# Estimated drift gillnet selectivity for albacore *Thunnus alalunga*

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Drift gillnet (DGN) fisheries, some directed toward albacore *Thunnus alalunga* and some toward other species, have operated in the north and south Pacific Ocean. These fisheries, some of which had their beginnings decades ago, expanded in the early 1980s and exerted a substantial, but as yet unknown, mortality on Pacific albacore populations. Knowledge of the selectivity of DGNs is useful for applying complex population-dynamics techniques to the albacore population.

Several DGN experimental surveys conducted in the north and south Pacific Ocean have produced data on albacore distribution and gear selectivity. In 1984–85 the Southwest Fisheries Science Center of the National Marine Fisheries Service (NMFS) undertook an experiment to quantify DGN mesh-size selectivity for albacore. The experiment produced size-selectivity data for a single mesh size used in the U.S. DGN commercial fishery for albacore (184 mm; all mesh sizes referred to are stretch mesh measurements), in the eastern North Pacific Ocean. Other experiments designed to sample albacore were conducted by the Japan Marine Fishery Resource Center in 1980 (JAMARC 1983), 1982 (JAMARC 1985), and 1983 (JAMARC 1986). These experiments used other mesh sizes which produced complimentary data used in this study. The objective of this analysis was to quantify drift gillnet mesh-size selectivity for albacore, using existing data collected from various experiments and surveys in the Pacific Ocean.

## Methods

Various experiments providing data have been conducted independently at different times and in different areas (Fig. 1). Consequently, some assumptions had to be made concerning comparability of nets used and availability and vulnerability of fish sizes to be sampled. However, there was enough information to provide insights into net selectivity for albacore. The nets used in all the experiments were similar to typical Japanese commercial drift nets. All nets had similar mesh-hanging ratios, twine/mesh-size ratios, and were of multifilament construction (Table 1). These are the most important factors affecting the selectivity curve for a given mesh size (Hamley 1975).

Detailed descriptions for the JAMARC experiments, including set locations, timing, mesh size placement, etc, are contained in the JAMARC references. These experiments were designed to obtain information on resource distribution and catch rates for possible future commercial fisheries. In brief, the JAMARC North Pacific experiment was a 1yr survey beginning in the spring of 1980 (Fig. 1). It targeted albacore using nets with mesh sizes of 130–250mm. The JAMARC 1982 and 1983 experiments in the South Pacific were conducted in the area shown in Fig. 1 and targeted all tuna-like species, using 180 mm mesh nets in 1982, and 118 mm and 160–180 mm mesh nets in 1983.

The NMFS experiment targeted albacore. A total of 27 night sets was made: 12 sets in waters south of Point Conception and within 300 mi of shore; 7 sets in the vicinity of the Guide Seamount south of the Farallon Islands; and 8 sets approximately 1000 mi west of Oregon near 142° W long. and 45° N lat. (Fig. 1). All sets used 184 mm mesh nets.

In all the experiments using mesh sizes of >130 mm, the amount of gear fished during each set ranged from 2760 m to 10,800 m, and the number of sets ranged from 11 to 176 (Table 1). Nets in each experiment were deployed and retrieved as in typical commercial operations. Nets were deployed at dusk, and retrieval began at first light often extending into midmorning. Soak times were ~10–16 h/set.

## Data collected

Data published by JAMARC are limited to fork length (FL) frequencies by mesh size by set. The NMFS data include fork length-frequencies, maximum or largest body girth, and opercular girths for each fish, and notation on the mode of capture for each fish (tangled, wedged, or gilled). Fish were described as wedged or gilled when inserted into a mesh so that the entire perimeter of the mesh held the fish. This occurred at locations on the body from the snout to the point of maximum body girth. Fish were described as tangled when snared or tangled by fins or tail. Length-frequencies for U.S. troll-caught fish from the same time and areas are available for

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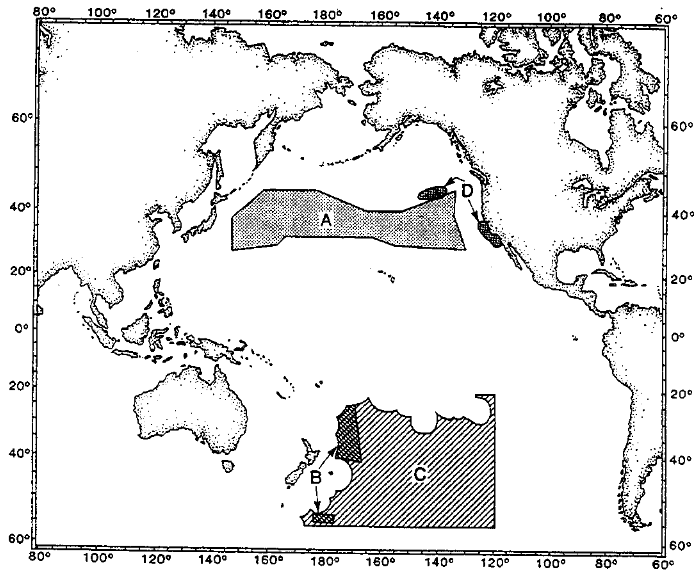


**Figure 1**
Areas sampled for albacore *Thunnus alalunga* by drift gillnets. **(A)** JAMARC 1980 survey (JAMARC 1983); **(B)** JAMARC 1982 survey (JAMARC 1985); **(C)** JAMARC 1983 survey (JAMARC 1986); **(D)** NMFS 1985 experiment.

**Table 1**
Characteristics of drift gillnets used, amount of gear fished, and alalunga caught for selected stretch mesh sizes.

| Survey | Mesh size | Twine size (dinier/ strand) | Net material | Hang-in-ratio (% stretch mesh Distance/ hanging) | No. set |
|---|---|---|---|---|---|
| JAMARC 1980 | 130 | 210/21 | Nylon | 56.1 | |
| (JAMARC 1983) | 150 | 210/24 | Nylon | 56.1 | |
| North Pacific | 160 | 210/27 | Nylon | 56.1 | |
| | 170 | 210/30 | Nylon | 55.5 | |
| | 180 | 210/33 | Nylon | 56.1 | |
| | 200 | 210/36 | Nylon | 56.1 | |
| | All | | | | 178 |
| JAMARC 1982 (JAMARC 1985) South Pacific | 180 | 210/30 | Nylon | 55.3 | 38 |
| JAMARC 1983 (JAMARC 1986) South Pacific | 118 | 210/10 | Nylon | | 11 |
| NMFS 1985 North Pacific | 184 | 210/18 | Polyester | 50.0 | 27 |

comparison. Sample sizes of albacore caught by mesh size for each experiment, as well as the quantity of gear fished, are shown in Table 1.

## Results

### JAMARC 1980 data

Gear selectivity can only be estimated because there is no information on the actual size structure of the North Pacific albacore population (Hamley 1975). Data from several mesh sizes fished simultaneously and assumptions about shape, variance, and efficiency of the selectivity curves are required. The JAMARC 1980 experiment provided the only published dataset containing this information. Length-frequencies obtained in the 1980 experiment for mesh sizes 130, 150, 160, 170, 180, and 200 mm are shown in Fig. 2 (A–F). In all these mesh sizes, albacore captured had size modes at 53, 62, and 78 cmFL.

Two options are available for calculating an indirect selectivity curve: (1) Fitting a predetermined distribution function to data, using a method similar to that of Ishida (1962); or (2) estimating the selectivity of different meshes to one common size-class (mode) of fish and extrapolating to other mesh sizes (Regier & Robson 1966). Lack of an objective mathematical function in determining the shape of the selectivity curve in the first method, and the need for fitting the selectivity curve "by eye," required that a combination approach was employed.

A basic assumption of gillnet selectivity analysis is that selectivity is the same for those combinations of length interval L(i) and mesh size M(j) where the ratios of L(i)/M(j) are equal (Regier

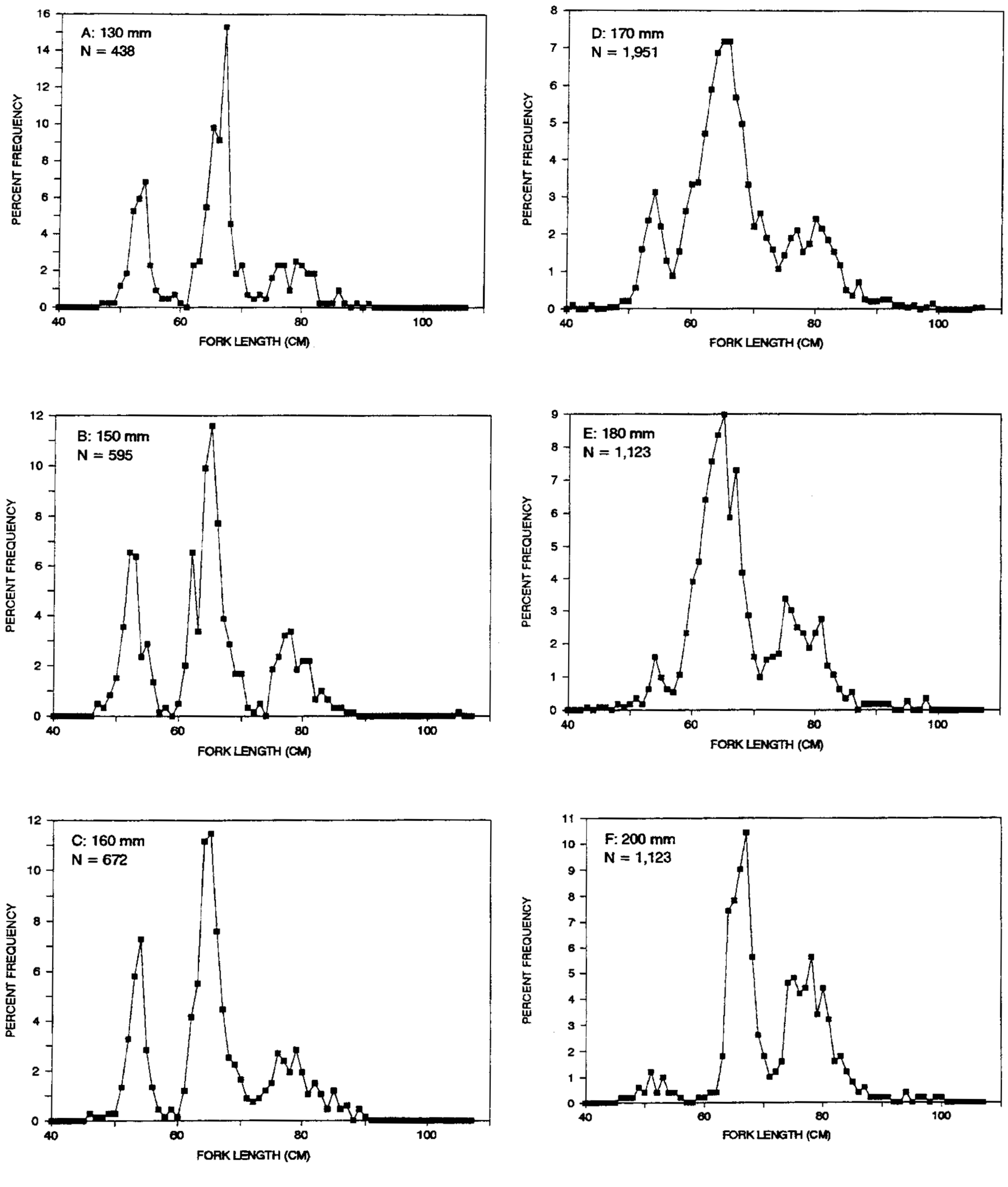


**Figure 2**

Percent frequency-of-occurrence of albacore *Thunnus alalunga* by fork-length interval by stretch-mesh size. Data from the 1980 JAMARC survey (JAMARC 1983). **(A)** 130mm mesh; **(B)** 150mm mesh; **(C)** 160mm mesh; **(D)** 170mm mesh; **(E)** 180mm mesh; **(F)** 200mm mesh.

& Robson 1966). This assumes that the length:girth ratio is the same for all fish. Each fork-length interval was divided by the appropriate mesh size of capture, and then multiplied by the appropriate observed frequency. This produced "generic" size-frequencies by mesh size. Each resulting size-frequency interval, by mesh size, was normalized to the greatest frequency. The resulting frequencies, one for each mesh size, were then scaled to an assumed 100% efficiency at the peak frequency sampled (the mid-60 cm mode); thus, differential sample sizes by mesh are taken into account. If all mesh sizes have the same selectivity curve, and no sampling variance, they would all be the same.

Rather than using the method of Ishida to describe a common selectivity curve (Regier & Robson 1966), the "mean" shape of the selectivity curve was estimated from the selectivity of the different mesh sizes for the largest (78 cmFL) and smallest (53 cmFL) modes captured by all mesh sizes. The curve obtained for the 53 cm mode described the left or ascending limb of the selectivity curve, and the curve for the 78 cm mode described the right or descending limb. Lengths between these two limbs were assumed to be sampled at 100%. This included some lengths with very low percent-frequencies (i.e., we assumed few fish were available) as well as the size mode near 62 cm. There was no assumption that the left and right limbs have the same shape.

For the 78 cm mode, the cumulative percent-frequency of capture vs. length of fish caught for all mesh sizes are shown in Fig. 3. When plotted on normal probability scales, cumulative percent-frequencies

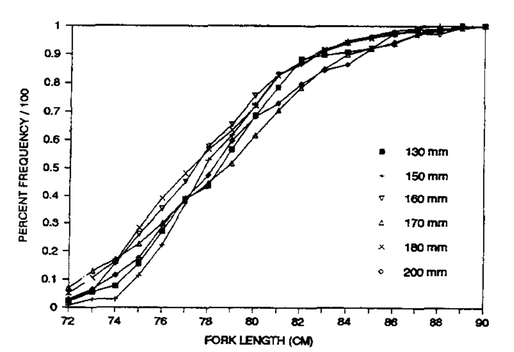


**Figure 3**
Cumulative percent frequency-of-occurrence by fork-length interval for 130 mm, 150 mm, 160 mm, 170 mm, 180 mm, and 200 mm stretch mesh sizes for the 78 cmFL mode of albacore *Thunnus alalunga* sampled in the 1980 JAMARC survey (JAMARC 1983).

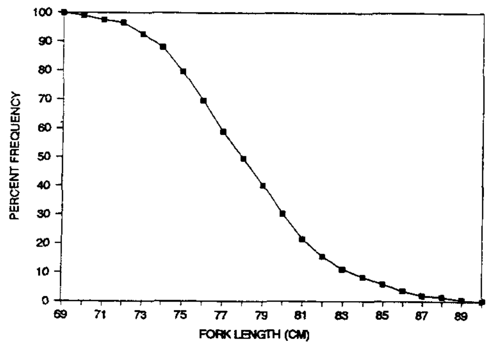


**Figure 4**
Mean selectivity-curve right limb for albacore *Thunnus alalunga* from the 78 cmFL mode sampled in the 1980 JAMARC survey (JAMARC 1983).

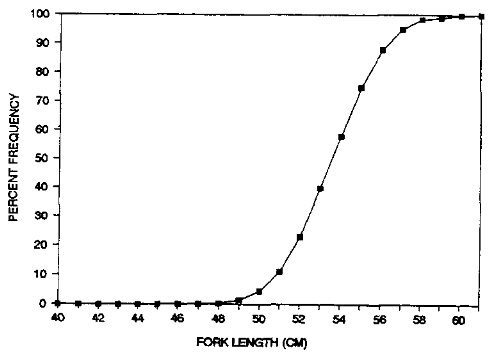


**Figure 5**
Mean selectivity-curve left limb for albacore *Thunnus alalunga* from the 53 cmFL mode sampled in the 1980 JAMARC survey (JAMARC 1983).

formed straight lines with virtually the same slopes. An average cumulative percent-frequency (subtracted from 100) provided the shape of the right limb (Fig. 4). This introduced the assumption of a constant variance and normal distribution (Hamley 1975). The same procedure provided the left limb of the selectivity curve which increased more rapidly or had a greater slope (Fig. 5).

These two limbs must now be placed appropriately on the X axis for each mesh size. This is accomplished separately for each limb by mesh size. The sampling efficiency at 53.5 cmFL for each mesh size was estimated by linear regression. The observed maximum

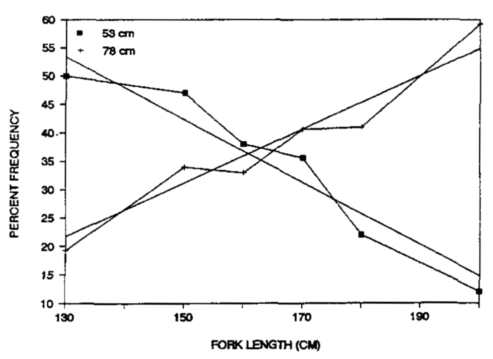


**Figure 6**
Linear regressions of observed maximum percent sampling efficiency at 53 cm and 78 cmFL against stretch-mesh size for albacore Thunnus alalunga.

**Table 2**
Estimated percent sampling efficiency for albacore *Thunnus alalunga* at fork lengths of 53 cm and 78 cm for various stretch mesh sizes.

| Mesh size (mm) | Fork length (% efficiency) 53cm | 78cm |
|---|---|---|
| 130 | 53.3 | 21.7 |
| 150 | 42.3 | 31.2 |
| 160 | 36.8 | 35.9 |
| 170 | 31.3 | 40.7 |
| 180 | 25.7 | 45.4 |
| 184 | 23.5 | 47.3 |
| 200 | 14.7 | 54.8 |

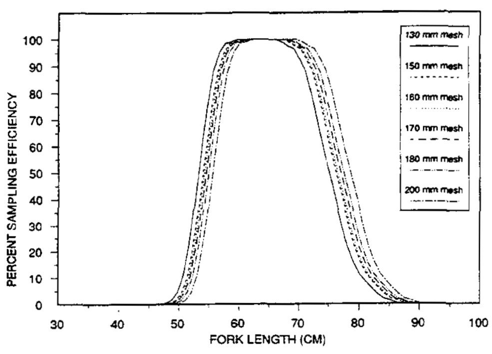


**Figure 7**
Selectivity curves (%) for albacore *Thunnus alalunga* for 130 mm, 150 mm, 160 mm, 170 mm, 180 mm, and 200 mm stretch-mesh sizes.

percent efficiency of sampling at the 53 cmFL peak was regressed against mesh size for all mesh sizes (Fig. 6). The estimated percent sampling efficiency at 53 cmFL for each mesh size is shown in Table 2. Using the same method, the percent sampling efficiency was estimated for 78 cmFL for each mesh size (Fig. 6, Table 2).

The family of selectivity curves by mesh size is shown in Fig. 7. These were determined by shifting the mean selectivity-curve limbs to the left or right so that sampling efficiencies at 53 and 78 cmFL matched the values in Table 2 for each mesh size. Fork lengths between the two limbs were assumed to be sampled with maximum efficiency, consistent with theory associated with unimodal selectivity curves (Hamley 1975).

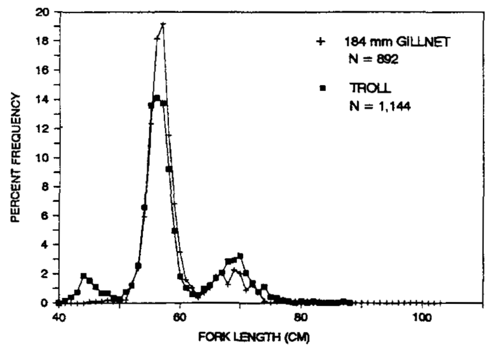


**Figure 8**
Percent frequency-of-occurrence by fork-length interval for albacore *Thunnus alalunga* sampled in the 1985 NMFS experiment by 184mm stretch mesh and by trolling.

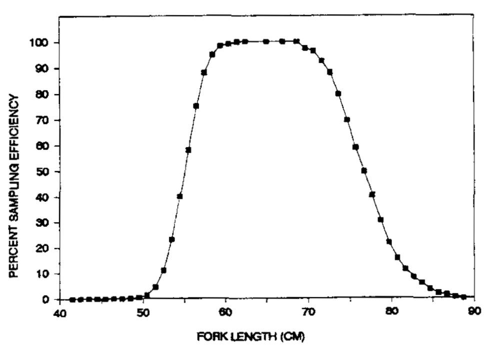


**Figure 9**
Selectivity curve for albacore *Thunnus alalunga* for 184 mm stretch-mesh size.

### NMFS 1985 experiment

Length-frequency data for albacore collected in the 184 mm mesh during the 1985 NMFS experiment are shown in Fig. 8. The estimated selectivity curve is shown in Fig. 9 and, as expected, is almost identical to the 180 mm mesh selectivity curve (Fig. 7). For comparison, length-frequencies from the NMFS experiment taken by both trolling jigs and drift netting in the same area are shown in Fig. 8. As predicted by the selectivity curve (Fig. 9), few fish <50 cm length were sampled by the 184 mm mesh even though the fish were assumed available to the net, as indicated by the size-frequency sampled by the trolling gear fished in the same area and time.

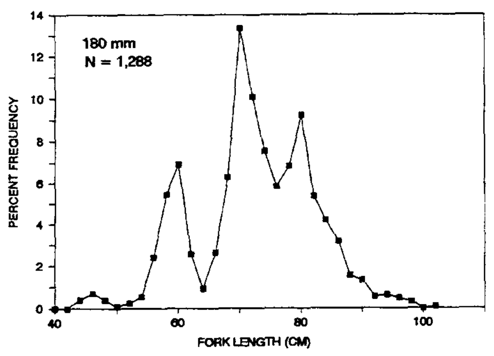


**Figure 10**
Percent frequency-of-occurrence by fork-length interval for albacore *Thunnus alalunga* for 180mm stretch mesh sampled by the 1982 JAMARC survey (JAMARC 1985).

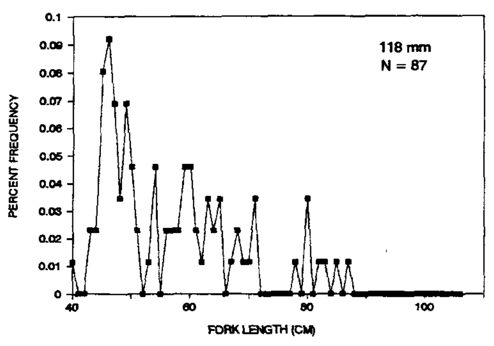


**Figure 11**
Percent frequency-of-occurrence by fork-length interval for albacore *Thunnus alalunga* for 118mm stretch mesh sampled by the 1983 JAMARC survey (JAMARC 1986).

### JAMARC 1982 experiment

The 1982 JAMARC South Pacific experiment collected data for a 180 mm mesh size. Length-frequency data obtained are shown in Fig. 10. The estimated selectivity curve for this mesh is the same as shown for the 180 mm mesh in Fig. 7. From inspection of the length-frequencies for 180 mm and 184 mm mesh sizes from the North Pacific, it was apparent that the South Pacific experiment sampled an albacore population with a different size structure. The results show a much greater proportion of fish in the 70–80 cmFL range than in the North Pacific sampling. This is also seen in samples taken from the U.S. troll fishery that operated in the South Pacific (Rensink 1991)

### JAMARC 1983 experiment

Length-frequency data obtained from the 1983 JAMARC South Pacific experiment using 118 mm mesh are shown in Fig. 11. The selectivity relationships developed from the North Pacific data do not accurately predict the expected selectivity curve for the 118 mm mesh. This is a result of small sample sizes and an observed peak size mode well below the sizes of albacore captured in the mesh sizes used to derive the selectivity curves.

## Discussion

Selectivity curves derived from the JAMARC 1980 experimental data appear similar in shape to selectivity curves presented for salmon *Onchorynchus nerka* and *O. keta*, slender tuna *Allothunnus fallai*, and mackerel *Scomberomorus niphonius*, and other fusiform fishes (Taguchi 1961, Ishida 1964, Shimazaki et al. 1984). The asymmetry of each selectivity curve (i.e., steeper on the left limb and flatter on the right limb) is similar to that observed for selectivity curves of other fusiform fishes (Hamley 1975) and is explained by the mechanics of capture. The smallest fish, retained by the net at some particular girth/mesh-perimeter ratio, tend to be caught near maximum girth. Also, the range of sizes providing the ratio is relatively narrow. For larger fish, the same ratio can be found over a larger range of fish sizes because the point of capture may be anywhere from the maximum girth forward to the snout tip. For example, maximum girth of albacore increases more rapidly than opercular girth as a function of length (Fig. 12) which extends or skews the

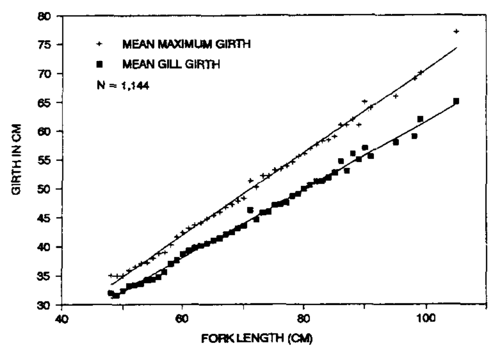


**Figure 12**
Relationship of albacore *Thunnus alalunga* maximum and opercular girths to fork length for 1144 fish sampled by the 1985 NMFS experiment.

right limb of the selectivity curve. This skewing can be troublesome when symmetrical or pre-determined selectivity curves are fit to data. The method used in this study minimizes this problem.

Assumptions that selectivity curves estimated from the 1980 JAMARC experiment applied to similar nets, such as the NMFS 184 mm mesh and the JAMARC-1982 180 mm mesh, appear acceptable from the data available. The principal factor limiting the application of these selectivity curves to other albacore populations is the girth/length relationships discussed above (Fig. 12). Significant changes in this relationship will change the steepness of the selectivity-curve limbs and the skewness.

Extrapolation of the mean selectivity curve to smaller mesh sizes than those providing the initial data may be improper based on the data observed for the 118 mm mesh. Although the sample size was relatively small, the apparent increase in tangling of larger fish caught in smaller mesh sizes compared with larger mesh sizes suggests that the right portion of selectivity curves for meshes <130 mm are more skewed. Tangled fish did not appear to be a problem in the NMFS or JAMARC 1980 datasets, presumably because all mesh sizes either gilled or wedged fish in the largest mode. Additionally, there may have been fewer larger fish available in the survey areas, as shown by troll-caught samples.

The absence of larger, tangled fish in both net-caught and troll-caught samples could result from reduced availability or vulnerability of larger fish in the areas sampled. Surface fisheries (i.e., drift net, troll, and pole-and-line) for albacore in the North Pacific produce catches with similar length-frequencies in the same areas (Bartoo & Foreman In press). However, albacore taken by subsurface longline gear at the same time and area are generally larger in length than those taken in the surface fisheries. This indicates albacore show differential availability or vulnerability between surface and subsurface gears. This could be due to spatial separation or behavior which may change with fish size. The results presented here assume that vulnerability to DGNs is relatively static over time.

## Acknowledgments

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## Citations

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