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).

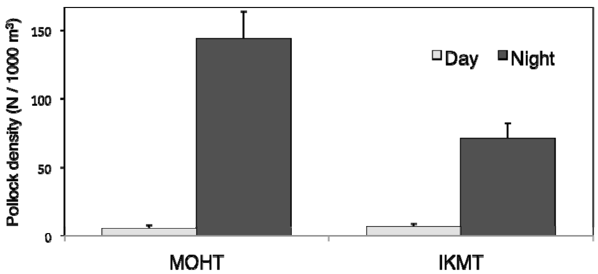

Fig. 4.2 Numerical density of age-0 walleye pollock near St. Paul Island, eastern Bering Sea, estimated by different sampling gears during the MIE-3 in September 2007; error bars: ±1 S.E.

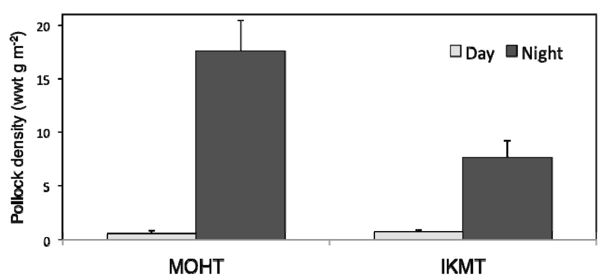

Fig. 4.3 Gravimetric density of age-0 walleye pollock near St. Paul Island, eastern Bering Sea, estimated by different sampling gears during the MIE-3 in September 2007; error bars: ±1 S.E.

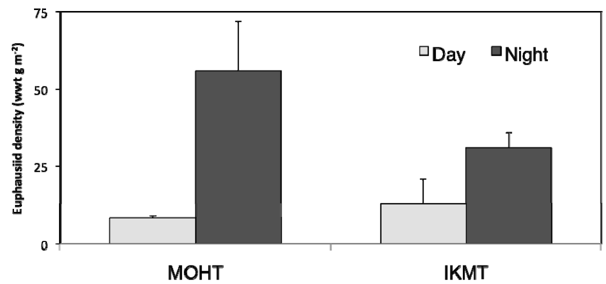

Fig. 4.4 Gravimetric density of *Euphausi pacifica* near St. Paul Island, eastern Bering Sea, estimated by different sampling gears during the MIE-3 in September 2007; error bars: ±1 S.E.

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.

		Mean	S.D.
MOHT	Day	55.4	6.5
	Night	57.6	8.9
IKMT	Day	53.2	6.9
	Night	56.4	8.6

** * *** N.S.

N.S.: no significance; *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

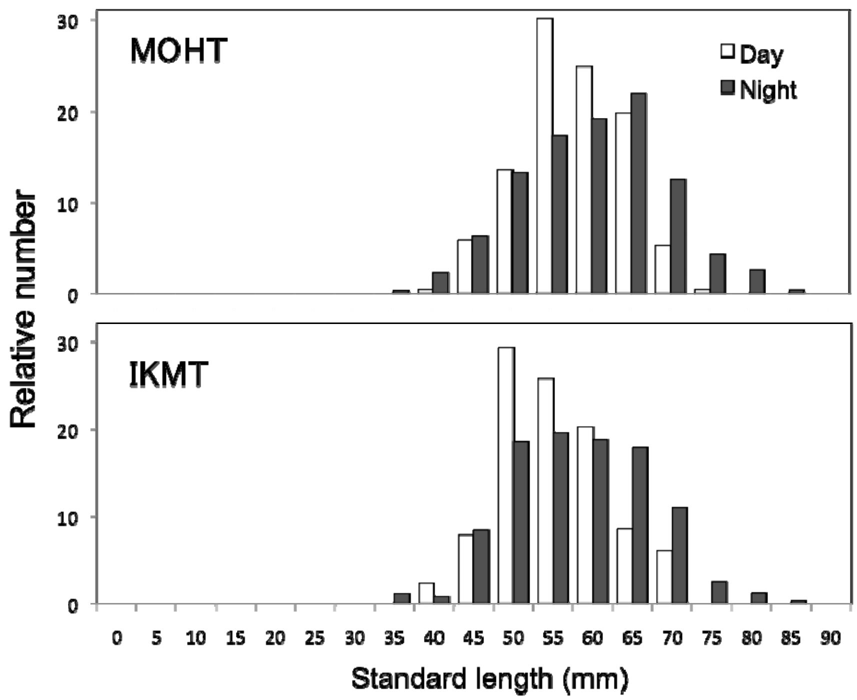

Fig. 4.5 Length frequency distribution of walleye pollock collected by different sampling gears near St. Paul Island, eastern Bering Sea, during the MIE-3 in September 2007.

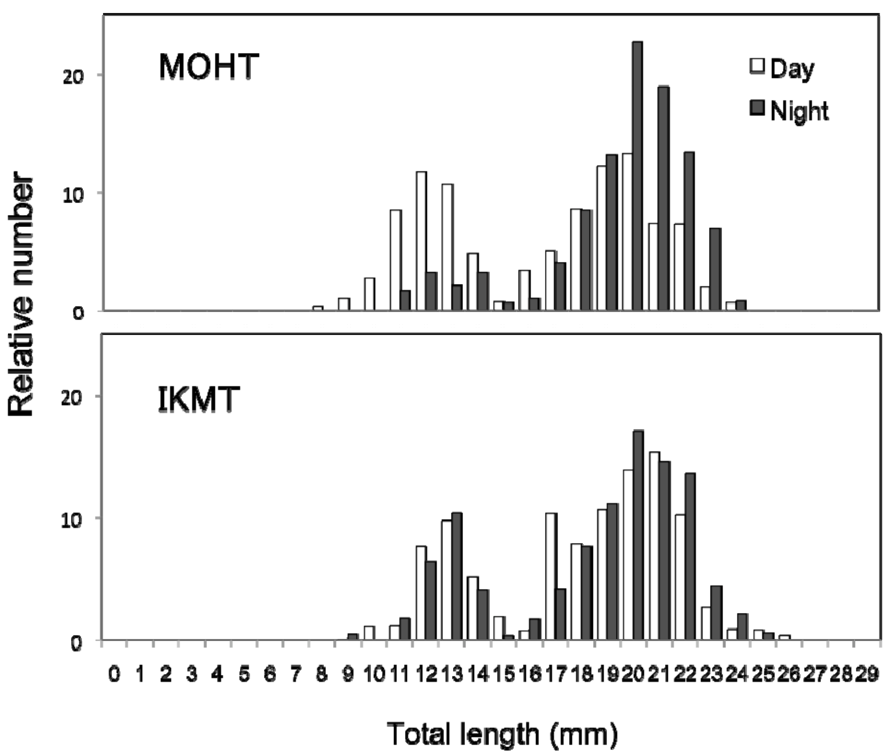

Fig. 4.6 Length frequency distribution of *Euphausia pacifica* collected by different sampling gears near St. Paul Island, eastern Bering Sea, during the MIE-3 in September 2007.

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.

		Mean	S.D.
MOHT	Day	17.0	4.0
	Night	19.6	3.0
IKMT	Day	17.6	3.9
	Night	19.2	3.6

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

Amakasu, K. 2004. A study on acoustic measurements of Antarctic krill *Euphausia superba*. Ph.D. dissertation, Tokyo University of Fisheries, Tokyo, 62 pp.

Ciannelli, L., Brodeur, R. and Napp, J. 2004. Foraging impact on zooplankton by age-0 walleye pollock (*Theragra chalcogramma*) around a front in the southeast Bering Sea. *Mar. Biol.* **144**: 515–526.

Isaacs, J.D. and Kidd, L.W. 1953. Isaacs-Kidd midwatertrawl: final report. *Scripps Inst. Oceanogr.* **53**: 1–18.

Kang, M., Furusawa, M. and Miyashita, K. 2002. Effective and accurate use of difference in mean volume backscattering strength to identify fish and plankton. *ICES J. Mar. Sci.* **59**: 794–804.

Oozeki, Y., Hu, F., Kubota, H., Sugisaki, H. and Kimura, R. 2004. Newly designed quantitative frame trawl for sampling larval and juvenile pelagic fish. *Fish. Sci.* **70**: 223–232.

Sadayasu, K., Mukai, T. and Iida, K. 2006. Comparing acoustic model estimations and *in situ* target strength measurements of juvenile walleye pollock (*Theragra chalcogramma*) *J. Acoust. Soc. Am.* **120**: 3060–3061.