Sampling juvenile skipjack tuna, *Katsuwonus pelamis*, and other tunas, *Thunnus* spp., using midwater trawls in the tropical western Pacific

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Skipjack tuna, *Katsuwonus pelamis*, a highly migratory species, is one of the most important stocks for commercial fisheries in the western Pacific. The spawning ground of this species extends throughout equatorial and subtropical waters but larvae are more abundant in lower than higher latitudes (Nishikawa et al., 1978). Young and preadult skipjack tuna migrate great distances seasonally between tropical and temperate waters, yet little information is available for juvenile stages of this species.

Exploitation of skipjack tuna in the western Pacific has increased in recent years; an annual catch of 940,000 metric tons was taken in 1993 (FAO, 1995). Stock assessment and management of the species require detailed biological information on each life stage but, largely because of sampling difficulties, data on juveniles of skipjack tuna and other tunas are relatively limited compared with those on adults. Juveniles swim well and thus escape many gear: ring nets, beam trawls, or small pelagic trawls (see Methot, 1986). Other gear and light traps will not provide adequate spatial or temporal coverage (Thorrold, 1993).

Consequently development of appropriate sampling gear has been an important part of our study of the early life history of skipjack tuna and other tunas. Since 1992, we have worked to develop a new method for capturing juvenile skipjack tuna and tuna spp., namely a midwater trawl net with a large mouth opening, capable of high-speed towing. This appeared to be an excellent gear for sampling juveniles. In a trial survey, we captured large numbers of juvenile skipjack tuna and other tuna by using the midwater trawl net in offshore waters of the tropical western Pacific. This study is based on 1992–94 research cruises and confirms the effectiveness of the new midwater trawling gear. We describe the specifications of this net and its effectiveness for collecting juvenile skipjack tuna and other tuna.

Materials and methods

The midwater trawl net Tansyu has a large mouth opening and was designed to be towed at high speed. It was developed in cooperation with Tohoku National Fisheries Research Institute and Nichimo Co. Ltd., Shimonoseki, Yamaguchi. Targets for the Tansyu included skipjack tuna and other tuna, ranging in size from 10 to 200 mm standard body length (SL). The goal was to capture sufficient numbers to characterize distribution and relative abundance. The Tansyu design was based on the midwater trawl net Yoko-2, which has been used for sampling sardine by Seikai National Fisheries Research Institute, Nagasaki (Takeshita et al., 1988). The total length of the net was 71.6 m and that of the headrope and footrope was 38.6 m (see Fig. 1). The net was composed of 8 wing panels, 12 body panels, and 6 codend panels; all were made of 380 D fine polyethylene ropes. Twine diameter was between 1.91 mm (P-30) and 5.06 mm (P-210). The stretched mesh size was 1000 mm at the wings and the first panels of the body, diminishing successively to 57 mm in the seventh panels of the body. The dimension of the fishing circle was 144 × 1000 mm (where 144 = no. of meshes at mouth of net and 1000 m = mesh size at first panel of net). A codend of 60-mm mesh size was attached to the end of the body. An inner net of 30-mm and 8-mm mesh size was put inside of the codend to collect samples. Attached to the headrope were 74 floats of 300-mm diameter. A steel chain of 28-mm diameter was attached to the footrope. Buoyancy of the floats and weight of the chain were 762.4 kg and 660.4 kg, respectively. The bridles to the bottom, center, and upper wings were 18 mm in diameter and 100 m long. The expected mouth opening was approximately 20 m wide, 18 m high, at a towing speed of 4.5 knots. The net was designed for a maximum towing speed of 5 knots. The Tansyu was designed to be used with 1.7 m × 2.8 m otter doors.

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A scale model of the Tansyu was constructed and tested in a tank at Nichimo Co. Ltd. to test its design and performance.

Research cruises were carried out from late October to early December, 1992–94. The survey covered an area from offshore of Palau past the Calorine Islands in the tropical western Pacific (Fig. 2). A 400-ton class stern trawler was chartered by the Fisheries Agency, Ministry of Agriculture, Forestry, and Fisheries, Tokyo, to conduct the midwater trawl trials.

Midwater trawling was typically conducted four times daily; standard duration of towing was approximately one hour. Towing time was defined as the duration from beginning of the net tow to commencement of warp hauling. Ten strata were occupied from near surface to 200 m, in 20-m increments of water depth; separate tows in each stratum were carried out. Depth of the net was established by noting the warp length, and towing speed was usually set 4 to 5 knots against the currents. A net-depth recorder (Furuno FNR-200) was used to monitor continuously the mouth opening and depth of the net throughout the trawling operation.

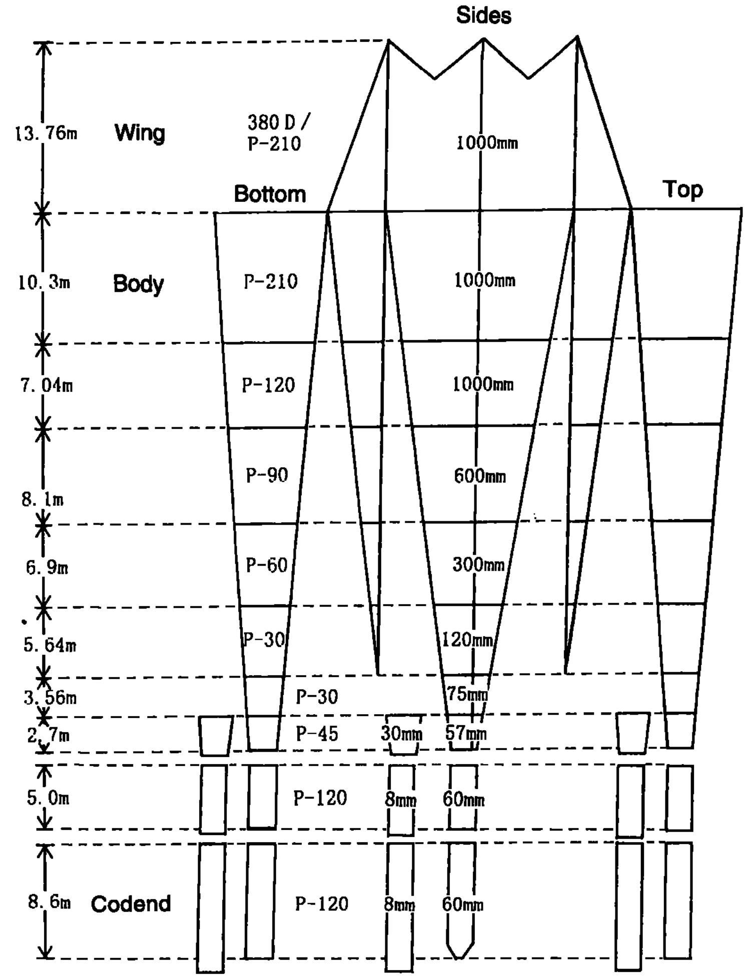

Figure 1

A schematic diagram of the midwater trawl net Tansyu that was developed to collect juvenile skipjack tuna and other tunas. The numerals on the left side indicate the length of each panel. The numerals within the diagram indicate twine size and mesh size of the net.

As soon as the net was brought on deck, the collection from the codend was weighed as whole wet weight; skipjack tuna and other tunas were sorted from the collection. Samples were fixed in 10% buffered formalin and preserved in 80% ethanol. All skipjack tuna specimens were identified after the cruise following the methods of Matsumoto et al. (1984). The species of tunas were identified as *Thunnus* spp. and samples of skipjack tuna and other tunas were measured individually to the nearest 0.1 mm SL with calipers.

In this report, the early life stages of skipjack tuna were defined as follows: larva: from hatching to less than 10 mm SL; juvenile: from 10 mm SL to less than 100 mm SL; and young: from 100 mm SL to less than 300 mm SL.

Results

The new trawl was deployed a total of 327 tows throughout the three years of the study. The target taxa, skipjack tuna and other tunas, were captured in 163 tows; skipjack tuna and other tunas co-occurred in 66 tows. Over four thousand skipjack tuna and other tunas were collected (Table 1). The incidence of juveniles collected remained high in all years. The maximum number of specimens collected in a single tow was over 100 juveniles of both taxa.

The diel distribution of sampling effort was 41.8% during daytime, 58.2% at nighttime (Table 2). For skipjack tuna, the mean daytime occurrence was about 5% higher than that at nighttime, and the mean daylight catch per tow was about four individuals greater than that at nighttime; a similar pattern was observed for other tuna, but the differences were not statistically significant. The whole wet weight for nighttime usually tended to be larger than that for daytime (Table 2). Other dominant species collected at nighttime were myctophids, cephalopods, and euphausids; those taken in daylight were engraulids and acanthurids.

Size classes of skipjack tuna and other tunas were widely represented; life stages from postlarva to early young were apparent. Where SL could be measured, specimens represented 92.2% of skipjack tuna, 93.5% of other tunas. Skipjack tuna SL ranged from 7.1 mm to 171.6 mm (Fig. 3); other tunas ranged from 8.0 mm to 139.8 mm (Fig. 4). The mean SL was 25.7 mm for skipjack tuna, 27.4 mm for other tunas, with modes at 10–20 mm and 20–30 mm, respectively. Juveniles were abundant and were the dominant life stage of both species in our samples. The composition of larvae, juvenile, and young was 1.6%, 97.6%, and 0.8% for skipjack tuna, 0.7%, 98.6%, and 0.7% for other tunas. Specimens of both taxa collected at night tended to be larger than those collected during daylight. For skipjack tuna, the size of specimens during daytime ranged from 7.1 mm to 81.8 mm (average 23.8 mm); at nighttime lengths ranged from 8.1 mm to 171.6 mm (average 27.7 mm). Tunas captured in daytime ranged from 8.0 mm to 54.7 mm (average 22.6 mm), at night from 11.0 mm to 139.8 mm (average 31.7 mm). There was a significant difference in the average SL of both species between daytime and nighttime (Cochran-Cox *t*-test, $P<0.05$). Young skipjack tuna and other tunas were collected only at night and the number of specimens per tow was less than six. Juveniles were as just as abundant at day as at night.

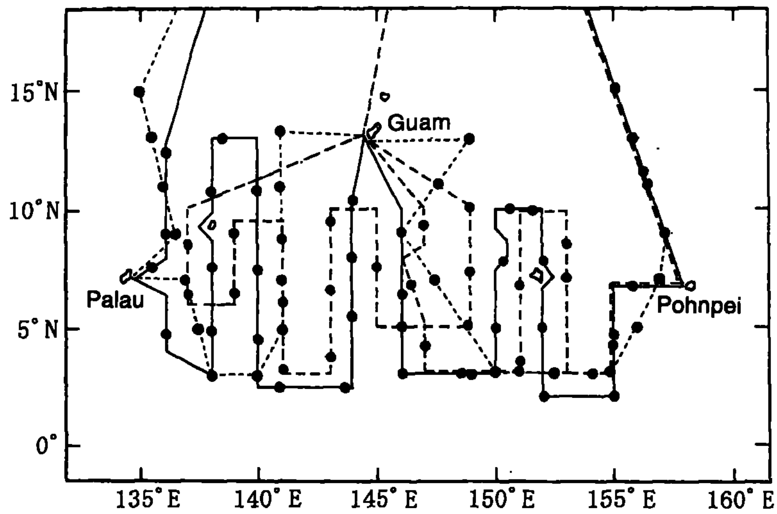

Figure 2

The sampling area. Stations (●) on the cruise tracks (---) indicate locations where the midwater trawls were deployed.

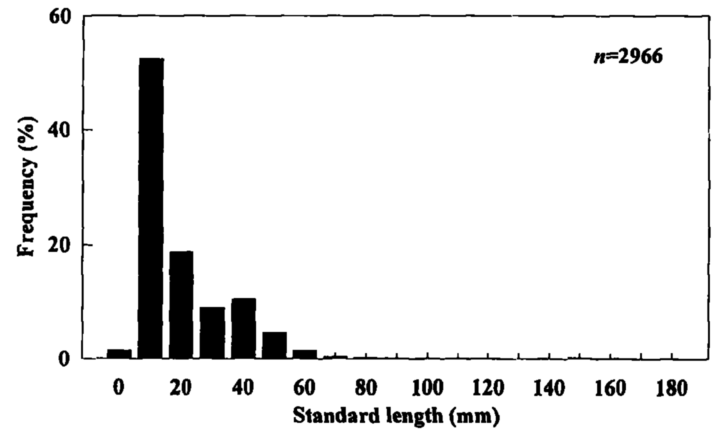

Figure 3

Length-frequency distribution of *K. pelamis* collected by the midwater trawl net in 1992–94 trial surveys.

Discussion

The midwater trawl net Tansyu made it possible to collect large numbers of juvenile skipjack tuna and other tunas during both day and night; this was not possible with the sampling gears previously available. The results of our survey demonstrate that the Tansyu was effective in collecting juveniles of skipjack tuna and other tunas.

In previous studies, various sampling gears were used for sampling larvae of skipjack tuna and other tunas (Table 3), the results of which demonstrate that

Table 1

Results of collection of juveniles and young *K. pelamis* and *Thunnus* spp. by the midwater trawl net in 1992–94. Inds. = individuals.

Species	Occurrence[1] %	Total catch (inds.)	Catch per tow[2] (inds.)
K. pelamis	49.8	3218	9.8
Thunnus spp.	27.5	1074	3.3

[1] Number of tows in which juveniles were caught/total tows × 100.
[2] Total catch of juveniles/total tows.

the maximum size of skipjack tuna and other tunas that could be collected with smaller plankton nets was about 12 mm; the usual size was 3 to 5 mm. Thus skipjack tuna and other tunas larger than 10 mm could easily escape from these gears. Davis et al. (1990) pointed out that net avoidance by larvae should be considered in calculating estimates of abundance of larval tunas.

Sampling efforts to collect juveniles (larger than 10 mm) have been reported in a few studies; King and Iversen (1962) tried to collect juvenile tunas with four kinds of trawl nets in the central Pacific, but only six juvenile tunas, size 18 to 60 mm, were collected. Higgins (1970) tried to collect juvenile tunas in Hawaiian waters using a midwater trawl net with a mouth opening 12 m × 8 m. He collected 578 skipjack tuna and 417 other tunas. Most samples rarely had juvenile stages of skipjack tuna and other tunas. Takuno and Ueyanagi (1978) tried to capture juveniles with a small pelagic trawl net in the tropical western Pacific, collecting 20 skipjack tuna and six yellowfin tuna, from 6 mm to 31 mm. These various results suggest that juvenile skipjack tuna and other tunas avoided the small trawl nets. The mouth opening and the towing speed of the Tansyu is much greater than those of small trawl nets used in previous studies. We therefore expected that the size of specimens that would be collected would be larger than those collected in previous studies if the survey area and period were chosen appropriately. Indeed, the size range of skipjack tuna and other tunas collected with the Tansyu was much greater than that collected with smaller nets. In addition, large numbers of juvenile skipjack tuna and other tunas could be collected.

Skipjack tuna and other tunas that reach the young stage are able to swim much faster than juveniles. In this study, the number of young skipjack tuna and other tunas collected was low, and these fish were caught only at night. These results indicate that net avoidance by young fish affected the number of specimens captured. The results of previous studies on swimming speeds of scombrids demonstrate that the "burst swimming speed" of adult tunas is usually from 10 to 20 fork lengths (FL) per second (Magnuson, 1978). If the burst swimming speed of young tunas (which might swim slower than adults) is, for discussion, assumed to be 10 FL per second, the speed at 20 cm FL would be estimated at approximately 3.9 knots. Therefore, the nets would need to be towed faster than 4 knots in order to sample young tunas of 20 cm FL. However, few young skipjack tuna and other tunas were collected with the Tansyu with its maximum towing speed of 5 knots. If large numbers of young skipjack tuna and other tunas were able to be collected, we would learn more about the swimming speed of young life stages of these fish and also their ecological characteristics, for example their swimming behavior and vertical distribution.

Other methods exist for collecting juvenile and young tunas, i.e. by means of light traps (Thorrold, 1993) or from stomach contents of tunas and billfish.

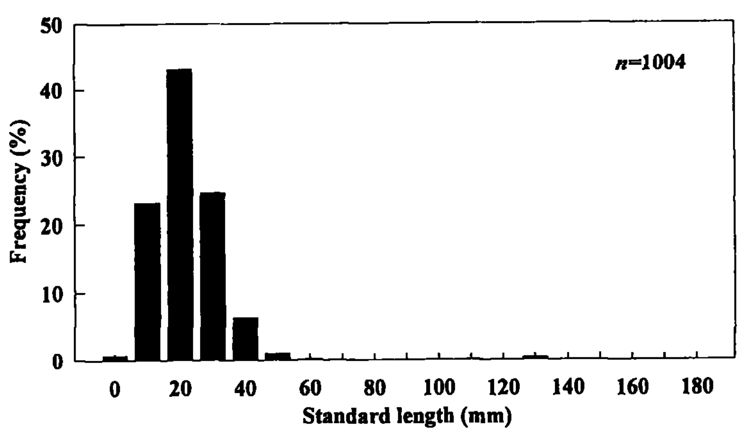

Figure 4

Length-frequency distribution of *Thunnus* spp. collected by the midwater trawl net in 1992–94 trial surveys.

Table 2

Comparison of catches between daytime and nighttime tows for *K. pelamis* and *Thunnus* spp. and total wet weight (g) of collections.

		K. pelamis		*Thunnus* spp.	
	Average catch (g)	Occurrence (%)	Catch per tow (inds.)	Occurrence (%)	Catch per tow (inds.)
Day	5405.5	52.9	12.5	28.7	3.7
Night	7010.1	48.1	8.1	27.0	3.0

Table 3
References for sampling larvae and juvenile skipjack tuna and other tunas.

Author(s)	Sampling gear	Size of sample
Strasburg, 1960	1-m ring net	3–12 mm larvae
Nishikawa et al., 1978	2-m ring net and 1.4-m ring net	<12 mm larvae
Davis et al., 1990	0.7-m bongo net and 0.7 ring net	3–11 mm larvae
Boehlert and Mundy, 1994	1-m² MOCNESS	2–8 mm larvae[1]
King and Iversen, 1962	1-m ring net	18–60 mm juveniles
	6-ft Isaccs-Kidd trawl	
	6-ft Isaacs-Kidd trawl	
	10-ft Isaacs-Kidd trawl	
Higgins, 1970	anchovy no. 2 Cobb pelagic trawl	7–47 mm larvae and juveniles
Takuno and Ueyanagi, 1978	midwater trawl	6–31 mm larvae and juveniles
Present study	midwater trawl	7.1–171.6 mm larvae, juveniles, and young fish
Thorrold, 1993	light trap	10–30 mm juveniles

[1] Boehlert, G. 1997. Natl. Mar. Fish. Serv., NOAA, 1352 Lighthouse Ave., Pacific Grove, CA 93950. Personal commun.

Yoshida (1971) studied the early life history of skipjack tuna using 1742 juveniles collected from the stomachs of billfishes in Hawaiian waters and the central South Pacific. Mori (1972) reported on the geographical distribution and the relative abundance of juvenile and young skipjack tuna based on collections from stomachs of tunas and billfishes in the Pacific, Indian, and Atlantic Oceans. This method was convenient and easy for sampling but produced results that should be carefully considered because they were not based on direct sampling from the habitat. Iizuka et al. (1989) using pelagic gill nets conducted research to collect young skipjack in southern Micronesian waters over a period of three years, collecting 49 young skipjack, 120 to 280 mm. The research resulted in small numbers of specimens of young skipjack tuna, and it was not clear whether the number of samples indicated the abundance of young stages.

The results of our study, in light of previous studies sampling skipjack tuna and other tunas, show that a wider size range of juveniles can be collected by using a trawl net with a larger mouth opening and by using a high towing speed, as with the Tansyu. A small ring net is appropriate for research based on sampling larvae because of its simplicity in operation. However, if it is necessary that diel patterns of vertical distribution of juvenile skipjack and other tunas be investigated, then the appropriate time and depth of towing should be selected, because ecological characteristics drastically affect the quantity of collections. Sampling of young skipjack tuna and other tunas, on the other hand, should be conducted at night with a trawl net with a large mouth opening or with a net that would minimize net avoidance by young-stage fish.

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