The Effect of Towing Bridles on Net Avoidance by Micronektonic Fishes in Nighttime Neuston Sampling

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The effect of the towing rope and bridles of the Maruchi A net on net avoidance by micronektonic fishes was evaluated in comparative sampling with a towing bridle-free ORI neuston net. Thirty samples were collected towing the two nets alternately at night in June 1996 in Sagami Bay. In spite of the smaller mouth opening, the ORI neuston net was more effective than the Maruchi A net in collecting the three most abundant species, *Myctophum asperum*, *M. nitidulum*, and Japanese anchovy, *Engraulis japonicus*, larvae in terms of number and size. For these three species, the ORI neuston net catches were 2.1 to 5.8 times higher than those of the Maruchi A net. These differences significantly increased with fish size and were 7.6, 6.8, 10.3, and 18.9 times higher for the 22.0–23.9, 24.0–25.9, 26.0–27.9, and 28.9–29.9 mm size classes of *M. asperum*, respectively. The myctophids ranged from 16.0 to 42.0 mm in standard length in the ORI neuston net samples, but the Maruchi A net rarely collected specimens larger than 30 mm SL.

Key words: Maruchi type A net, surface tow, net avoidance, neuston sampling, myctophid fish

Introduction

Between 1940 and 1991, the Japanese Fisheries Agency adopted the Maruchi type A net (henceforth referred to as the Maruchi net), a conical plankton net with a mouth 130 cm in diameter, as the standard net for egg and larval abundance surveys of commercially important pelagic fishes like Japanese sardine, anchovy, saury, and mackerel (Nakai, 1962; Watanabe, 1988, 1990; Kuroda, 1991). Samples have been collected for almost 40 years from the Kuroshio and its adjacent waters, which cover an area of ca. 400×1500 km (Kuroda, 1991). These long-term monitoring samples that have been routinely collected in the same area using the same method are expected to provide valuable retrospective information on the abundance of various neustonic organisms. This is fundamental for depicting decadal changes in the oceanic ecosystems, which is one of the main components of the ongoing international project GLOBEC (Global Ocean Ecosystem Dynamics) (e.g. Francis and Hare, 1994).

In net sampling, net avoidance resulting from the effect of towing bridles has been shown to be considerable (UNESCO, 1968; Barkley, 1972; Mori, 1981; Watanabe, 1988; Nakamura, 1994). Due to technical difficulties, however, knowledge of this effect based on comparative sampling with bridle and bridle-free nets is extremely limited.

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The ORI neuston net (henceforth referred to as the ORI-n net) was designed to eliminate the effect of towing bridles on net avoidance (Matuo *et al.*, 1976). Therefore, catches with the two nets can be compared to evaluate the effect of bridles. The purpose of this study is to evaluate the catchability of micronektonic fishes using standard Maruchi net sampling, so as to reduce the effect of towing bridles.

Materials and Methods

The two nets were towed alternately for 5 min at 2 kts (1 m/s), and 30 samples, 15 for each net, were collected at night from 21:20 to 01:04 on June 14–15, 1996, within a radius of 2 nautical miles 34°8′N and 139°6′E, in Sagami Bay. The sea was dead calm during the sampling (waves 0–1, swell 1, winds 0–2.1 m/s). The sea surface temperature at each sampling station ranged from 15.6°C to 16.3°C.

Figure 1 shows sketches of the Maruchi and ORI-n nets. The Maruchi net is a conical plankton net, 4.5 m long, with a mouth 130 cm in diameter. The mesh in the anterior 3.0 m is 2.0×2.0 mm and that in the posterior 1.5 m is 0.33×0.33 mm. The ORI-n net is designed to be towed from its side otter board, so no bridle, towing wire, or ropes are present just in front of the net mouth (Fig. 1). The net is 60 cm wide×40 cm high at the mouth and 1.8 m long, with a 0.5×0.5 mm mesh.

The Maruchi net was towed at the ship's side with one third of its mouth above the surface, following the method adopted by the Japanese Fisheries Agency (Hattori, 1964). The ship's light was switched off during the tow. The ORI-n net was towed in the 0–30 cm layer in the same manner as the Maruchi net, with 10 cm of its mouth above the surface. The ORI-n net was towed further from the ship than the Maruchi net (8–10 m vs. 1–3 m). All the samples were fixed in 10% buffered formalin and the standard length (SL), or notochord length (NL) of pre-notochord flexion larvae, was measured. The catch was converted into the number of individuals per 1,000 m^3 of filtered seawater.

Results

The species composition and catch numbers are shown in Table 1. *Myctophum asperum* was the most abundant and

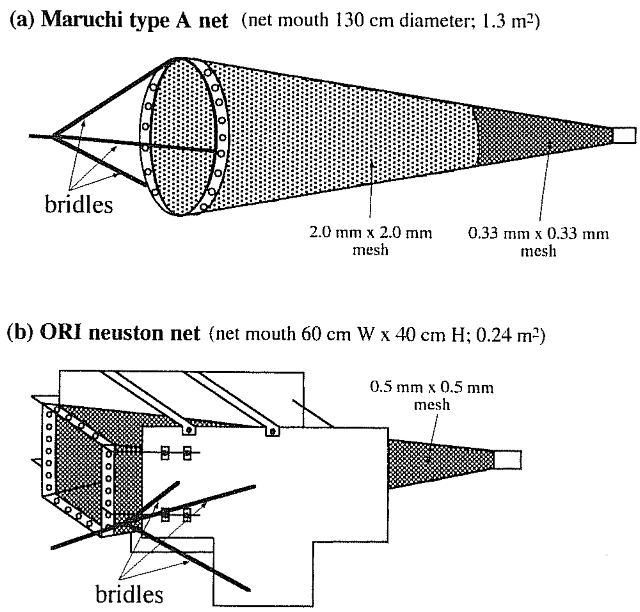

Figure 1. Sketches of Maruchi type A and ORI neuston nets.

accounted for 41.1% and 57.5% of the total catches of the Maruchi and ORI-n nets, respectively. The Japanese anchovy, *Engraulis japonicus*, (40.2% and 22.9%) and *M. nitidulum* (9.4% and 14.7%) were the other common species.

The size range and catchability of the 6 species, expressed as average catch in number per tow and per 1,000 m^3, are shown in Table 1. The ratio of the ORI-n net catch to that of the Maruchi net per 1,000 m^3 (b/a in Table 1) was greater than 1 (1.2–10.4) for every species, indicating the higher catchability of the ORI-n net. In spite of the smaller mouth of the ORI-n net, the maximum sizes of the two abundant myctophid species were larger in the ORI-n catch than in the Maruchi net catch, although there was little difference between the two nets in the size ranges of the anchovy larvae (Table 1).

In the Maruchi net sampling, the peak catch of *M. asperum* was 11.3±18.0 inds. per 1,000 m^3 (avg.±S.D.) in the 18.0–19.9 mm size class (Fig. 2a). The catches gradually decreased down to 0.5±1.2 inds. per 1,000 m^3 with increasing size up to the 32.0–33.9 mm size class. Individuals larger than 30.0 mm were rarely collected with the Maruchi net. In the ORI-n sampling, the peak catch of 46.8±36.5 inds. per 1,000 m^3 was observed in the 24.0–25.9 mm size class, which was 6.0 mm larger than the peak size class in the Maruchi net sample (Fig. 2a). The ORI-n catches of *M. asperum* also decreased with increasing size, but this net caught individuals up to 42.0 mm SL (Fig. 2a). The average ORI-n catches were 3.0 and 2.8 times higher in the 18.0–19.9 mm and 20.0–21.9 mm size classes, respectively (*U*-test: $p<0.1$). The catch ratios increased significantly with the size of *M. asperum* and were 7.6, 6.8, 10.3, and 18.9 times higher for the 22.0–23.9, 24.0–25.9, 26.0–27.9, and

Table 1. The total catch numbers, size range, average catch per 5 minute tow, and corrected average catch per 1,000 m^3 of filtered water volume for each species collected with the Maruchi A and ORI neuston nets.

Species	Maruchi type A net: Total catch no. inds. (%)	Size range (mm)	Ave. catch per tow ($n=15$)	Ave. catch per 1000 m^3 (a)	ORI neuston net: Total catch no. inds. (%)	Size range (mm)	Ave. catch per tow ($n=15$)	Ave. catch per 1000 m^3 (b)	Catch ratio b/a
Myctophids			(±S.D.)				(±S.D.)		
Myctophum asperum	193 (41.1)	15.2–32.5	12.9±18.3	44.5	188 (57.5)	16.5–42.0	12.5±8.1	224.9	5.1
Myctophum nitidulum	44 (9.4)	16.1–21.5	2.9±3.4	10.0	48 (14.7)	16.1–38.0	3.2±3.9	57.6	5.8
Symbolophorus evermanni	5 (1.1)	17.3–19.1	0.3±0.4	1.0	5 (1.5)	17.4–19.5	0.3±0.9	5.4	5.2
Myctophum orientale	5 (1.1)	18.4–23.9	0.3±0.7	1.0	1 (0.3)	18.5	0.1±0.2	1.8	1.7
Centrobranchus brevirostris	1 (0.2)	14.2	0.1±0.2	0.3	3 (0.9)	14.2–15.3	0.2±0.5	3.6	10.4
Others									
Engraulis japonicus larvae	189 (40.2)	5.0–27.3	12.6±14.5	43.5	75 (22.9)	6.1–27.5	5.0±4.7	90.0	2.1
Other fish larvae and juveniles	33 (7.0)	4.2–83.5	2.2±2.5	7.6	7 (2.1)	4.4–37.0	0.5±0.8	9.0	1.2
Total	470 (100.0)	4.2–83.5	31.0±23.2	107.0	327 (100.0)	4.4–42.0	22.1±8.1	397.6	3.7

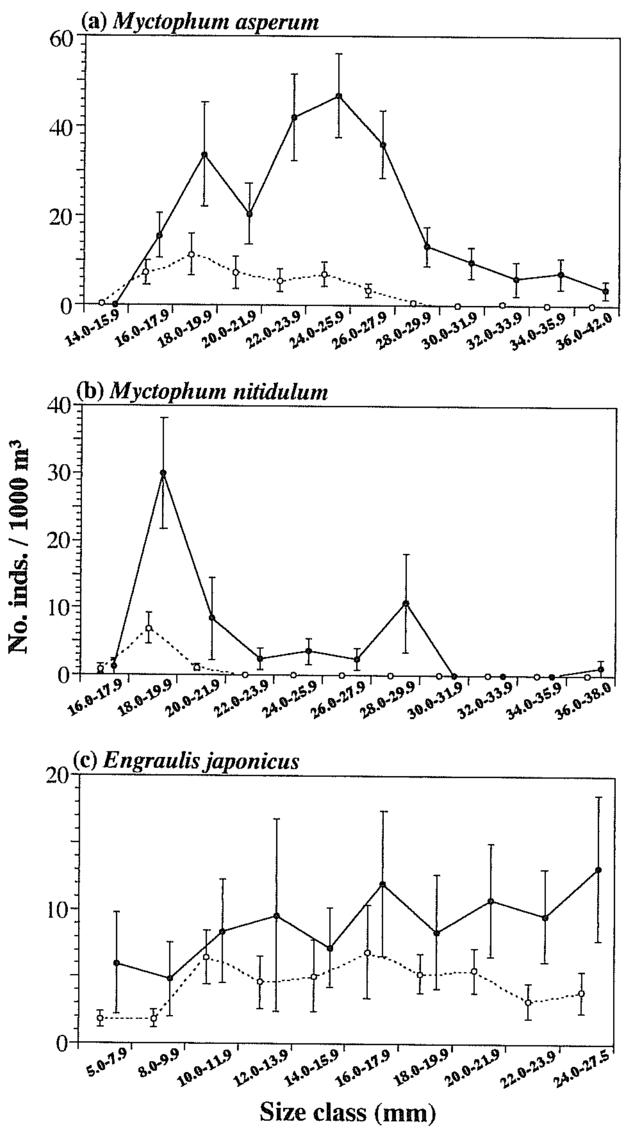

Figure 2. Average catches of (a) *Myctophum asperum*, (b) *Myctophum nitidulum*, and (c) *Engraulis japonicus*, per 1,000 m^3 in different size classes with the Maruchi A net (open circles) and ORI neuston net (closed circles). The bars indicate the standard error.

28.0–29.9 mm size classes, respectively ($p<0.01$). These results proved that the ORI-n net collects fish of all size classes more effectively than the Maruchi net, especially larger individuals.

In *M. nitidulum* the peak catch observed was in the 18.0–19.9 mm size class in both nets (Fig. 2b). In this size class, the average ORI-n catch per 1,000 m^3 was 4.3 times larger than the Maruchi catch, i.e. 30.0 vs. 7.0 inds. ($p<0.05$). The Maruchi net did not catch individuals larger than 22.0 mm SL, while the ORI-n net caught 2.4–10.8 inds. per 1,000 m^3 in the larger 22.0–29.9 mm class (Fig. 2b). Specimens larger than 30.0 mm SL were rarely collected in either net, except for a few in the 36.0–38.0 mm range in the ORI-n net catch (Fig. 2b).

The average ORI-n catches of Japanese anchovy larvae were also larger than the Maruchi net catches for every size class, although the difference was not significant due to the large standard deviation in the catches of both nets (Fig. 2c). The catch ratios (ORI-n net catch/Maruchi net catch) tended to decrease from 3.3 to 1.3 with size in the three smaller size classes (5.0–7.9 mm NL, 8.0–9.9 mm SL, and 10.0–11.9 mm SL) and increase with size from 1.6 to 3.4 in larger larvae (18.0–27.5 mm SL), suggesting an effect from the two different mesh sizes in the Maruchi net (Fig. 2c).

Discussion

Knowledge on the micro-distribution of myctophids and anchovy larvae in the upper 1–2 m layer of the open sea is extremely restricted. Surface migratory myctophid fishes were observed at night from the ship's side, swimming randomly in the upper ca. 2 m layer and were easily dipnetted. Anchovy larvae are known to migrate up to the sea surface at night to inflate their swim bladder to reduce their specific gravity (Uotani, 1973; Hunter and Sanchez, 1976). But the sinking rate of individuals with an inflated swim bladder was measured as 0.5–0.7 cm/s (Hunter and Sanchez, 1976), suggesting a rather even distribution of the larvae in the upper 1 m layer at night. Based on the observations of myctophids and anchovy larvae mentioned, we supposed that their distribution patterns in the upper 1 m layer are even when comparing the catchability of the two nets. For the further evaluation, however, more detailed study on the nighttime micro-distribution is badly needed on 10 cm scale in the upper 1 m layer.

It is well known that net avoidance increases as the size of the mouth of the net decreases (Fleminger and Clutter, 1965; McGowan and Fraundorf, 1966; Murphy and Clutter, 1972; Mori, 1980). Our results showed that the smaller ORI-n net more effectively collected myctophid fishes in terms of both number and size. This suggests that the towing bridles of the Maruchi net have a large effect on net avoidance by micronektonic and larger larval fishes. Nakamura (1994) reported a similar result, comparing the catchability of the smaller bridle-free BONGO net, with its 23.4 cm mouth diameter, with that of a larger ring net 130 cm in diameter, in sampling anchovy larvae larger than 7 mm SL.

Turbulence accompanying the ship's bow wave might also affect catchability, since the Maruchi net was towed closer to the ship than the ORI-n net (Matuo *et al.*, 1976). Myctophids are rather poor swimmers. Remotely operated vehicle (ROV) observations showed that their usual mode of escape is slow zigzag swimming, suggesting that turbulence caused by the bow of a ship cruising at 1 m/s is not likely to significantly affect the catch of the Maruchi net, especially when the sea is dead calm, as it was in this study. This view is also supported by the fact that the ORI-n net with its small mouth opening of 0.24 m^2 collected a considerable number of myctophids.

The average catches with the two nets of *M. asperum* and *M. nitidulum* were not significantly different for juveniles smaller than 18.0 mm, indicating a low avoidance rate in small individuals. The filtering efficiency of Maruchi nets is reported to be about 75% for nighttime tows (Anraku and Azeta, 1966), while that of ORI-n nets with a 0.33×0.33 mm mesh aperture is 92% (Matuo, 1980). The filtering efficiency of an ORI-n net with the 0.5×0.5 mm mesh used in this study is estimated to be close to 100%. If the filtering efficiency (75%) of the Maruchi net is adopted, the catch should be corrected by a factor of 0.75. However, the effect of the smaller mouth area of the ORI-n net would cancel this factor, since net avoidance with the smaller mouth of the ORI-n net is thought to be considerably higher than with that of the Maruchi net (1.3 m^2).

For anchovy larvae, the catch ratios of the two nets decreased with increasing size from the 5.0 to 11.9 mm size classes, indicating that the catchability of the Maruchi net increased with size in larvae smaller than 11.9 mm SL, probably due to a decrease in escape or extrusion through the mesh. The ratios, however, tended to increase with size for individuals of 18.0–27.5 mm SL, suggesting that for the larger fish net avoidance due to the bridles becomes more significant than escape, extrusion through the mesh. The funneling effect (Omori *et al.*, 1965) by the adoption of the 2.0 mm×2.0 mm mesh might be expected in the larger larvae in the Maruchi net catch, but the present data showed no such effect probably because the larger fish avoid the net by the effect of the towing rope and bridles before entering into the net.

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References

Anraku, M. and M. Azeta (1966) Observations on four models of a fish larva net made of two different fabrics having unequal porosities. Inform. Bull. Planktol. Japan, **13**, 34–40. (in Japanese with English abstract).

Barkley, R.A. (1972) Selectivity of towed-net samplers. Fish. Bull. US., **70**, 799–820.

Fleminger, A. and R.I. Clutter (1965) Avoidance of towed nets by zooplankton. Limnol. Oceanogr., **10**, 96–104.

Francis, R.C. and S.R. Hare (1994) Decadal-scale regime shifts in the large marine ecosystems of the North-east Pacific: a case for historical science. Fish. Oceanogr., **3-4**, 279–291.

Hattori, S. (1964) Studies on fish larvae in the Kuroshio and adjacent waters. Bull. Tokai Reg. Fish. Lab., **40**, 1–111. (in Japanese with English abstract).

Hunter, J.R. and C. Sanchez (1976) Diel changes in swim bladder inflation of the larvae of the northern anchovy, *Engraulis mordax*. Fish. Bull. US., **74**, 847–855.

Kuroda, K. (1991) Studies on the recruitment process focusing on the early life history of the Japanese sardine, *Sardinops melanostictus* (Schlegel). Bull. Tokai. Fish. Res. Lab., **3**, 25–178. (in Japanese with English abstract).

McGowan, J.A. and V.J. Fraundorf (1966) The relationship between size of net used and estimates of zooplankton diversity. Limnol. Oceanogr., **11**, 456–469.

Matuo, Y., T. Nemoto and R. Marumo (1976) A convertible neuston net for zooplankton. Bull. Plankton Soc. Japan, **23**, 26–30.

Matuo, Y. (1980) Study of invertebrate neuston in the neighboring seas of Japan. Univ. of Tokyo Doctor's Thesis, 109 pp. (in Japanese).

Mori, K. (1980) Migration of a sparid fish, *Pagrus major*, from pelagic to demersal life as observed in Yuya Bay, Yamaguchi. Bull. Seikai Reg. Fish. Res. Lab., **54**, 59–78. (in Japanese with English abstract).

Mori, K. (1981) Volumetric sampling of ichthyoplankton—a review. Report of fisheries resource investigations by the scientists of the Fisheries Agency, Japanese Government, **22**, 29–52. (in Japanese with English abstract).

Murphy, G.I. and R.I. Clutter (1972) Sampling anchovy larvae with a plankton purse seine. Fish. Bull. US., **70**, 789–798.

Nakai, Z. (1962) Apparatus for collecting macroplankton in the spawning surveys of iwashi (sardine, anchovy, and round herring) and others. Bull. Tokai Reg. Fish. Res. Lab., **9**, 221–237.

Nakamura, M. (1994) Comparison of capture probability between two different net samplers for the anchovy larva *Engraulis japonicus*. Nippon Suisan Gakkaishi, **60**, 741–747. (in Japanese with English abstract).

Omori, M., R. Marumo and Y. Aizawa (1965) A 160-cm opening-closing plankton net. J. Oceanogr. Sci. Japan, **21**, 9–16.

UNESCO (1968) Micronekton. Report of working party No. 4. Zooplankton sampling. Unesco Monogr. Oceanogr. Methodol., **2**, 164–167.

Uotani, I. (1973) Diurnal changes of gas bladder and behavior of postlarval anchovy and other related species. Bull. Japan. Soc. Sci. Fish., **39**, 867–876. (in Japanese with English abstract).

Watanabe, Y. (1988) Bias corrections of the number of saury larvae and juveniles captured by surface ring net tows. Bull. Tohoku Reg. Fish. Res. Lab., **50**, 49–58. (in Japanese with English abstract).

Watanabe, Y. (1990) A set of brightness categories for examining diel change of catch efficiency of saury larvae and juveniles by a neuston net. Bull. Jpn. Soc. Fish. Oceanogr., **54**, 237–241.

円錐型プランクトンネット（丸稚A型）の曳網索が夜表性魚類マイクロネクトンの網口逃避に与える影響

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丸稚A型ネットの曳網索が夜表性魚類マイクロネクトンの網口逃避に与える影響を，このネットと網口前方に曳網索が存在しないORIニューストンネットを夜間に15回ずつ交互に曳網した結果をもとに評価した．ORIニューストンネットは丸稚A型ネットに比べ網口面積がより小さいにもかかわらずアラハダカ（*Myctophum asperum*），ススキハダカ（*M. nitidulum*），カタクチイワシ（*Engraulis japonicus*）仔魚を個体数のうえで2.1–5.8倍多く採集し、サイズのうえでもより大型の個体を効率的に採集した．アラハダカでは両ネット間の差はサイズとともに広がり，標準体長22.0–23.9，24.0–25.9，26.0–27.9及び28.0–29.9 mmの個体はORIニューストンネットによりそれぞれ7.6，6.8，10.3，18.9倍有意に多く採集された．ハダカイワシ科魚類はORIニューストンネットでは体長16.0–42.0 mmの個体が採集されたが，丸稚A型ネットでは30 mmより大型の個体は殆ど採集されなかった．

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