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# Tuna Larvae Abundance: Comparative Estimates from Concurrent Japanese and Australian Sampling Programs

When estimating the absolute abundance of organisms, the accuracy and bias of sampling methods should be assessed (Andrew and Mapstone 1987). In ichthyoplankton sampling the absolute abundance of organisms will probably never be known; the characteristics of accuracy and bias in different sampling methods can only be inferred by concomitant sampling of the same population. The Fishery Agency of Japan Far Seas Fisheries Research Laboratory (FSFRL) has used a 2 m ring net to sample ichthyoplankton for many years. It has been the principal tool for sampling tuna larvae, particularly southern bluefin tuna, in the eastern Indian Ocean (Yabe et al. 1966; Ueyanagi 1969; Yonemori and Morita 1978; Yukinawa and Miyabe 1984; Yukinawa and Koido 1985). The net routinely samples large volumes of water (approximately 5,000 $m^3$ in a 30-min oblique tow), yet catches of tuna larvae on these surveys are generally low. These low catches may reflect a naturally low abundance of tuna larvae, a contention supported by previous studies (Wade 1951; Strasburg 1960; Klawe 1963; Richards 1969; Richards and Simmons 1971; Conand and Richards 1982). In this paper we compare catches of tuna larvae by traditional Japanese methods with those developed by CSIRO Division of Fisheries for quantitative surveys. A series of simultaneous tows were made by the CSIRO, FRV *Soela* and the FSFRL, FRV *Shoyo Maru* on the southern bluefin tuna spawning grounds in the east Indian Ocean in January 1987.

## Methods

Two identical 2 m ring nets were deployed concurrently by the FSFRL (Fig. 1, Table 1) in surface and oblique tows. For the oblique tow, a predetermined length of warp (approximately 130 m) was rapidly paid out from the stern so that the net reached a depth of 30 m (approximately 4–10 minutes). The warp was then retrieved at a fixed rate until the net reached the surface (approximately 21–26 minutes). The tow profile actually achieved was determined after the tow from traces made by the depth distance recorder. The 20-min surface tow was deployed close to the hull on the starboard side, amidships, with approximately 7/8 of the net below the surface, fishing a depth range of 0–1.75 m.

Two identical 70 cm ring nets were deployed concurrently by CSIRO (Fig. 1, Table 1) in surface and oblique tows. The oblique tow fished from the surface to the thermocline (the thermocline during the experiment was at approximately 32 m) to cover the full known depth range of the tuna larvae (CSIRO, unpubl. data). An operator, guided by real-time depth information from a sensor on the net, produced a V-shaped tow profile, with a descent time of approximately 8 minutes and an ascent of 12 minutes. The surface tow was deployed for 10 minutes, concurrent with the oblique tow, from a boom on the port side amidships, clear of the wake of the vessel. It was towed approximately 0.5 m under the surface, oscillating between about 0 and 2 m due to the roll of the vessel in the 0.5 m swell.

The volume of water filtered for each net was calculated in the following ways. The volumes filtered by both surface and oblique tows with the 70 cm net were calculated from the distance travelled, measured by calibrated flowmeter readings inside the net, and the mouth area of the net. Volumes filtered by oblique tows with the 2 m net were calculated from the distance travelled (determined from the depth distance recorder behind the net) and the mouth area of

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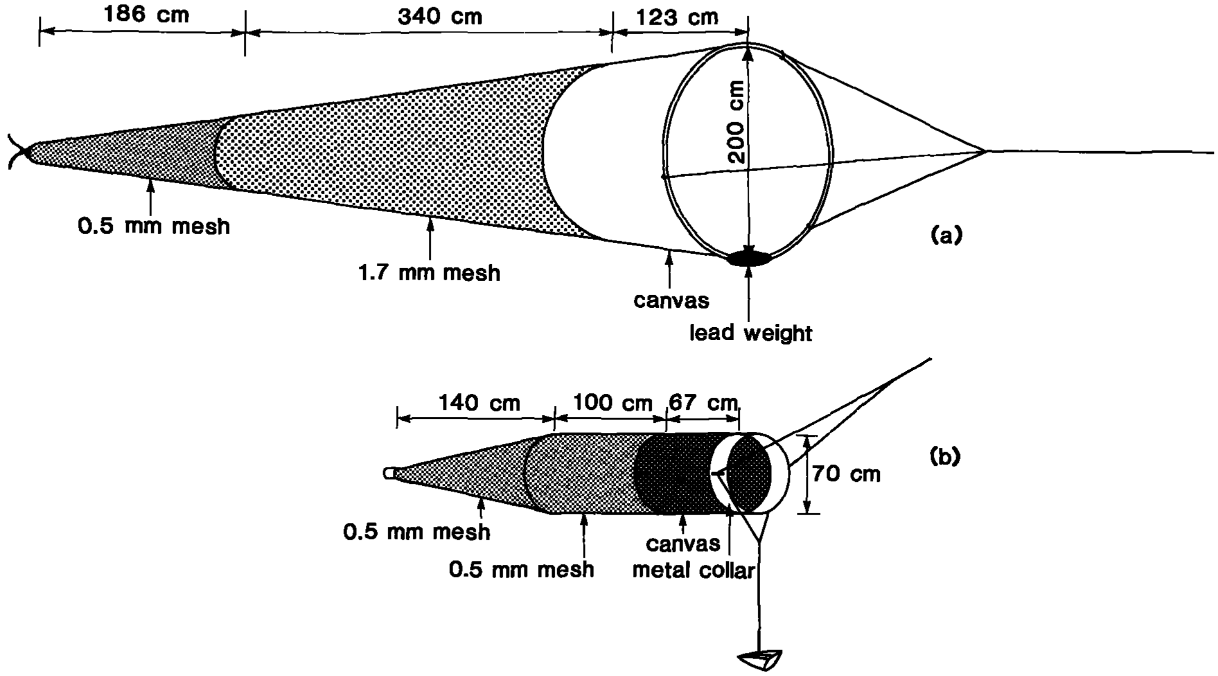


FIGURE 1.—The 2 m and 70 cm nets in their deployed configuration.

TABLE 1.—Specifications of the 70 cm net used by CSIRO and the 2 m net used by FSFRL.

| Specification | 70 cm net | 2 m net |
|---|---|---|
| Shape | cylindrical-conical | conical |
| Mouth opening | 70 cm internal diameter, circular, maintained by aluminium collar 18 cm wide | 200 cm internal diameter, circular, maintained by galvanized iron pipe |
| Mouth area | 0.385 $m^2$ | 3.142 $m^2$ |
| Net material | Estal monofilament, plain with mesh aperture of 0.5 mm throughout | forward section of multifilament, twist lock with mesh aperture of 1.7 mm, followed by nylon monofilament, plain with mesh aperture of 0.5 mm |
| Net colour | dyed dark blue | natural (white) |
| Canvas collar | 67 cm width | 123 cm width |
| Bridle | two-wire | three-rope |
| Depressor | 22 kg Scripps attached by two-wire bridle | 30 kg weight attached to frame |
| Flowmeter | General Oceanics[1] mechanical, attached inside mouth frame 17 cm from rim | Tsurumi-Seiki depth distance recorder, towed behind the net |
| Cod end | solid, thread mounted PVC with 0.5 mm stainless steel drainage screen | netting tied at end to form soft cod end |

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

the net. The 2 m net used at the surface was not fitted with a meter so the distance travelled was estimated from the ships speed (2 knots) and the tow duration (20 minutes). Only the submerged mouth area of the 2 m net was used to calculate the volume filtered.

The *Soela* and the *Shoyo Maru* met on 27 January 1987 at lat. 15°S, long. 116°E. The two vessels, approximately 250 m apart, steamed at 2 knots. Concurrent surface and oblique tows were made by both vessels at six stations in daylight between 1300 and 1700 h local time; the start of tows on each vessel was co-ordinated by radio and visual communication. The distance separating the two vessels during the tows was determined by radar.

The plankton samples taken by the 70 cm net were preserved in 95% ethanol and those from the 2 m net in 10% formalin. Samples were sorted, and tuna larvae identified to species (where possible) and measured (standard length) in the respective laboratories. At FSFRL the samples were sorted in petri dishes with the unaided eye, whereas at CSIRO samples were sorted in a rotatable sorting ring under a dissecting microscope with dark-field illumination. Both laboratories used a dissecting microscope to aid in identification of larvae.

The relative efficiency of the 70 cm and 2 m nets was described by ratios of the mean catch per unit volume for each method of deployment (surface and oblique tows) assuming that small catches are more prone to error than large catches (Snedecor and Cochran 1967). The significance of differences in the number of tuna larvae per unit volume collected by the 2 m and 70 cm net in surface and oblique tows was tested by two-factor ANOVA of split-plot design (Winer 1971). The data were log ($x$ + 1) transformed to make variances homogeneous (Cochran's test; $C$ = 0.47; df = 4,5; $P > 0.05$). Differences in the mean lengths of larvae caught by net type and tow type were analyzed by the Kruskal-Wallis test (corrected for ties), and multiple comparisons (with unequal sample sizes) were made using the Dunn test (Zar 1984).

## Results

The stations were at approximately 2.4 km intervals and the vessels were, on average, 260 m apart during tows. The range of volumes filtered by net and tow type was 505-560 m$^3$ for a 70 cm net in oblique tow; 244-307 m$^3$ for a 70 cm net in surface tow; 4,600-5,650 m$^3$ for a 2 m net in oblique tow; and 3,600 m$^3$ for a 2 m net in surface tow. Mean displacement volume of plankton caught by the 70 cm net was higher in oblique tows (27.3 mL/1,000 m$^3$) than in surface tows (4.4 mL/1,000 m$^3$). Both surface and oblique tows with the 70 cm nets caught a total of 283 tuna larvae whereas the 2 m nets caught 123 (Table 2). The species composition of the sorted and identified catches was similar except for an unidentified component in the CSIRO catches. This was due to a more conservative approach to identification by the less experienced CSIRO staff. The species composition of the FSFRL samples suggests that most CSIRO *Thunnus* spp. were probably *Thunnus alalunga*.

TABLE 2.—Numbers of tuna larvae taken in 2 m net hauls (surface and oblique) by FRV *Shoyo Maru* and in 70 cm net hauls (surface and oblique) by FRV *Soela*.

| Species | 2 m net | | 70 cm net | |
|---|---|---|---|---|
| | *n* | % | *n* | % |
| *Thunnus maccoyii* | 9 | (7.3) | 21 | (7.4) |
| *Thunnus obesus* | 3 | (2.4) | 0 | (0) |
| *Thunnus albacares* | 7 | (5.7) | 0 | (0) |
| *Thunnus alalunga* | 77 | (62.6) | 78 | (27.6) |
| *Thunnus albacares/alalunga* | 25 | (20.0) | 66 | (23.3) |
| *Katsuwonus pelamis* | 1 | (0.8) | 1 | (0.4) |
| *Thunnus* spp.[1] | 0 | (0) | 117 | (41.3) |
| Total | 123 | | 283 | |

[1]Small larvae 2.1–3.8 mm SL but usually < 3.3 mm SL not having the pigment pattern needed to distinguish to species.

The mean catch in the 70 cm net in oblique and surface tows was 16.5 and 144.7 tuna larvae/ 1,000 m$^3$, respectively. Catches in the 2 m net in oblique and surface tows were much lower, 1.4 and 3.7 tuna larvae/1,000 m$^3$, respectively. The ratio of the mean catches (70 cm net/2 m net) was 11.8 (SE $\pm$ 3.5) for oblique tows and 39.6 (SE $\pm$ 10.7) for surface tows. Catches in the 70 cm net were significantly higher than in the 2 m net ($F$ = 140.9; df = 1,5; $P < 0.001$) and catches in surface tows were significantly higher than oblique tows ($F$ = 11.3; df = 1,10; $P < 0.01$). The difference in catch between surface and oblique tows was mainly attributable to the 70 cm net; hence, there was a significant interaction between net type and tow depth ($F$ = 6.1; df = 1,10; $P < 0.05$) (Fig. 2).

There were significant differences in the mean lengths of larvae caught by net and tow type (Kruskal-Wallis test; $H$ = 21.74; df = 3; $P <$ 0.001). The mean length of tuna larvae caught in the 2 m oblique tows (4.03 mm) was significantly greater (Dunn test; $P < 0.05$) than those caught in 2 m surface tows (3.60 mm), 70 cm oblique tows (3.56 mm), and 70 cm surface tows (3.65 mm) (Fig. 3). This was due to a lower proportion of small larvae (and the absence of larvae less

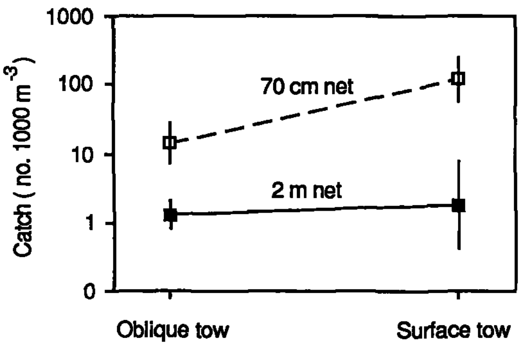


FIGURE 2.—Geometric mean catch (1,000 m$^{-3}$) by the 70 cm and 2 m net in surface and oblique tows and 95% confidence intervals. Catch has been plotted on a log scale.

than 3.0 mm) rather than an increased proportion of large larvae in the 2 m oblique tow (Fig. 3).

## Discussion

No attempt was made to control the many variables that could contribute to the difference in abundance estimates of the two sampling programs; we were more interested in the relative effectiveness of existing methods rather than in the effects of specific variables. CSIRO estimates based on surface and oblique tows were 93 and 13 times greater than corresponding estimates by FSFRL. The most obvious and

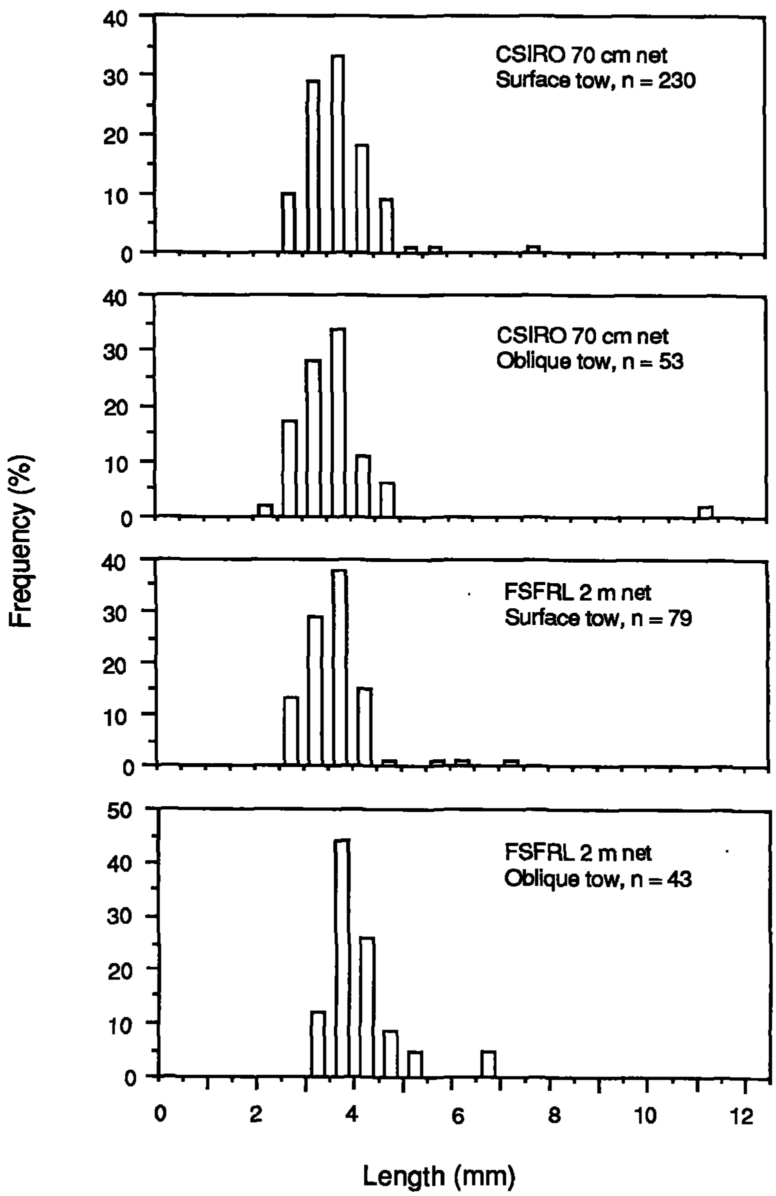


FIGURE 3.—Length-frequency distribution of tuna larvae caught in 2 m net hauls (surface and oblique) by FRV *Shoyo Maru* and in 70 cm net hauls (surface and oblique) by FRV *Soela*.

arguably the most important difference between the nets used by the programs is that the FSFRL 2 m net has 1.7 mm mesh in the forward section. Larvae are apparently lost by mesh escapement through this section. This type of multimesh construction may "herd" the larvae, but this advantage seems to be greatly outweighed by escapement. If we assume that the 1.7 mm mesh retains no larvae, then catches by the 2 m net can be recalculated for the 1.05 m diameter opening of the remaining 0.5 mm mesh section. This gave mean catches of 12.3 and 5.09 larvae/1,000 $m^3$ for surface and oblique tows, respectively. Based on this assumption, the CSIRO catches were still 12 times larger than FSFRL catches for surface tows and about 3 times greater for oblique tows. Reanalysis of the ANOVA using these data produced the same differences and levels of significance as in the original analysis. This demonstrates that, although escapement through the 1.7 mm mesh may account for a significant loss of larvae, other factors must also contribute to the lower catches by the FSFRL program.

A number of factors could cause increased avoidance of the 2 m net and hence reduce catches. While it might be expected that the 2 m net would reduce net avoidance by virtue of its size, this may have the opposite effect owing to an increase in the reaction distance to it (Barkley 1964, 1972; Wiebe et al. 1982). It has been well established that samplers that have no bridle obstructing the mouth (such as bongo nets and the 70 cm net) are far more efficient samplers than nets with conventional triple-rigged bridles (such as the 2 m net) owing to increased avoidance of the latter (Posgay and Marak 1980). Other factors that could increase avoidance of the 2 m net include the 30 kg depressor attached directly to the frame of the net, increasing visibility and turbulence and hence the reaction distance, and the high visibility of the undyed (white) net compared with the blue 70 cm net (Smith and Richardson 1977).

The volume filtered by the 2 m net may also have been overestimated as it was measured outside the net by the depth/distance recorder. This would result in lower apparent catch rates. Reduced filtering efficiency due to clogging in the 0.5 mm section, which may be a problem with the 2 m net because of its low open area ratio (Tranter and Heron 1967), would not be detected. In the laboratory, the sorting of larvae from samples without the aid of a microscope could result in extraction of fewer larvae in the FSFRL program, thus further reducing apparent catches.

The 70 cm net caught greater numbers of tuna larvae in the surface tow relative to the oblique tow than did the 2 m net. Catches in the 2 m net surface tow may have been reduced by increased avoidance because the net is towed very close to the hull of the *Shoyo Maru*. Alternatively, the oblique tow may have oversampled surface waters where the larvae are more abundant. The tow profiles for the 2 m oblique tow do suggest that this occurred to some extent. Clogging of the 0.5 mm mesh in the surface tows would not account for the disproportionately low catches because clogging would have been more likely to occur in the oblique tows which caught greater volumes of plankton.

We are not sure of the reasons for the differences in lengths of larvae caught by the two programs because of the many possible confounding factors. The greater mean length of larvae in the FSFRL oblique tows was due to fewer small larvae rather than to greater catches of large larvae. This could have resulted from differences in net deployment or in processing of samples, or could simply have been an artifact of the small sample size collected by the 2 m net in oblique tows. It would not have been due to differential loss of small larvae through the 1.7 mm mesh because this did not occur in surface tows with the same net.

The estimated abundance of tuna larvae in CSIRO surface and oblique tows was much higher than the corresponding estimates by the FSFRL program. We assume that larger catches are more accurate than smaller catches because towed nets are inefficient samplers owing to avoidance and mesh escapement (Clutter and Anraku 1968; Murphy and Clutter 1972; Clarke 1983) and subsequent treatment of samples (removal from nets, sorting, and enumeration) is likely to lead to the loss of larvae resulting in underestimation rather than overestimation. This would suggest that the 70 cm net as it is deployed in the CSIRO program is more efficient at catching tuna larvae than the 2 m net used in the FSFRL program, despite its much smaller size.


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