

## A HIGH-SPEED MIDWATER ROPE TRAWL FOR COLLECTING COASTAL PELAGIC FISHES

RONALD C. DOTSON AND DAVID A. GRIFFITH

National Marine Fisheries Service  
Southwest Fisheries Science Center  
P.O. Box 271  
La Jolla, California 92038

### ABSTRACT

The development and testing of a new high-speed midwater rope trawl (HSMRT) was initiated in the fall of 1992 by the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service, Southwest Fisheries Science Center and the California Department of Fish and Game (CDFG). The HSMRT was designed to collect fishery-independent data for adult coastal pelagic fish species including Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), jack mackerel (*Trachurus symmetricus*), and Pacific mackerel (*Scomber japonicus*). Originally the trawl was constructed as a four-panel net with 53-meter head- and footropes with 6.5-meter meshes in the opening panels tapering down to 5-centimeter meshes in the rear and 10-centimeter meshes in the cod end. The net was modified after several cruises in 1992 and 1993 aboard NOAA's *David Starr Jordan* and CDFG's *Mako*. During fishing operations, targeted speeds of 4 to 4.5 knots were obtained by both vessels. For shallow tows, deployment took approximately 30 minutes with a fairly small crew (4–5 people). Fork lengths of fish captured ranged from 136 to 280 mm for Pacific sardine, 30 to 140 mm for northern anchovy, 50 to 320 mm for jack mackerel, and 60 to 450 mm for Pacific mackerel. Mature hydrated female sardine were taken during April–May, 1994, only by the *Mako*, which generally fished in deeper water than the *David Starr Jordan*. The HSMRT worked well on both the *David Starr Jordan* and the *Mako*, but because the *Mako* had less horsepower, it was unable to maneuver while trawling or to tow the net shallower than 18 meters below the surface.

### INTRODUCTION

Fisheries research on coastal pelagic fish species (northern anchovy, *Engraulis mordax*; Pacific sardine, *Sardinops sagax*; jack mackerel, *Trachurus symmetricus*; and Pacific mackerel, *Scomber japonicus*) may require fishery-independent means to sample adult fish. Fishery-independent samples are generally advantageous because scientists are able to regulate sampling protocols and locations. A wider range of sizes or a more representative sample of adult fish may be obtained.

Commercial fisheries for coastal pelagic species typically use round haul fishing gear such as either purse

seines or lampara nets near shore to capture coastal pelagic species off California (Browning 1980). Neither the National Marine Fisheries Service's (NMFS) *David Starr Jordan* nor CDFG's *Mako* have the capability to fish with round haul gear, but both vessels are suitable for trawling. Small midwater trawls towed at 2 knots had been used on the *David Starr Jordan* to capture adult and juvenile anchovy, with bycatches of juvenile jack and Pacific mackerel. Adult sardine, jack mackerel, and Pacific mackerel are, however, fast enough to escape a trawl net towed at two knots. Adult Pacific mackerel, jack mackerel, and sardines were caught in large commercial midwater trawls towed at speeds of 4–6 knots by Russian fishermen (Macewicz and Hunter 1993).

A cooperative project between NMFS, Southwest Fisheries Science Center (SWFSC), and CDFG was launched in late 1991 to develop a high-speed midwater rope trawl (HSMRT) capable of collecting the required samples from vessels (*David Starr Jordan* and *Mako*) operated by both agencies. We chose a rope trawl design similar to those used for the pollock (*Theragra chalcogramma*) and Pacific whiting (*Merluccius productus*) fisheries in the Pacific Northwest to provide the greatest mouth opening for herding and capturing fish.

The need to collect juvenile through adult sizes of anchovy, sardine, jack mackerel, and Pacific mackerel meant that the net had to capture and retain fish as small as 50 mm long and potentially as large as 800 mm long. The net had to be towable at depths from near surface to at least 100 m. Based on the experiences of Russian trawlers (Macewicz and Hunter 1993) and fisheries on other pelagic species, we decided that a towing speed of 5 knots would be fast enough to capture adult pelagic fish.

Before the development of our HSMRT, no sampling gear was available that could be used on all vessels operated by NMFS and CDFG to collect adult and juvenile pelagic fish species. The contract to build the net was awarded to Gourock Trawls in Seattle, Wash.<sup>1</sup> The HSMRT (net design no. R2024504) was built and delivered to the SWFSC for testing on November 6, 1992.

<sup>1</sup>Reference to trade names or businesses does not imply endorsement by the National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

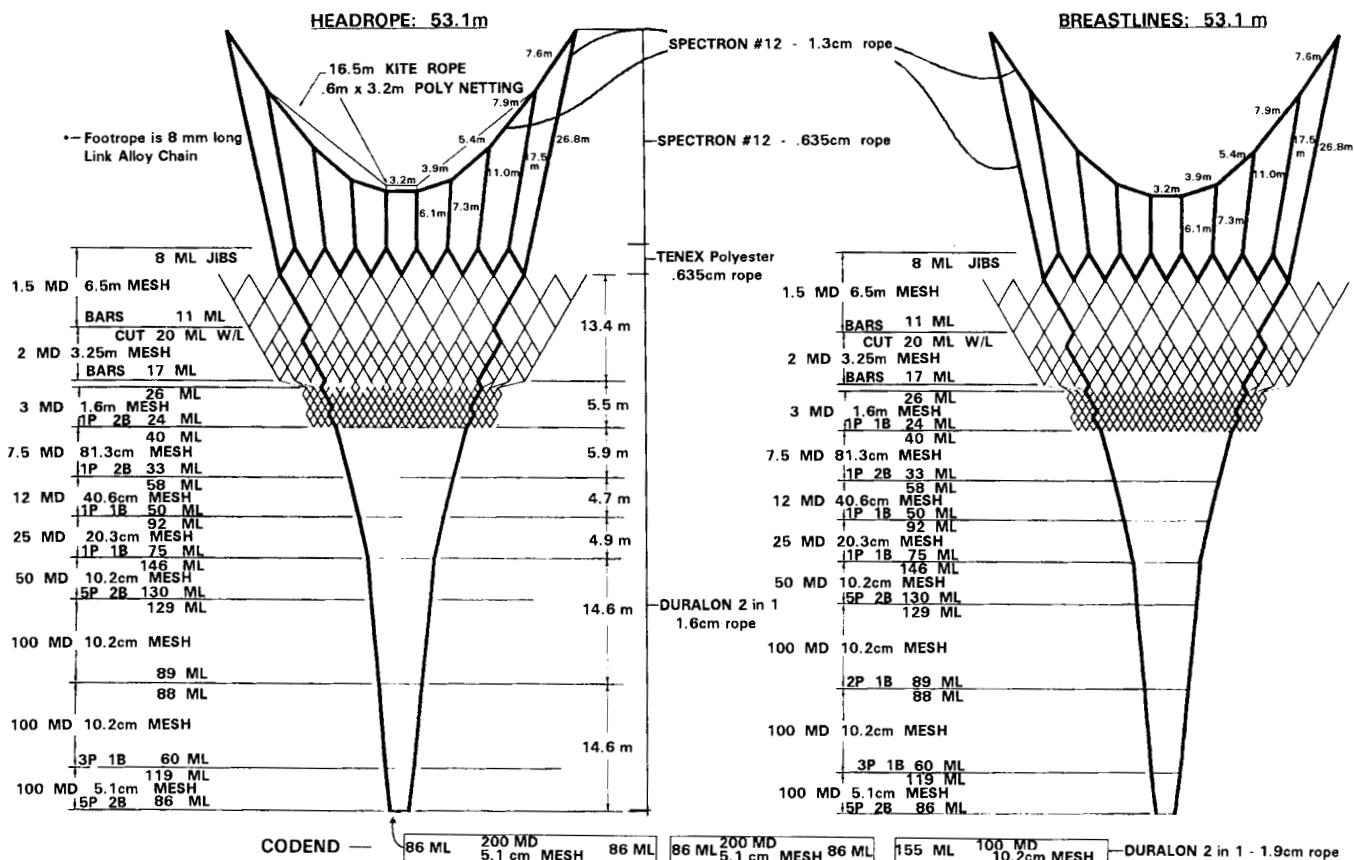


Figure 1. Diagram of high-speed midwater rope trawl (design #R202825A) with final modifications.

## MATERIALS AND METHODS

### Net Description

The HSMRT is a four-panel net that initially had a 53-m (174-ft) headrope and footrope, with 6,502-mm (256-in) meshes in the forward portion decreasing to 51-mm (2-in) meshes in the rear of the net and ending with a 102-mm (4-in) mesh cod end (figure 1). A funnel of 51-mm (2-in) mesh was built into the center to prevent escapement. Net twines were a combination of Spectra, nylon, and polypropylene.

The net was modified by Gourcock Trawls in March 1993 after numerous tests on both the *David Starr Jordan* and *Mako* in 1992. Most of the Spectra twine was replaced with nylon because of excessive abrasion of the Spectra, and a new net design number (R202825A) was assigned. Further testing in 1993 indicated that there was too much drag and poor retention of anchovy and sardine. The 2.3-m<sup>2</sup> double foil Suberkrüb doors were therefore replaced by 1.8-m<sup>2</sup> doors (figure 2). A kite tied into the headrope to increase vertical height of the mouth opening was abandoned after testing indicated it did not work well. In March 1994, NMFS, Alaska Fisheries Science Center (AFSC) staff removed the funnel in the

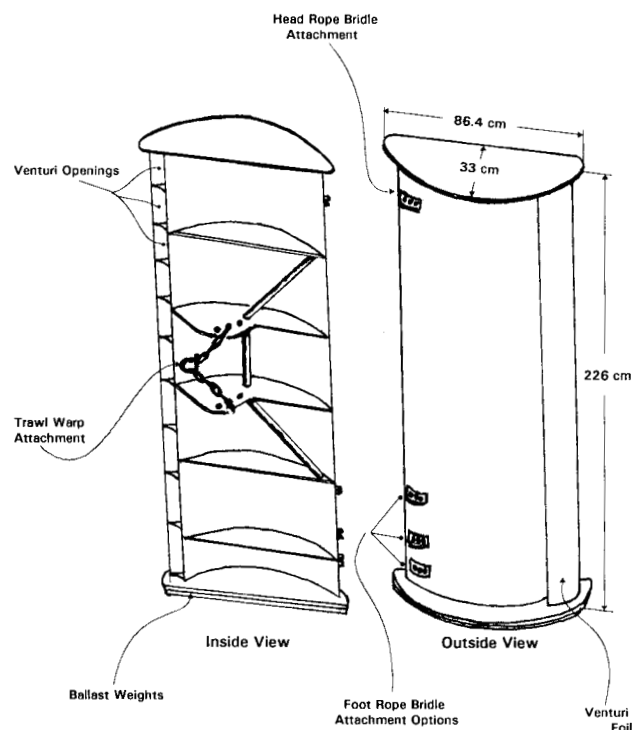


Figure 2. Detailed illustration of the 1.8-m<sup>2</sup> Suberkrüb-style double foil mid-water doors used with net #R202825A.

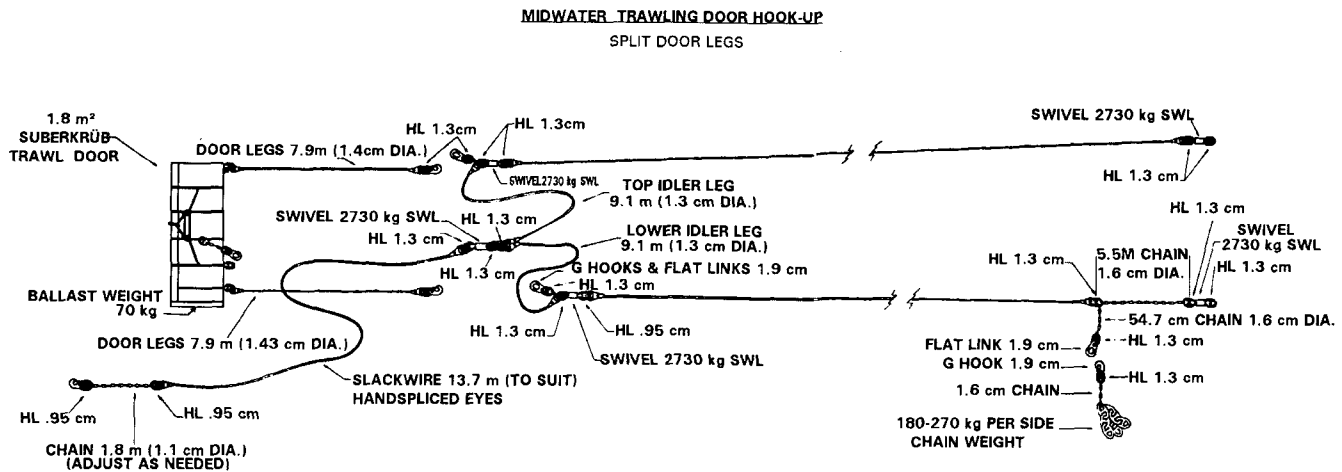


Figure 3. Equalizer bridle rig used with net #R202825A. The *David Starr Jordan* used 270-kg chain weights and 70-kg door ballast weights. The *Mako* fished with 180-kg chain weights and 35-kg door ballast weights. HL = hammer locks; SWL = safe working load.

center of the net to reduce drag, replaced 400 51-mm (2-in) tapered meshes in the rear of the net with 200 102-mm (4-in) tapered meshes, added a square intermediate of 400 51-mm (2-in) meshes just forward of the 102-mm-mesh cod end, and added a 13-mm-mesh liner to retain small fish (figure 1).

A bridle rig with zero setback (short section of chain between bottom bridle and footrope swivel) was used with weight chains of 180–270 kg (400–600 lbs) on the footrope bridles (figure 3). Costs for materials in the HSMRT during 1994, excluding labor, were about \$13,000, with an additional cost of \$3,825 for the 1.8-m<sup>2</sup> Suberkrüb double foil midwater doors.

### Vessel Descriptions

The *David Starr Jordan* has a steel hull, is 52 m long, displaces 873 gross tons, and has twin screws with engines rated at 900hp (combined). The *Mako* has a steel hull, is 24 m long, displaces 146 gross tons, has a single screw with a Kort nozzle, and an engine rated at 503hp. Since the *Mako* was more limited in towing ability, its specifications were used as criteria for the net design.

### Fishing the Net

Procedures for fishing the HSMRT were developed during cruises in 1992 and 1993 and during the sardine daily egg production method (DEPM) survey conducted from April 11 to May 14, 1994 (Arenas et al. 1996). A Wesmar scanning sonar (60kHz on the *David Starr Jordan* and 160kHz on the *Mako*) was used to find a target or multiple targets. Large schools of pelagic fishes could be detected at maximum ranges of about 500 meters on the *Mako* and 800 meters on the *David Starr Jordan*. If the schools were located during daylight hours, the position was noted, the immediate area surveyed for other schools, and the track line resumed if sufficient time remained

before dark. Fishing was done only between sunset and sunrise because success is minimal during daylight hours (Mais 1974). At dark, the schools were relocated with the sonar and color depth sounder, and fishing began.

A minimum deck crew of four was required to set and retrieve the HSMRT. The total time from starting until all the trawl warp was deployed was about half an hour. The net was set at a speed of 3 knots and would sink to a depth of 80–100 meters before all the trawl warp was deployed and before the ship's speed was increased to raise the depth of the net. Downswell sets minimized entanglement of the large meshes and helped keep the Furuno netsonde on the headrope straight while the net was set.

Headrope depth was recorded on the *Mako*, and both headrope depth and vertical net height were recorded on the *David Starr Jordan*. Vertical net height on the *Mako* was determined with time/depth recorders (TDR, Wildlife Computers Model Mk3e). As the ship approached a school detected by sonar, it changed course to cross over the school. When the school passed under the ship, the depth of school was noted and the fishing depth of the net was adjusted by speeding up or slowing the vessel. It was much easier to lower the net than to raise it, so the net was generally brought in at a shallow depth and dropped slightly, if needed. Both vessels were able to tow at speeds of 4.0–4.5 knots. The duration of each tow was not standard (see below), but we generally retrieved the net once it had passed through a school or schools. Retrieval (until the cod end came on board) took about half an hour. A commercial fish-spotter pilot (Lo et al. 1992) was occasionally used to locate fish and to help set the net.

During fishing trials with the net on both vessels, we experimented with various door settings, chain weights, setbacks (increasing the length of the footrope

bridle over that of the headrope bridle), and scopes of trawl warp (amount of cable out) in order to balance the net, maximize towing speed, and determine the best fishing depths and net configuration. Doors were equipped with several attachment holes for the trawl warp and bridles (figure 2). Different attachment points altered the angle of attack of the door's leading edge and changed the spread and lift provided by the door.

To fish near the surface, where most coastal pelagic species were found, the *David Starr Jordan* set 275 meters of 16-mm (0.625-in) trawl warp, 270-kg (600-lb) weight chains, even setback, and both bottom plates on the foot of each trawl door giving them a weight of 300 kg each. The *David Starr Jordan* was able to fish at headrope depths of 10 meters from the surface, and sometimes as little as 5 meters. The vertical height of the net was 15 meters, with a wingspread of 23–25 meters.

The configuration for fishing near the surface from the *Mako* was 137 meters of 16-mm (0.625-in) trawl warp, 180-kg (400-lb) weight chains, even setback, and with one 35-kg plate removed from the foot of each trawl door with a resultant door weight of 265-kg each. With this configuration, the *Mako* was able to fish the headrope within 15 meters of the surface, with a vertical net height of 18 meters and wingspread of 20 meters.

The *David Starr Jordan* was positioned about two miles upswell of the target to allow setting and positioning of the net before reaching the target. It was possible to detect fish entering the mouth of the net when using the Furuno netsonde. When it appeared that a quantity

of fish had been captured, the tow was terminated to avoid capturing more than the 200 pounds of fish that was considered adequate for a sample.

The *Mako* positioned itself one mile upswell of the target before setting. The *Mako* netsonde did not monitor the mouth of the net, therefore the net was pulled after a set period of time or if, after large or multiple targets were passed, it was assumed that enough fish had been captured.

The *David Starr Jordan* could maneuver quite well in light to moderate seas, making course changes of 20° when approaching a school, and sometimes turning 180° if the school was missed. While turning, the net would sink; how much it sank depended on the sharpness of the turn.

The *Mako* had very little maneuverability with the net out, and turns often caused one of the doors to break the surface of the water. These differences between the *Mako* and *David Starr Jordan* probably result from the *Mako*'s smaller horsepower rating, smaller rudder, shorter trawl warp lengths, and lighter door weights.

## RESULTS

Pacific sardine, northern anchovy, Pacific mackerel, and jack mackerel were all captured with the high-speed trawl during the DEPM survey. The size ranges of fish captured for each species were: Pacific sardine, 136–280 mm; northern anchovy, 30–140 mm; Pacific mackerel, 60–450 mm; and jack mackerel, 50–320 mm (tables 1 and 2).

TABLE 1  
 Total Catch Weight and Length Ranges for Coastal Pelagic Species Caught by the High-Speed Midwater Rope Trawl  
 Aboard the *David Starr Jordan* during the 1994 DEPM Survey

Haul no.	Northern anchovy	Pacific sardine	Pacific mackerel	Jack mackerel
5		229 kg 200–280 mm	0.7 kg 340 mm	490 kg 240–320 mm
8	670.2 kg 70–100 mm			
9		17.8 kg 180–280 mm	24.1 kg 220–410 mm	3.3 kg 200–300 mm
12	0.2 kg 30–50 mm		0.04 kg 60 mm	0.09 kg 50–60 mm
14	8.5 kg 80–130 mm			
18		0.6 kg 240–260 mm	2.8 kg 300–370 mm	
26		6.1 kg 170–280 mm	115 kg 170–310 mm	2,235.5 kg 160–260 mm
27		9.1 kg 170–200 mm	52.1 kg 190–340 mm	494.7 kg 170–260 mm
29			42.4 kg 370–450 mm	
30			55.1 kg 390–450 mm	
31		58.5 kg 170–200 mm	16.1 kg 210–290 mm	0.4 kg 170–260 mm

TABLE 2  
 Total Catch Weight and Length Ranges for Coastal Pelagic Species Caught by the High-Speed Midwater Rope Trawl  
 Aboard the R/V *Mako* during the 1994 DEPM Survey

Haul no.	Northern anchovy	Pacific sardine	Pacific mackerel	Jack mackerel
3		0.4 kg 181–187 mm	0.7 kg 220–290 mm	
4		8.8 kg 168–225 mm	0.07 kg 210 mm	
5		14.7 kg 158–200 mm		
6		2.4 kg 156–202 mm		
7		21.2 kg 160–203 mm		
9		49.5 kg 148–202 mm	10.2 kg 170–360 mm	6.6 kg 150–200 mm
10		45.8 kg 148–197 mm	5.3 kg 180–290 mm	2.8 kg 150–190 mm
14	11.9 kg 120–140 mm			
15	10.4 kg 110–140 mm			
16	82.2 kg 100–120 mm			
17	26.2 kg 110–140 mm			
20		0.6 kg 157–179 mm	2.9 kg 180–230 mm	3.9 kg 150–200 mm
21	38.3 kg 110–140 mm	0.1 kg 136 mm		

In addition to the four target species, we captured large numbers of lanternfishes (*Myctophidae* spp.), with ribbonfishes (*Trachipteridae* spp.), snipe eel (*Nemichthyidae* sp.), blackdragons (*Idiacanthidae* spp.), torpedo rays (*Torpedo californica*), Molas (*Mola mola*), slender sole (*Lyopsetta exilis*), Pacific sanddab (*Citharichthys sordidus*), Pacific whiting (*Merluccius productus*), California smoothtongue (*Leuroglossus stilbius*), California barracuda (*Sphyræna argentea*), tuna crabs (*Pleuroncodes planipes*), market squid (*Loligo opalescens*), and various medusae and salps.

A disadvantage of sampling with a trawl is that it is impossible to determine from mixed catches whether they represent one school of mixed species or several schools of different species sampled over the course of the trawl. Trawling through an area where no targets were seen with electronics was generally nonproductive, and a few tows made during daylight produced no significant catches.

## DISCUSSION

The HSMRT proved to be effective for sampling both young and adult coastal pelagic fish species ranging in size from 40 to 450 mm. The HSMRT was more effective in capturing adults, particularly Pacific mackerel, than the slower and smaller midwater trawls used during surveys of the California Current pelagic fish (Mais 1974). The HSMRT's design is similar to nets used to

capture juvenile tunas (Tanabe and Ogura 1995). In areas where fish schools could be located with the sonar and depth-sounding equipment, it was generally possible to trawl with the net through the area and collect samples.

To determine if the HSMRT sampled a broader range of size classes than commercial round haul gear, we compared length-composition data for the HSMRT and purse seine samples from the Southern California Bight during the 1994 DEPM survey. No sardine longer than 230 mm were found in purse seine catches in nearshore areas, but they were caught in the high-speed trawl. Sardine smaller than 150 mm were poorly represented in the off-shore trawl catches but made up a significant fraction of the purse seine catch (figure 4).

The primary restriction of the HSMRT is that it must be towed in moderately deep water, usually at least 70 meters. Because it sank during setting and hauling back, we typically set the net in water deeper than 200 meters and hauled back in water deeper than 150 meters. Towing was restricted to waters deeper than 70 meters for fear of the net sinking enough to snag the bottom during a course change or if the ship slowed down. Further experimentation may reduce this minimal bottom depth slightly, but probably to no shallower than 50 meters with the present hardware configuration. Some changes in the present hardware setup, such as adding floats to the headrope or changes in door settings, may

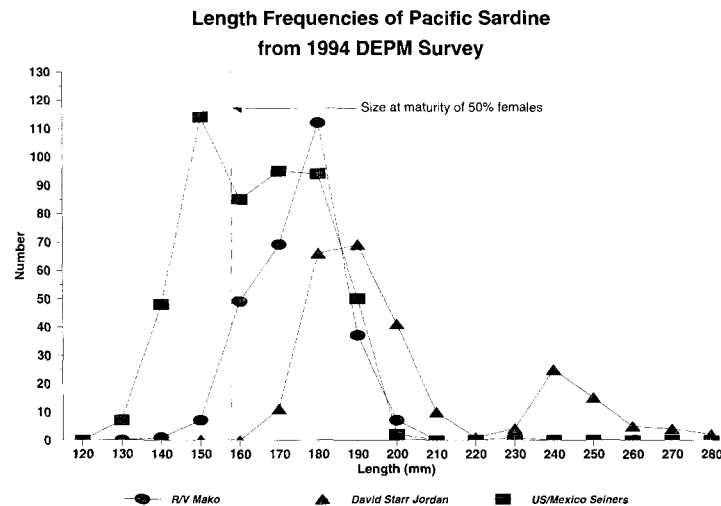


Figure 4. Length frequencies of Pacific sardine (*Sardinops sagax*) sampled during the 1994 DEPM survey within the Southern California Bight (includes Ensenada, Mexico).

allow fishing in shallower water. A fishing vessel must experiment with different door configurations, setback, and scope ratios to determine which are best for that individual vessel and the fishing application.

During the sardine DEPM survey in 1994, the larger and more powerful *David Starr Jordan* fished the HSMRT nearer the surface (as shallow as 5 meters headrope depth) than the *Mako* (minimum headrope depth of 15 meters) and encountered dense schools. These depths and schools fished by the *David Starr Jordan* were similar to those fished with purse seines by the commercial industry. The *Mako*, in contrast, fished on less dense schools of sardine and anchovy at depths of 20 to 40 meters.

Samples of sardine and anchovy collected by the *Mako* consistently contained mature females with hydrated eggs. The *David Starr Jordan*, which generally fished the net at shallower depths, did not capture any females with hydrated eggs. Samples from commercial seiners that fished in the shallow coastal waters were mostly immature females and small males (males not sexed). These preliminary results indicate that hydrated females are found primarily at depths of 20 to 50 meters. These collections of hydrated females, however, may be due to many factors other than depth. Time of collection and area fished were major influences in their occurrence (Butler et al. 1996).

We believe that the effectiveness of this net in capturing fast-swimming pelagics like Pacific mackerel, jack mackerel, and Pacific sardines bodes well for its use in sampling other pelagic species. The design of the HSMRT—which allows relatively high-speed towing by medium-sized vessels; easy deployment and retrieval with standard deck gear; a small crew; and capture of a wide size range of specimens—makes it an attractive sampling tool. The net may also be useful in studies of adult

and subadult Pacific whiting (*Merluccius productus*), juvenile salmon (*Oncorhynchus* spp.), and juvenile pollock (*Theragra chalcogramma*) in the open ocean. Our results (figure 4) suggest that the greatest range in lengths of sardine and anchovy might be obtained by combining commercial (purse seine) and HSMRT samples.

## ACKNOWLEDGMENTS

We would like to thank Dave King and Jim Smart of the NMFS Alaska Fisheries Science Center, Seattle, for their participation in the early trials of the net, for suggesting modifications, and for making many changes in the HSMRT design. We would also like to thank the officers and crew of the NOAA vessel *David Starr Jordan* and the CDFG vessel *Mako* for their efforts during the testing and early use of this net.

## LITERATURE CITED

- Arenas, P. R., J. R. Hunter, and L. D. Jacobson. 1996. The 1994 Mexico–U.S. spawning biomass survey for Pacific sardine (*Sardinops sagax*) and the 1995 CalCOFI Sardine Symposium. Calif. Coop. Oceanic Fish. Invest. Rep. 37 (this volume).
- Browning, R. J. 1980. Fisheries of the North Pacific. 2d ed. Alaska Northwest Pub. Co., 423 pp.
- Butler, J. L., M. L. Granados, G. J. T. Barnes, M. Yaremko, and B. J. Macewicz. 1996. Age composition, growth, and maturation of the Pacific sardine (*Sardinops sagax*) during 1994. Calif. Coop. Oceanic Fish. Invest. Rep. 37 (this volume).
- Lo, N. C. H., L. D. Jacobson, and J. L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515–2526.
- Macewicz, B. J., and J. R. Hunter. 1993. Spawning frequency and batch fecundity of jack mackerel, *Trachurus symmetricus*, off California during 1991. Calif. Coop. Oceanic Fish. Invest. Rep. 34:112–121.
- Mais, K. F. 1974. Pelagic fish surveys in the California Current. Calif. Dep. Fish Game Fish Bull. 162:1–79.
- Tanabe, T., and M. Ogura. 1995. Research on distribution of juvenile tunas by midwater trawl net in the tropical western Pacific. Rep. to 46th Tuna Conference, Lake Arrowhead, Calif. 13 pp.