sessions at PICES XVI

MIE-AP Endnote 3
Proposal for a ½ or ¾ -day workshop at PICES XVI on
"Lessons learned during MIE-1 and MIE-2: Reconciling acoustics and trawl data"

Micronekton is one of the important but largely understudied components of marine ecosystems functionally linking small zooplankton and higher trophic levels. Recent advances in acoustic devices and efforts to standardize sampling gears undertaken by both PICES and ICES communities have made the sampling of micronekton more precise. Nevertheless, the issue of inter-calibrating the growing number of micronektonic gears is still unresolved. The PICES Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) organized two field experiments (off Hawaii in 2004 and off Japan in 2005) to collect comparative data for several micronekton sampling gears and a wealth of acoustic information. The main objective of this workshop will be: (1) to finalize the analysis and to compare MIE-1 and MIE-2 data sets; (2) to present and discuss acoustic data sets from both cruises; (3) to compare ICES and PICES inter-calibration experiments; and finally (4) to discuss new developments in the field of micronekton quantitative techniques.

Recommended convenors: Evgeny A. Pakhomov (Canada) and Orio Yamamura (Japan).

PICES Fifteenth Annual Meeting Workshop Summary

MIE-AP Workshop W9
Micronekton sampling gear inter-calibration experiment

Convenors: Evgeny A. Pakhomov (Canada) and Orio Yamamura (Japan)

Background

The PICES Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) was established to evaluate efficacy of sampling gears and the procedures employed by different investigators to sample micronekton in the North Pacific and other parts of the world's oceans. MIE-AP carried out their first 8-day cruise from October 6–13, 2004, aboard the NOAA ship *Oscar Elton Sette* in Central North Pacific waters off the west side of Oahu Island (MIE-1). The second cruise (MIE-2) took place from September 27 to October 3, 2005, on board R/V *Hokko Maru* in Oyashio waters off Japan. The workshop reviewed data and findings from both cruises.

Summary of presentations

Pakhomov *et al*. recommended pursuing the use of larger size-classes of micronekton (10 mm instead of 5 mm) for inter-comparison of gears. They noted that the Cobb trawl mouth area should be adjusted according to the mesh size, which really catches micronekton. The use of total mouth area can result in underestimating plankton and micronekton densities. It was suggested that perhaps acoustic data should be encouraged to become an "ideal" universal gear.

Suntsov *et al*. provided a remarkable overview of ichthyoplankton and an inter-comparison of their diversity between different gears. It also appears

from their research that the Hokkaido net was the best gear for the quantitative and qualitative sampling of fish larvae. Two important questions were raised in this presentation: (a) What kind of analysis (*e.g*. community structure analysis) could be conducted with the data sets? and (b) Would further analysis of the adult population be beneficial for the community analysis of larvae?

Yamamura *et al*. compared six different sampling gears during their MIE-2 cruise. Sample composition, to a large extent, was mono-specific, which simplified the inter-calibration. Their experiment revealed that the MOHT gear is among the most reliable and cost-effective micronekton gear developed to date, providing high quality and quantity micronekton samples. The development (in progress) of a closing/opening mechanism could put this gear in the position to become a standard micronekton gear in the North Pacific and elsewhere in the world. It was also found that towing speed matters, *e.g*. MOHT had the fastest towing speed, which raises standardization issues.

Yasuma *et al*. presented very encouraging results of developing a technique for an acoustic identification of myctophid fishes. The inter-comparison between acoustic and gear estimates of micronekton was highly recommended as the next step. Concern was raised on how organism orientation affects the target strength estimates. Authors were strongly encouraged to continue their analyses.

List of papers

Oral presentations

Evgeny A. Pakhomov, M.P. Seki, A.V. Suntsov, R.D. Brodeur and K.R. Owen
Comparison of three sampling gears during the first Micronekton Intercalibration Experiment (MIE-1): Size composition of selected taxonomic groups and total macroplankton and micronekton

Andrey V. Suntsov, Michael P. Seki, Evgeny A. Pakhomov and Richard D. Brodeur
Diversity and abundance of Hawaiian ichthyoplankton: Comparison of three types of midwater nets

Orio Yamamura, Hiroya Sugizaki, Shin-suke Abe, Kazuhiro Sadayasu, Ryu-ichi Matsukura, Kazushi Miyashita, Akihiro Hino and Tadashi Tokai
Inter-calibration of micronekton sampling gear during the 2005 MIE-2 cruise

Hiroki Yasuma, Kazushi Miyashita and Orio Yamamura
Acoustic identification and density estimate of a lanternfish, *Diaphus theta,* off Hokkaido, Japan

PICES Sixteenth Annual Meeting
October 26–November 5, 2007
Victoria, Canada

2007 Report of the Advisory Panel on *Micronekton Sampling Inter-calibration Experiment*

A subset of the Advisory Panel on *Micronekton Sampling Inter-calibration Experiment* (hereafter MIE-AP) and several observers (*MIE-AP Endnote 1*) met on the evening of October 28, 2007, immediately after the BIO workshop on "*Lessons learned during MIE-1 and MIE-2: Reconciling acoustics and trawl data*". Details of this workshop (W1) can be found in the *Session Summaries* chapter of this Annual Report. Discussion topics of the MIE-AP meeting are listed in *MIE-AP Endnote 2*.

Developments in micronekton quantification (Agenda Item 1)

Models were developed to predict backscattering volume to allow for comparisons between acoustic data and the net data. The new system, J-QUEST, was shown to quantify the epipelagic micronekton and nekton but appeared to be inefficient in detecting the mesopelagic fishes, and myctophids in particular. The discussion revolved around the possibility of using a red light or another part of the light spectrum to which myctophids are less sensitive. Experimental trials indicated that myctophids were able to detect and avoid J-QUEST while it used red light.

After briefly reviewing current sampling gears, present information points to the Matsuda–Oozeki–Hu Trawl (MOHT) gear as being among the most reliable and cost effective micronekton gears to date. It provides high quality and quantity micronekton sampling. Dr. Hiroya Sugisaki reported that the development of a closing/opening mechanism is underway (trials are to be conducted within months). Equipping MOHT with the opening/closing mechanism on the codend could put this gear in the position to become a standard micronekton gear world-wide, and in the North Pacific, in particular.

Comparison between ICES and PICES inter-calibration experiments (Agenda Item 2)

After a brief review of both ICES and PICES micronekton inter-calibration experiments, the Panel concluded that it is generally impossible to undertake a comparison of these experiments due mainly to incomparable gears used for sampling, and because the ICES experiment concentrated on mesozooplankton in a fjord system in Norway.

Progress on acoustic data analyses (Agenda Item 3)

Acoustic data from the MIE-2 cruise (Oyashio waters off Japan, September 27–October 3, 2005) are mostly analyzed and reconciled with the trawl data. Acoustic data collected during the MIE-1 cruise (off the west side of Oahu Island, Hawaii, October 6–13, 2004) still require some work and cleaning. Data collected during the MIE-3 cruise (the eastern Bering Sea, September 18–27, 2007) have yet to be released by the U.S. colleagues who provided the vessel. The data will be analyzed jointly by Japanese and U.S. scientists.

Compatibility of acoustic and trawl data (Agenda Item 4)

Preliminary results indicate that the comparability of the trawl and acoustic estimates is low. This points to problems associated with both sampling techniques, which have been discussed. The closest results were obtained between MOHT and acoustics. MIE-AP felt that research to improve the acoustics estimates should be continued.

Overview of MIE-3 (Agenda Item 5)

The third micronekton inter-calibration experiment (MIE-3) was carried out onboard the R/V *Oscar Dyson* in the eastern Bering Sea, from September

18–27, 2007. The ship was engaged in the BASIS (Bering-Aleutian Salmon International Surveys) program under NPAFC, (North Pacific Anadromous Fish Commission) operated by the Auke Bay Laboratory, NOAA/NMFS. Dr. Jim Murphy kindly donated the ship time for the micronekton experiment. This experiment was led by Dr. Orio Yamamura (Hokkaido National Fishery Research Institute, Japan). Other participants included: Drs. Hiroki Yasuma (Hokkaido University, Japan) and Andrey Suntsov (Northwest Fisheries Science Center, U.S.A.).

The sampling gears planned to be compared were the 1.8-m Isaacs–Kid mid-water trawl (IKMT), MOHT and Cantrawl 300/262 rope trawl. However, due to the limited time available for the experiment, only IKMT and MOHT were used. A comparison between IKMT and MOHT was essential because there are so much historical data collected with an IKMT. Aside from the sampling gears, backscattering data were recorded using a Simrad EK-60 echosounder with 15, 38, 70, 120 and 200 kHz transducers.

Due to rough seas, the ship time assigned for the experiment was reduced to 24 hours. Therefore, the nets were deployed at a 60-m depth station near St. Paul Island instead of near the shelf break of the eastern Bering Sea. The sampling was in a day/night sequential design, with different gears towed sequentially at each location, with triplicate samples collected during daylight and night at the same ship speed (3 knots).

The catch was exclusively dominated by age-0 walleye pollock (>99%), offering a good opportunity for gear comparison. The nets showed similar catchability during daytime (1.1 times larger for MOHT in density estimate), but MOHT showed significantly higher catchability in night sampling (2.8 times higher). In the comparison of body length frequency distribution, MOHT caught slightly larger fish than IKMT, suggesting net avoidance from the latter net.

The echo sounding data are yet to be released by the U.S. colleagues and will be analyzed jointly by Japanese and U.S. scientists.

Future activities (Agenda Item 6)

The members of MIE-AP felt that there will be no further inter-calibration experiments. It appears to be extremely difficult to obtain ship time, and the Panel expressed its gratitude to the member countries that donated the ship time to conduct three experiments. The participants also concluded that much of the data have been worked up at this point, and some encouraging results were obtained.

There was unanimous agreement for the suggestion that it was time to prepare the final MIE-AP report and to write related publications in the peer-reviewed literature. It was suggested that some travel funds should be requested to facilitate the data analysis. In particular, the identification of fish and crustaceans collected during the MIE-1 cruise should be completed before writing the final report. In this regard, MIE-AP requested PICES to cover travel expenses for Dr. Suntsov to come from the Northwest Fisheries Science Center (Newport, Oregon) to the University of British Columbia (Vancouver) for 7–10 days to assist with fish identification. Furthermore, the MIE-3 cruise data need to be worked up.

Realistically, an advanced report on the MIE-AP activities could be available at the next PICES Annual Meeting in Dalian, China. Most of the work has been divided between groups of experts, and MIE-AP Co-Chairmen were charged with the task of overseeing the progress. To facilitate the development of the final report, MIE-AP requested financial support for one of Co-Chairmen (Dr. Evgeny Pakhomov) to travel to Dalian.

Below is a preliminary draft of the MIE-AP final report structure (the names listed in parentheses are responsible for writing each section):
1. Introduction, background, major idea of micronekton inter-calibration experiments (Brodeur, Pakhomov, Yamamura)

2. MIE-1
   - Description of the experiment
   - Composition and diversity indices of the samples: crustaceans (Pakhomov, Brodeur), fish (Suntsov), squid (Seki)
   - Abundance and (biomass) of the micronekton
   - Size structure (Pakhomov)

- Acoustic data (Domokos)
- Inter-comparison between gears and between gears and acoustics (All, lead: Pakhomov, Domokos)

3. MIE-2
- Description of the experiment
- Composition and diversity indices of the samples: crustaceans (Yamamura), fish (Yamamura), squid (Yamamura)
- Abundance and (biomass) of the micronekton
- Size structure (Yamamura)
- Acoustic data (Yasuma)
- Inter-comparison between gears and between gears and acoustics (lead: Yamamura)

4. MIE-3
- Description of the experiment
- Composition and diversity indices of the samples: crustaceans (Yamamura), fish (Suntsov, Yamamura), squid (Yamamura)
- Abundance and (biomass) of the micronekton (Yamamura)
- Size structure (Yamamura, Suntsov)
- Acoustic data (Yasuma)
- Inter-comparison between gears and between gears and acoustics (lead: Yamamura)

5. General conclusions and recommendations.

MIE-AP Endnote 1

Participation list

Members

Richard D. Brodeur (U.S.A.)
Kazushi Miyashita (Japan)
Evgeny A. Pakhomov (Canada, Co-Chairman)
Orio Yamamura (Japan, Co-Chairman)

Observers

Seok-Gwan Choi (Korea)

Reka Domokos (U.S.A.)
Yasuzumi Fujimori (Japan)
Hideki Hamaoka (Japan)
Julian A. (Tony) Koslow (U.S.A.)
Todd W. Miller (U.S.A.)
A. Jason Phillips (U.S.A.)
Hiroaki Saito (Japan)
Hiroya Sugisaki (Japan)
Andrei V. Suntsov (U.S.A.)
Hiroki Yasuma (Japan)

MIE-AP Endnote 2

MIE-AP meeting agenda

1. New developments in the field of micronekton quantification: Could acoustics be the way forward?
2. Is it possible to undertake a comparison between ICES and PICES inter-calibration experiments?
3. How far are we in the acoustic data set analyses?

4. Compatibility of acoustic and trawl data: Caveats, problems and solutions
5. Lessons from the MIE-3 cruise
6. An inter-sessional workshop to look at the data from 3 inter-calibration experiments and to discuss drafting of the MIE-AP report (schedule, contents and allotment of writers)

PICES Sixteenth Annual Meeting Workshop Summary

BIO Workshop (W1)
Lessons learned during MIE-1 and MIE-2: Reconciling acoustics and trawl data

Co-Convenors: Evgeny A. Pakhomov (Canada) and Orio Yamamura (Japan)

Background

Micronekton is one of the important but largely understudied components of marine ecosystems functionally linking small zooplankton and higher trophic levels. Recent advances in acoustic devices and efforts to standardize sampling gears undertaken by both PICES and ICES communities have made the sampling of micronekton more precise. Nevertheless, the issue of inter-calibrating the growing number of micronektonic gears is still unresolved. The PICES Advisory Panel on *Micronekton Sampling Inter-calibration Experiment* (MIE-AP) organized two field experiments (off Hawaii in 2004 and off Japan in 2005) to collect comparative data for several micronekton sampling gears and a wealth of acoustic information. The main objective of this workshop was: (1) to finalize the analysis and to compare MIE-1 and MIE-2 data sets; (2) to present and discuss acoustic data sets from both cruises; (3) to compare ICES and PICES inter-calibration experiments; and finally (4) to discuss new developments in the field of micronekton quantitative techniques.

Summary of presentations

Two contributions on the analysis of acoustic data described attempts to compare acoustic data with the densities of micronekton estimated by trawling during MIE-1 and MIE-2 cruises. The main conclusion was that the acoustic data represented an important technique to quantify micronekton. While showing some significant progress, both failed to reconcile the acoustic and trawl data. The main problems were associated with:
- additional noise induced by other acoustic systems during the MIE-1 experiment;
- absence of target strength measurements for the micronekton species (particularly for MIE-1); and

- undersampling the micronekton due to net avoidance or loss of gelatinous zooplankton (both MIE-1 and MIE-2).

J-QUEST technology for observing and quantifying micronekton using acoustics and video appeared to be very advantageous for resolving some outstanding issues between acoustic and trawl density assessments, although it still has some difficulties in species identification of micronekton. MIE-AP concluded that using acoustics in a diverse community (*e.g.* MIE-1) requires numerous measurements of the individual species target strengths. The absence of such measurements translates into large discrepancies between acoustic and trawl density estimates. At the same time, when only a few species dominate the micronekton community (*e.g.* MIE-2), it is possible to achieve reasonable agreement between acoustic and trawl density estimates. It was concluded that a newly developed MOHT net appears to be consistently the best sampling gear for micronekton and perhaps should be recommended as a standard gear for use by PICES nations to collect micronekton.

After looking at the intercomparison of gears used during the MIE-1 and MIE-2 cruises, MIE-AP concluded that when a small number of species (or a single species) was dominant in micronekton community, the intercalibration between gear types appeared to be a relatively straight forward exercise. The catchability ratios between gear types produced comparable densities. However, in a highly diverse community, as it was during MIE-1, only the size composition data of large taxonomic groups lumped into 10-mm size intervals can be compared quantitatively with any success. This approach allowed the calculation of intercalibration coefficients between three gear types used during MIE-1 and yielded relatively accurate (within 12–30%) intercomparison of micronekton densities obtained by different gears.

List of papers

Oral presentations

Réka <u>Domokos</u>, Evgeny A. Pakhomov, Michael P. Seki and Jeffrey J. Polovina (Invited)
Acoustic characterization of the mesopelagic community off the Leeward coast of Oahu, Hawaii

Hiroki <u>Yasuma</u>, Kazushi Miyashita and Orio Yamamura
Acoustic monitoring of a lanternfish *Diaphus theta* in the northwestern Pacific

Evgeny A. <u>Pakhomov</u>, M.P. Seki, A.V. Suntov, R.D. Brodeur and K.R. Owen
Inter-comparison of three sampling gears during the first Micronekton Intercalibration Experiment (MIE-1): Size composition approach

Hiroya <u>Sugisaki</u> and Koichi Sawada (Invited)
Introduction to J-QUEST research project: Quantification of micronekton using an integrated system of echosounder and stereo TV cameras

PICES Seventeenth Annual Meeting
October 24–November 2, 2008
Dalian, People's Republic of China

2008 Report of the Advisory Panel on *Micronekton Sampling Inter-calibration Experiment*

At the 2007 Annual Meeting, the Advisory Panel on the *Micronekton Sampling Inter-calibration Experiment* (MIE-AP) prepared to submit a draft of the final report at the time of 2008 Annual Meeting. However, the necessity of conducting additional sample analyses from the MIE-1 and MIE-2/3 cruises caused a delay in the preparation of the draft report. Consequently, the Advisory Panel decided to postpone the draft submission until PICES-2009. A brief description of the analyses, presently ongoing, follows.

MIE-1

Scientists participating in MIE-1 have finished identification of all fish and squid specimens collected during the cruise, but they still have some crustacean samples to identify. Although about half samples have already been analyzed, currently the complete size- frequency analyses of all crustaceans and other plankton from remaining samples are underway. The addition of more samples will provide higher statistical power in the comparative analysis by reducing the deviation of data.

To date, three papers directly from the results of the cruise are at different stages of preparation (sampling gear comparison, comparison between nets *vs.* acoustics, and fish larvae).

MIE-2 and 3

Comparison of sampling efficiency for dominant fish species has been finished for both of the cruises. But that for euphausiids, including size-frequency distribution, is underway. Scientists at Hokkaido University analyzed acoustic data obtained during the MIE 2/3 cruises, including density estimate and geostastical analyses of fish/euphausiids. Publication of two papers are anticipated from the gear comparison (one for comparison of sampling efficiency of fish by different fishing gears; another for euphausiids), and one paper from the net/acoustic comparison. Scientists at Hokkaido University analyzed acoustic data obtained during the MIE 2/3 cruises, including density estimate and geostastical analyses of fish/euphausiids.

Apart from these analyses, Japanese scientists made a cruise to test J-QUEST, an integrated system to visualize and quantify micronekton, in August 2008. A topical issue for this year is a new lighting apparatus which is invisible to fish and therefore does not affect fish behavior. The development of J-QUEST will be summarized in the final report.

Appendix 4

PICES Press Articles

Micronekton - What are they and why are they important?

Richard D. Brodeur, Michael P. Seki, Evgeny A. Pakhomov and Andrey V. Suntsov

Background

Micronekton are relatively small but actively swimming organisms ranging in size between plankton (< 2 cm), which drift with the currents, and larger nekton (> 10 cm), which have the ability to swim freely without being overly affected by currents. Although there are some precise definitions based on Reynolds numbers, micronekton may be operationally defined as taxa too vagile to be caught with conventional plankton nets and too small to be retained by most large-meshed trawls. Micronekton are diverse taxonomically. The principal groups include the cephalopods (small species and juvenile stages of large oceanic species), crustaceans (including adult euphausiids, pelagic decapods and mysids), and fishes (mainly mesopelagic species and juveniles of pelagic nekton). Although not generally fished commercially because of their relatively small size and high lipid content, mesopelagic fishes represent a substantial biomass in oceanic waters and are a critical but poorly understood intermediate trophic link between the mesozooplankton and the higher trophic levels including fishes, seabirds and marine mammals. Many studies have shown that micronektonic species are a primary food source for a wide variety of harvested nektonic species.

Fig. 1   Diversity of life forms considered as micronekton.

Many micronektonic species can be found close to shore or near the sea surface (*e.g.*, Abookire *et al.*, 2002, *Fish. Bull. U.S.*, 100: 376-380), but most occur in the midwater

pelagic realm mainly at the edge of, or beyond the continental shelves. Indeed, micronekton are one of the most conspicuous and ecologically-important components of the vast mesopelagic zone of the world's oceans, arguably the largest and one of the least variable ecosystems on the planet. This dark, cold, and relatively unproductive system extends from around 200 m to depths greater than 1000 m, and many of these organisms have evolved unique adaptations to this environment (Fig.1). Most mesopelagic micronektonic organisms undertake extensive vertical migrations on a daily basis, occupying the productive surface waters at night and descending to midwater during the daytime to reduce predation. Diel vertical migration of micronekton has been shown to contribute significantly to the rapid vertical transport of organic material from epipelagic to mesopelagic zones, referred to as the biological pump, where carbon fixed as living organic matter plus anthropogenic substances, such as insecticides and pollutants, are transported to deep-sea ecosystems. These micronektonic organisms in turn may be consumed by epipelagic predators in the near-surface waters, large nekton such as tunas, sharks and swordfishes that migrate dielly with the micronekton, and deep-sea fishes that migrate up to midwater. All of these predators capitalize on this vast and highly predictable food source.

Despite their importance to many consumers in the ocean, relatively scant attention has been paid to micronekton as a whole, especially compared to the primary consumer and top trophic levels that they link. Much of what is known and published in the literature was generated in the 1960s and 1970s and was not synthesized in any manner. A need was identified within the PICES community, especially among the ecosystem modelers, for a summary of the available information on micronekton in the North Pacific. In response to this, a scientific session dedicated to micronekton was held during the 1997 PICES Annual Meeting in Pusan, Korea, that brought together a large number of experts within the North Pacific region. It was at that time that a proposal was put forth to establish a PICES Working Group to assimilate knowledge of micronekton and their sampling in the North Pacific. This led to the formation of Working Group 14 (WG 14) on *Effective sampling of micronekton* which met for the first time in 2000. Initial summaries of the sampling conducted by each member nation were contained in a report presented at the PICES/CoML/IPRC workshop on "Impact of climate variability on observation and prediction of ecosystem and biodiversity changes in the North Pacific" held in Honolulu, in March 2001 (Brodeur, 2001, *PICES Sci. Rep.*, 18: 86-90). Prior to the 2000 PICES Annual Meeting in Hakodate, Japan, WG 14 co-sponsored a symposium on "Advanced techniques of sampling gear and acoustic surveys for estimation of fish abundance and

behavior", the proceedings of which has since been published electronically and available from Hokkaido University (Iida, 2003). The final report of that group (Brodeur and Yamamura (Eds.), 2005, *PICES Sci. Rep.*, **30**) synthesizes what is known about the distribution, biomass, growth, reproduction, and trophic relationships of micronekton in the North Pacific Ocean and adjacent seas, with a summary of the present state of sampling of these organisms. It also attempted to identify key knowledge gaps that should be filled in the coming years.

Included in the terms of reference was a request to examine the efficacy of available micronekton sampling gears and propose new sampling devices if the available ones were not adequate for the task. One of the recommendations included in the WG 14 report is that although a number of gears are presently being used to sample micronekton in the North Pacific and other parts of the world's oceans, there has been little effort expended in comparing the relative sampling efficiency and selectivity of these gears. The merits and shortcomings of many different gear types for sampling micronekton have been discussed at length in reports and publications arising from the SCOR Working Group on *Methods of Sampling Micronekton* (Pearcy, 1981, *Biol. Oceanogr.*, 2(2-4): 1-456). In most studies, only one type of gear was used so it is impossible to deduce the various biases associated with each gear. Moreover, sampling gears have become more advanced in time (see review by Wiebe and Benfield, 2003, *Prog. Oceanogr.*, 56: 7-136) and the older technologies have been abandoned, often without any inter-calibration with the gears that replace them. This has hampered efforts to look at inter-decadal or even regional comparisons of micronekton composition and biomass since very often, different gears are used.

As a result of the recommendations of WG 14, PICES formed an Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) in 2002, to conduct a field study to compare micronekton sampling gears and other quantifying technologies such as acoustics and visual sampling methods, similar to that done by the International Council for the Exploration of the Sea (ICES) in the North Atlantic Ocean utilizing mainly plankton gears (Wiebe *et al.*, 2002, *ICES Coop. Res.*, 250, 25 pp). The role of MIE-AP was to oversee planning and implementation of the field program and dissemination of the results to the scientific community.

Initial field work

A preferred location is thought to be one that is known to contain high densities of all major micronektonic categories (midwater fishes, cephalopods, and crustaceans), and thus it would have to be an area that has been sampled previously to a great extent. It should also be an area that is relatively uniform over various spatial and temporal scales, and exhibits a high degree of repeatability among

repeat tows taken at the same station, so that the majority of variability between tows could be ascribed to gear differences. It is desirable that the ocean conditions in the study area be relatively calm to facilitate deployment and recovery of complex gear types. Finally, the station should be in relatively deep water but also close to shore to minimize transit time. Although there are several areas within the PICES region that meet these requirements, the one recommended by MIE-AP is the area off the Hawaiian Islands. A pilot cruise was organized by the Panel to occur just prior to the PICES Annual Meeting in Honolulu to take advantage of the possibility that many potential participants would be attending the meeting. The leeward side of Oahu was chosen as the location for the experiment for several reasons including the benign weather conditions and relatively homogeneous distribution of the target taxa.

Ship time was secured on the NOAA research vessel, the *Oscar Elton Sette*, based in Honolulu, Hawaii. This vessel is over 70 m long and has the capability to tow large dual-warp trawls requiring doors as well as large and small single-warp midwater trawls. The ship also has several additional oceanographic winches equipped with conducting cable and sufficient deck space to stage several gear types. It also has advanced acoustic and oceanographic sampling capabilities needed for such a study.

An international team of experts in micronekton taxonomy and sampling and acoustics (Table 1) was assembled for the cruise, and the ship sampled continuously for seven days, alternating among three different gears (Fig. 2): a 140 m^2 pelagic Cobb trawl, a 4 m^2 Hokkaido University Rectangular Frame Trawl (HN), and a 2-m Midwater Trawl (IKMT). Sampling was conducted entirely during daylight and night periods, avoiding the crepuscular migration periods when the mesopelagic layer was in flux. Daytime

Table 1   Micronekton inter-calibration experiment cruise participants.

| Organization/Institute	Name
Institute of Ocean Sciences, Fisheries & Oceans, Canada	Douglas Yelland
Earth & Ocean Sciences, University of British Columbia, Canada	Evgeny Pakhomov Larissa Pakhomova
Graduate School of Fisheries Sciences, Hokkaido University, Japan	Masayuki Abe Hiroki Yasuma
Pacific Islands Fisheries Science Center, National Marine Fisheries Service (NMFS), U.S.A.	Michael Seki (Chief Scientist) Daniel Curran Donald R. Hawn Reka Domokos
Northwest Fisheries Science Center, NMFS, U.S.A.	Richard Brodeur
Harbor Branch Oceanographic Institution, U.S.A.	Andrei Suntsov
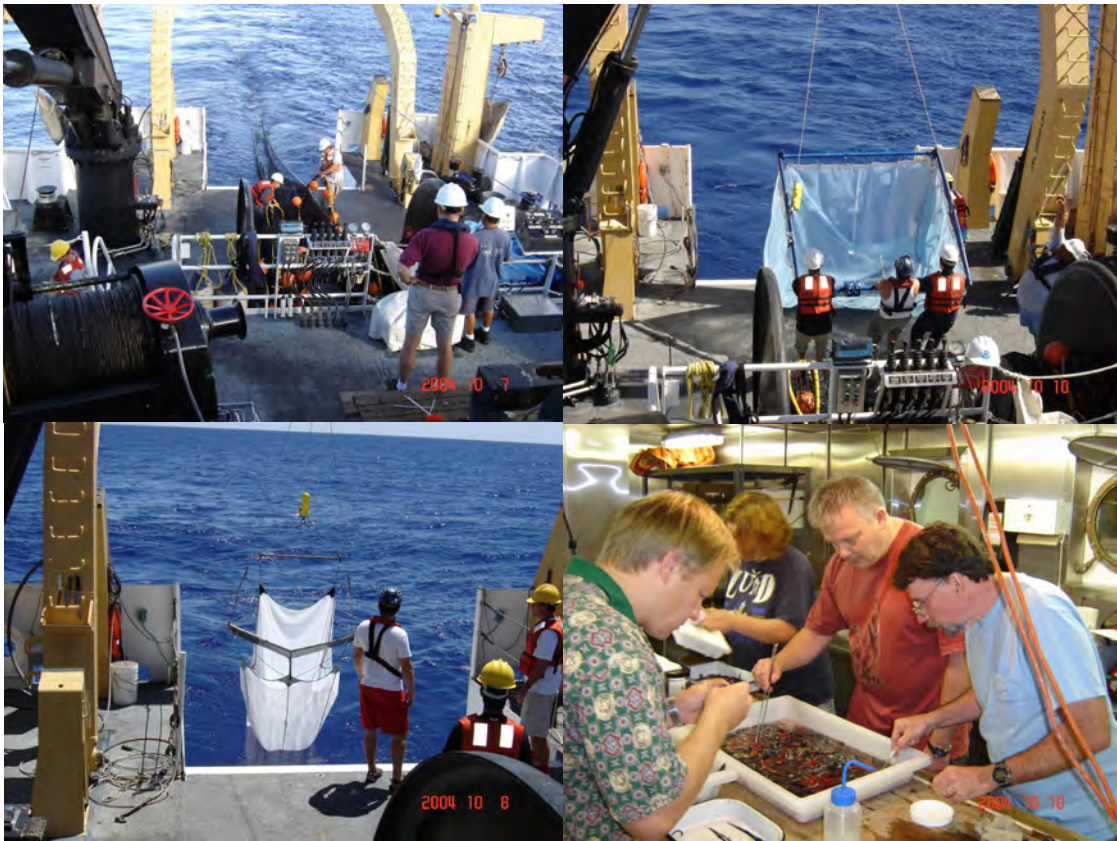
Fig. 2   *Deployment of the different sampling gears and sorting the catch.*
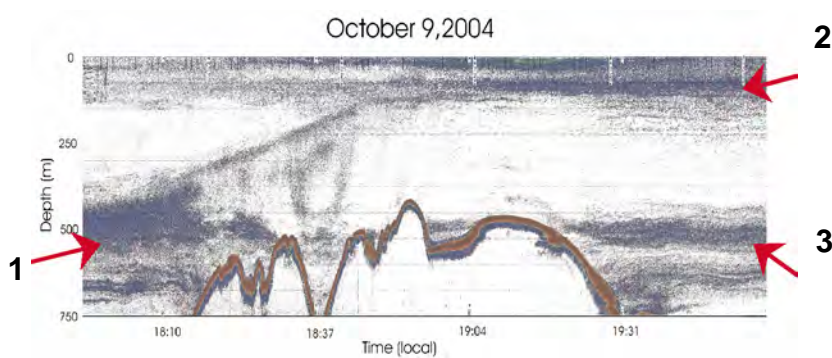

Fig. 3   *An EK-60 38 kHz echogram collected from 1800-2000 h on October 9, 2004, showing the dusk migration of the scattering layer from a normal daytime depth around 550 m up to the surface, and the locations of sampling during the micronekton inter-calibration experiment. (1) Day tows ≈ 550 m, (2) Night tows ≈ 120 m, (3) One series night tows ≈ 550 m.*

sampling was entirely in a deep layer (typically targeting 550 m), while nighttime sampling was mainly targeted the upper 120 m of the water column, although one series was conducted at depth to sample the non-migratory layer (Fig. 3).

Preliminary results from the cruise were presented at a MIE-AP Workshop convened prior to PICES XIII. It was found that while small sampling gears provided similar micronekton abundances, densities measured using both HN and IKT were generally significantly higher than densities obtained by Cobb trawl for main taxonomic groups sampled during the survey (Fig. 4), in part because these nets had finer mesh sizes than the Cobb trawl. The Cobb trawl, however, caught substantially larger organisms

than either of the other gears due principally to its large mouth opening.

Deployment of the three types of gear resulted in a collection of approximately 43-46 species of fishes from 24-25 families. At present, these numbers exclude all representatives of the rather speciose midwater family Myctophidae, which were not identified to species at sea. The majority of fish families (21) encountered during our sampling are truly mesopelagic with only few representatives from coastal and epipelagic communities.

The quantitative composition of the entire fish collection was very uneven, with myctophids contributing close to 60% of all specimens collected. The second most abundant

were in the family Gonostomatidae (largely due to abundant and ubiquitous *Cyclothone* spp.) which totals close to 38% of the total catch. The remaining families contributed less than 4% to the total fish collection.
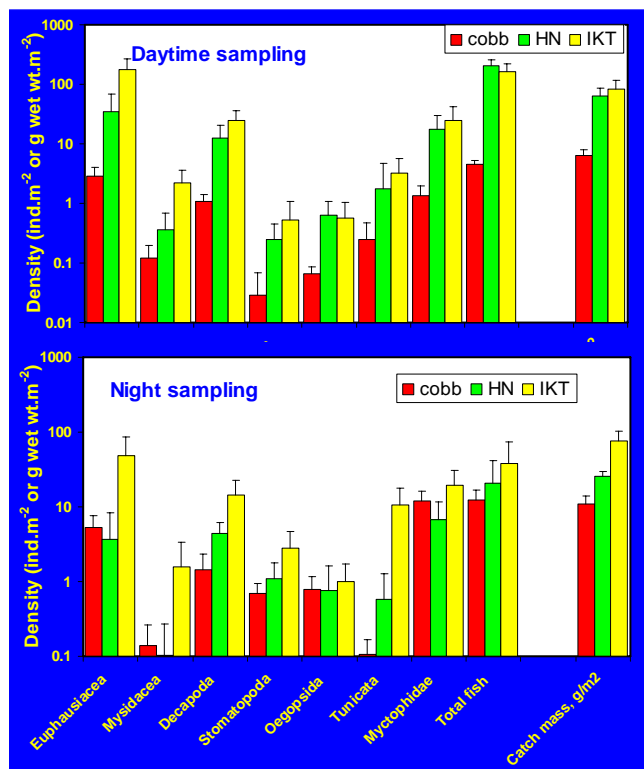

Fig. 4   Comparative catch by three sampling gears of the main taxonomic groups and overall catch biomass during day (top panel) and night (bottom panel) sampling during the inter-calibration cruise.

Based on our preliminary taxonomic treatment, we calculated basic community indices to estimate diversity, evenness and species richness (Fig. 5). As seen for densities of particular midwater groups, these indices are very similar for the HN and IKT gears. This is particularly evident for the number of species and for daytime diversity and evenness indices. Both day and night deployment of the Cobb Trawl clearly procured more species per trawl, which is also reflected in the higher diversity and evenness indices. After completing our taxonomic analysis, we expect to analyze additional data on ichthyoplankton and invertebrate abundances and species composition to complement inter-gear comparison and estimate relative catchability for each gear.

In terms of acoustics, two prominent scattering layers were observed at ~10-140 m and ~450-750 m. The surface layer was due primarily to organisms migrating to the surface at night, while the deep scattering layer was a permanent feature that may be representative of non-migratory organisms and/or organisms that migrate up from deeper

water during the night (Fig. 3). The water column between the two prominent scattering layers lacked significant backscatter indicating that the water column was basically devoid of organisms outside the layers, which was verified by a single haul during daytime that fished only the upper 300 m and came back nearly empty.
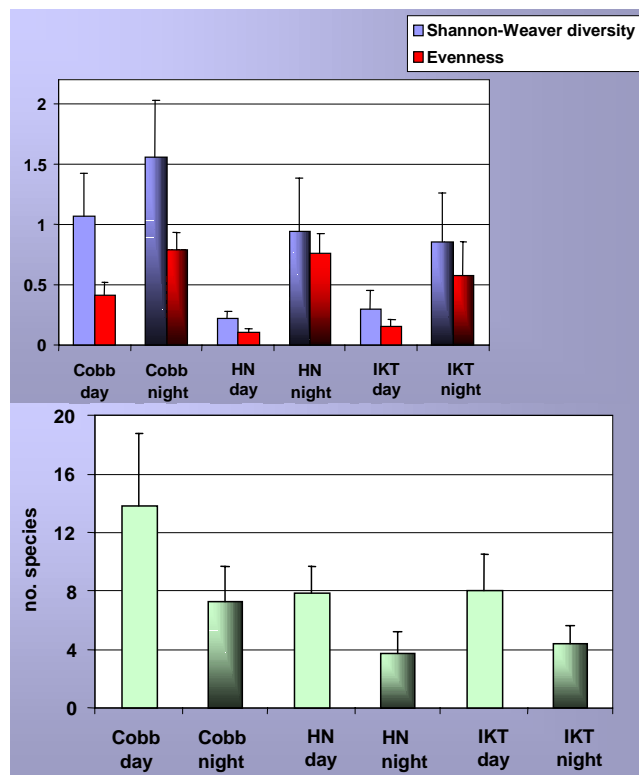

Fig. 5   Diversity and evenness indices (top panel) and total number of species (bottom panel) caught by each sampling gear by time of day.

Future directions

Preliminary analysis from the 2004 experiment indicated that individual gears sampled different, often non-overlapping, size groups of plankton and micronekton. This appeared to be relevant for our ability to interpret the data acquired from the multiple acoustic frequencies. However, it also points out that successful inter-comparisons during future cruises requires a closer scrutiny of gear-types and net mesh sizes prior to the experiment. Adoption of a "standard" sampling gear (such as a Rectangular Midwater Trawl (RMT 1+8) or a 3-m IKMT) and mesh sizes was suggested to facilitate comparisons. Based on the success and preliminary findings of the first cruise, MIE-AP recommended conducting a second experiment within the subarctic North Pacific using a larger variety of micronektonic sampling gears. This cruise is tentatively planned for summer 2005 (or 2006, depending on ship time availability) in the Bering Sea.

Dr. Richard Brodeur (rick.brodeur@noaa.gov) is a Research Fisheries Oceanographer working in the Fish Ecology Division of the Northwest Fisheries Science Center, NOAA Fisheries, and is based in Newport, Oregon. He received his M.S. in oceanography from Oregon State University, and his Ph.D. in fisheries from the University of Washington. Following a postdoc at the Pacific Biological Station in Nanaimo, B.C., Canada, he began his career working on early life history and recruitment dynamics of walleye pollock in the Subarctic Pacific for the Alaska Fisheries Science Center. He returned to Oregon to work on habitat preferences and trophic ecology of juvenile salmon. He has published on a variety of topics ranging from satellite oceanography to fish bioenergetics to fisheries acoustics, but has focused much of his research on micronekton and nekton. Dr. Brodeur is the Co-Chairman of the PICES WG 14 on Effective sampling of micronekton.

Dr. Michael Seki (Michael.Seki@noaa.gov) is the Deputy Director of the Pacific Islands Fisheries Science Center located in Honolulu, Hawaii and has been with NOAA Fisheries since 1980. He has conducted studies on marine resources in the Pacific region including seabirds, sea turtles, tropical snappers, oceanic squid, tunas, and billfishes, and has authored or co-authored over 40 scientific papers on topics such as open ocean food webs (ecosystems) and the influence of the physical oceanographic environment on the distribution and abundance patterns of living marine resources. Mike received his M.S. in oceanography from the University of Hawaii, and his Ph.D. in marine environment and resources from Hokkaido University (Graduate School of Fisheries Science). Dr. Seki is the Co-Chairman of the PICES Advisory Panel on Micronekton sampling inter-calibration experiment.

Dr. Evgeny Pakhomov (epakhomov@eos.ubc.ca) is a Faculty in Biological/Fisheries Oceanography at the Department of Earth and Ocean Sciences of the University of British Columbia, Vancouver, Canada. His research focuses on topics ranging from species ecology, at the level from zooplankton to fish, to ecosystem structure as well as physical-biological and biochemical coupling. Recently, Evgeny has developed interests in the applications of stable isotopes (bulk and compound specific measurements) in food web studies to reconstruct trophic pathways in pelagic ecosystems. He has also published on variability and responses of marine ecosystems to climate change using stable isotopes, large-scale and retrospective analyses. Dr. Pakhomov co-chairs the PICES Advisory Panel on Micronekton sampling inter-calibration experiment.

Dr. Andrey Suntsov (ASuntsov@HBOI.edu) is a Postdoctoral Fellow at Harbor Branch Oceanographic Institution, Florida. After graduating from Moscow State University in 1993, he started work on oceanic ichthyoplankton/mesopelagic fishes at P.P. Shirshov Institute of Oceanology in Moscow. He entered the graduate program at the Virginia Institute of Marine Science, earning his M.S. in 1997. Andrey subsequently returned to Russia and completed his doctorate degree on ichthyoplankton in Peruvian waters in 2003. At present, Andrey is involved in the study of age and growth patterns of deep-sea fishes from the North Atlantic. His research interests encompass early life history of marine fishes, oceanic micronekton and mesopelagic biology.

Recent results of the micronekton sampling inter-calibration experiment

by Orio Yamamura

Micronekton (osteichthyes, cephalopods and crustaceans) are ubiquitous in oceanic and neritic areas and are an important component of marine ecosystems. In terms of body size and swimming ability, they are intermediate between mesozooplankton and nekton, so they have an important role in transporting organic materials from the productive euphotic zones to the less productive mesopelagic layers through diurnal vertical migration. Furthermore, in subarctic ecosystems micronekton have indispensable roles in smoothing the seasonal variation of prey availability during the less productive autumn and winter seasons.

MIE-1 cruise

The PICES Working Group (WG 14) on *Effective sampling of micronekton* was established in 1997, under the direction of the Biological Oceanography Committee, to tabulate information on micronekton in the North Pacific, including taxonomic composition, biomass, sampling methods and trophic relationships. At the recommendations of WG 14, PICES formed an Advisory Panel on *Micronekton sampling inter-calibration experiment* (MIE-AP) in 2002, to conduct a field study to compare micronekton sampling gears and other quantifying technologies such as acoustics and visual sampling methods. The initial field survey, MIE-1, was carried out aboard the NOAA R/V *Oscar Elton Sette* in October 2004, off Oahu, Hawaii. Three sampling gears were compared: a 140-m pelagic Cobb trawl, a 4-m Hokkaido University Rectangular Frame Trawl (HUFT), and a 1.8-m Isaacs-Kidd Mid-water Trawl (IKMT). For detailed description and results of that survey, please refer to Brodeur *et al*. in PICES Press Vol. 13(1), pp. 7–11.

MIE-2 cruise

In September–October 2005, AP-MIE conducted its second cruise aboard the R/V *Hokko-maru* (902 t) of the Hokkaido National Fisheries Research Institute (HNFRI), Japan. *Hokko-maru*, launched in 2004, is a state-of-the-art 65-m stern trawler with a MOCNESS-10 and has capabilities to deploy other mid-water sampling gears, including stern trawls equipped with a MULTI-SAMPLER (an opening-closing multiple cod-end system, Simrad Inc.). Other gears compared during the cruise were the Matsuda–Oozeki–Hu Trawl (MOHT; Oozeki *et al*., 2004) and HUFT (**Fig. 1**). The former gear is a 5-m^2 rectangular mid-water trawl with a newly developed depressor, which enables the net to be towed at a desired depth at higher speed (5 knots) with a near perpendicular and stable angle of 8°. For the latter gear, two nets with different mesh sizes (3 mm and 9 mm) were used separately. In addition to the sampling gears, backscattering from the scattering layers was recorded using a Simrad EK-60 echosounder with 38, 70, 120 and 200 kHz transducers. The scientists onboard were: Orio Yamamura (HNFRI), Hiroya Sugisaki (Tohoku NFRI), Kazuhiro Sadayasu, Shinsuke Abe and Ryuichi Matsukura (all Hokkaido University). Since the cruise overlapped the dates of PICES XIV in Vladivostok, Russia, members of AP-MIE from countries other than Japan were not able to participate in the cruise.

Basically, every fishing gear was towed at 4 stations which were all located at the outer shelf of the Doto area, off southeastern Hokkaido Island (bottom depth 380–480 m), during the daytime and nighttime, with an exception of MT (rope trawl with multi-sampler), which was towed at

Fig. 1   Comparison of sampling gears during the MIE-2 cruise: MOHT (left top), MOCNESS-10 (right top), rope trawl with multi-sampler (left bottom), and HUFT (right bottom).

2 stations only during the daytime. Every gear sampled the 0–300 m layer. In total, the myctophid *Diaphus theta* was dominant in both numbers (>80%) and weight (>70%). A brief comparison of catch efficiency of different gears for *D. theta* revealed that MOHT was evidently the most effective gear for the sampling of micronekton (**Fig. 2**).
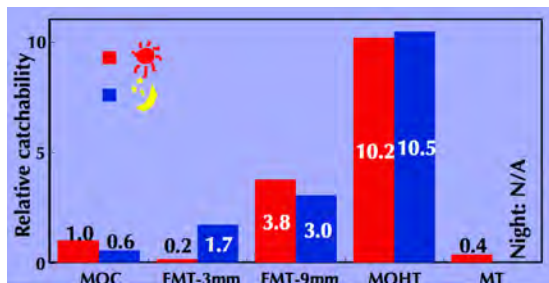

Fig. 2   Comparison of catchability (number of Diaphus theta *(in >40 mm SL) per volume of seawater filtered) for different sampling gears during MIE-2: MOCNESS-10 (MOC), Hokkaido University Frame Trawl (FMT), Matsuda–Oozeki–Hu Trawl (MOHT), and rope trawl with multi-sampler (MT). Numbers are standardized so that MOCNESS-10 during daytime = 1.0.*

MIE-3 cruise

After the MIE-2 cruise, AP members were keen to find ship time for some unfinished business. A direct comparison between IKMT and MOHT was essential because there are so much historical data collected with an IKMT. After two years, the third experiment was carried out onboard the R/V *Oscar Dyson* in the eastern Bering Sea, from September 18–27, 2007. Despite the vessel being engaged in an NPAFC/BASIS salmon survey, Dr. Jim Murphy of the Auke Bay Laboratory (NOAA/NMFS) kindly donated ship time for our experiment. The scientists participating in the experiment were: Orio Yamamura (HNFRI), Hiroki Yasuma (HU) and Andrey Suntsov (NWFSC, NOAA). Although 48–72 hours of ship time were expected for the experiment, the actual duration was only 24 hours due to the extraordinarily rough weather in the Bering Sea during autumn. The gears compared during this cruise were a 1.8-m IKMT and a MOHT. A Cantrawl 300/262 rope trawl was also included in the arsenal, but the limited time window excluded this gear from the comparison. To reduce the time required for each deployment, a site adjacent to St. Paul Island, with a bottom depth of *ca.* 60 m, was chosen for the experiment where age-0 walleye pollock were densely distributed. The

sampling was in a day/night sequential design, in which different gears were towed sequentially at each location, with triplicate samples collected during daylight and night at the same ship speed (3 knots). Aside from the sampling gears, backscattering from the scattering layer was recorded using a Simrad EK-60 echosounder with 15, 38, 70, 120 and 200 kHz transducers. The catch was dominated by age-0 walleye pollock (>99%), offering a good opportunity for gear comparison (**Fig. 3**). The catchabilities of the nets were compared by relative number of pollock per volume of seawater filtered by the nets. The nets showed similar catchability during the daytime (1.1 times larger for MOHT in density estimate), but MOHT showed significantly higher catchability in night sampling (2.8 times higher). The fact that the catch efficiencies during the daytime were similar for both gears indicates that visual avoidance by age-0 pollock was virtually identical between these gears. The 2.8 times difference for nighttime tows may represent the difference in the stability of net angle and net mouth opening during hauls.
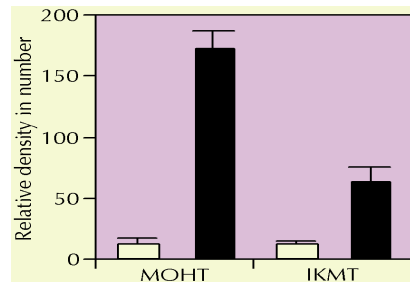

Fig. 3   Comparison of catchability (number of walleye pollock per volume of seawater filtered) between MOHT and IKMT during MIE-3; open bars: daytime, solid bars: nighttime.

How do we proceed?

We have undertaken 3 inter-calibration experiments, providing data for direct and indirect comparison of 8 different micronekton sampling gears. The results suggest that MOHT is the most reliable sampling gear for micronekton. Nevertheless, a brief comparison between acoustic and net sampling suggests that MOHT still underestimates the standing stock by >50%. Fortunately, some data sets are available for direct comparison between results of acoustic and net sampling. We are planning to include a comparison in the final AP-MIE report to be submitted to BIO next fall at PICES XVII in Dalian, China.

Dr. Orio Yamamura (orioy@affrc.go.jp) is a Fisheries Biologist working for Ecosystem Studies in Hokkaido National Fisheries Research Institute (HNFRI), Kushiro, Japan. He received his M.S. and Ph.D. in Marine Ecology from Hokkaido University and then began his career at HNFRI. Orio's research focuses on topics ranging from trophodynamic processes of walleye pollock in the coastal area to carrying capacity for salmonids in the Bering Sea. Since 2005, he has supervised the Steller sea lion research program in Hokkaido Island. Orio co-chairs the PICES Advisory Panel on Micronekton sampling inter-calibration experiment*.*

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