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# STOCK-RECRUITMENT RELATION IN TUNA POPULATIONS

by

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Among five species of large-sized tunas of genus Thunnus except two coastal species of T. tonggol (Bleeker) and T. atlanticus (Lesson), biological investigations distinguish sixteen established or apparent subpopulations (Table 1). This paper reviews relationships between stock sizes of parents and recruits of them that are exploited and investigated at different degree of intensities.

Bluefin tuna has long been fished by a good many types of fisheries. Information from these various sources indicates wide fluctuation in stock size. Atlantic statistics present a range of annual catch from 25,000 tons in 1961 to 46,200 tons in 1965. Trend of catch differs among fisheries, continuous constant level in longline, purse seine and pole-and-line but decrease in trap since 1967 (ICCAT 1971, 1973b, Bard et al. 1973, Rodriguez-Roda 1973). Mather (1973) noted decline of medium-sized bluefin tuna against no substantial change of small- and large-sized fish. Mather et al. (ms) seem to attribute the variation of size composition to random fluctuation in year class strength. Literal investigations of ancient manuscripts lead Uda (1952) and Ito (1961) to believe long-term fluctuation in stock size of bluefin tuna in the western Pacific over past hundred years (Fig. 1). Nakamura (1969) noted year-to-year shift of modal sizes of catch from the western Pacific. His observation also implies occurrence of dominant year classes.

Two types of fisheries exploit southern bluefin tuna, Australian surface fishery of trolling and pole-and-line for youngs of 2- to 5-ages and Japanese longlining for immatures and adults of 4- to 10-ages or older (e.g. Hayasi, Shingu and Hisada 1972). The fish seem to spawn only in the eastern Indian Ocean among the wide distribution range, but the spawning season lasts as long as six months (Shingu 1970). Fluctuation in year class strength in southern bluefin tuna is not remarkable. But careful examination of data manifests occurrence of dominant year classes at young and immature stages taken by surface fishery (Hisada unpublished) and by longline fishery (Shingu and Hisada 1971, Warashina and Hisada 1974) in the waters adjacent to Australia. Hayasi's calculation (ms) failed to relate sizes of recruits with parent stocks that decreased to only seven percent of initial size for thirteen years, even though he stressed necessity of more advanced evaluation of abundance of fish at different stages of life history (Fig. 2).

Albacore is taken by longline fishery over the whole distribution range. Remarkable fluctuation in year class strength is known in two subpopulations in the North Atlantic and the North Pacific which are intensively exploited by surface fishery at immature stage. As to the Atlantic subpopulation, Bard (1974) pointed positive correlation between cpue of longline fishery in a year and that of surface fishery in three to five years later, indicating that decline of parent stock from about 4.9 to about 2.8 resulted in decline of recruitment. According to Suda (1966) stock-recruitment relation in the North Pacific appears to follow Ricker's curve (1954) for eight year classes, in which parent stock changed from 2.0 to 0.7 and rised recruitment slightly.

Bigeye tuna spawn in tropical waters seemingly throughout a year and disperse higher latitude at immature stage (Suda et al. 1959, Kikawa 1966, Kume 1969a). Statistics of longlining, only substantial fishing on this fish, in the Pacific Ocean exhibits fairly remarkable fluctuation in year class strength (Kume 1969b). At the same time, it appears reasonable to assume Ricker's model (1954) for average stock-recruitment relationship therein (Suda 1970). Investigations and fishing in the other two oceans are not yet intensive enough so as to reveal change of year class strength.

Compared to other tunas, yellowfin tuna has plastic ecology, spawning in wide range of time and space (Kikawa 1966, Honma and Hisada 1971). Surface fisheries exploit the fish at young, immature and adult stages, especially in large-scale in the eastern Atlantic and eastern Pacific, while longlining plays important role in harvesting immatures and adults in the western Atlantic, western Pacific and Indian Oceans. Hook rate in the Atlantic Ocean declined from over four percent in the 1950's to 0.82 percent in 1965 and 0.57 percent in 1971, suggesting shrinkage of parent stock in longline fishery to one-seventh in the 1970's. Spawning index halved from 1965 to 1971 (Honma 1974). ICCAT (1973c, p. 46) also expressed fear on such decline of spawning stock. Nevertheless year classes for 1964 to 1969 and possibly 1970 were still strong and weak recruit occurred in only 1967 and 1968 (ICCAT 1973a). Thus there appeared no stock-recruitment relation yet. Schaefer (1957, 1967) presented good fit of logistic curve to the eastern Pacific subpopulation in the years when the catch comprised mainly youngs of 1- to 3-ages. IATTC (1973, unpublished) advanced analytical studies in addition to examination of production model for stock assessment in recent years when development of purse seining expands both fishing ground and range of size of fish. Estimates of recruitment increased for recent years but this does not straightly mean actual increase of the stock. Kamimura et al. (1966) applied Ricker's model (1954) to stock-recruitment relation of yellowfin tuna in longline fishery in the central and western Pacific. Actual points, however, scatter in the right limb of the curve. Honma and Suzuki (1972) obtained scattered points in effort-catch relation of longline-caught yellowfin tuna in the Indian Ocean. They as well as Suda (ms) noted that variation in year class strength is more remarkable in the Indian Ocean than in the Atlantic and Pacific.

In spite of recent drastic change in stock and fishery under fairly extensive surveys, stock-recruitment relation was found only in albacore in the North Atlantic and North Pacific, yellowfin tuna in the central and western Pacific, and bigeye tuna in the Pacific Ocean. Among these four subpopulations, the points of only the North Atlantic albacore are distributed in left ascending limb of stock-recruitment curve, i.e. decrease of parents caused decrease of recruits, even though range of parent stocks did not not exceed the comparable changes in the other two subpopulations. Furthermore the other 12 subpopulations failed to show effect of decline of parent stock on size of recruit. These phenomena suggest that prolific species such as tunas are not easily reduced by depletion of parents. There are some possible causes for masking stock-recruitment relation. One of them is statistical error of indices of parent stock sizes, and another variation of survival of juveniles due to environmental changes as suggested by remarkable fluctuation in bluefin tuna with the most limited spawning ground and season.

Nevertheless important for standing point of management is that often intensified fishery causes reduction of its productivity. For example recent calculation shows that total catch of southern bluefin tuna does not increase with fishing intensity so high as to reduce the relative stock fecundity (Fig. 3). The comparable results were obtained for yellowfin tuna and albacore (Hayasi, Honma and Suzuki 1972). In other words, rise of fishing intensity to a level of decreasing recruit or left descending limb on stock-recruitment curve must be avoided not only from biological reason but also from economical points of view.so a

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Table 1. Subpopulations of large sized tunas.

| Species | Areas | Fishing gears | Remarks |
|---|---|---|---|
| Bluefin | Atlantic Ocean and Mediterranean Sea | Trolling, trap, pole-and-line, purse sine, longline and others | Possibly two further division originating in the Carribbean and Mediterranean Seas |
| Bluefin | Pacific Ocean | As above | A single subpopulation in the North Pacific with minor southward expansion of habitat |
| Southern bluefin | Southern hemisphere | Trolling, pole-and-line, and longline | A single subpopulation originating in the eastern Indian Ocean |
| Albacore | North Atlantic | As above | |
| Albacore | South Atlantic | Longline | Possible mixing with subpopulation in the Indian Ocean |
| Albacore | North Pacific | Trolling, pole-and-line, purse seine and longline | |
| Albacore | South Pacific | Pole-and-line and longline | |
| Albacore | Indian Ocean | Longline | Possible mixing with subpopulation in the South Atlantic Ocean |
| Bigeye | Atlantic Ocean | Mainly longline | Possible mixing with subpopulation in the Indian Ocean |
| Bigeye | Pacific Ocean | As above | Possible mixing with subpopulation in the Indian Ocean |
| Bigeye | Indian Ocean | As above | Possible mixing with subpopulations in the Atlantic and Pacific Oceans |
| Yellowfin | Eastern Atlantic | Pole-and-line, purse seine and longline | Possible mixing with subpopulation in the western Atlantic |
| Yellowfin | Western Atlantic | Mainly longline | Possible mixing with subpopulation in the eastern Atlantic |
| Yellowfin | Eastern Pacific | Pole-and-line, purse seine and longline | Possible mixing with subpopulation in the western Pacific |
| Yellowfin | Western Pacific | Mainly longline | Possible mixing with subpopulations in the eastern Pacific and Indian Oceans |
| Yellowfin | Indian Ocean | As above | Possible mixing with subpopulation in the western Pacific, and westward expansion to southeastern Atlantic |

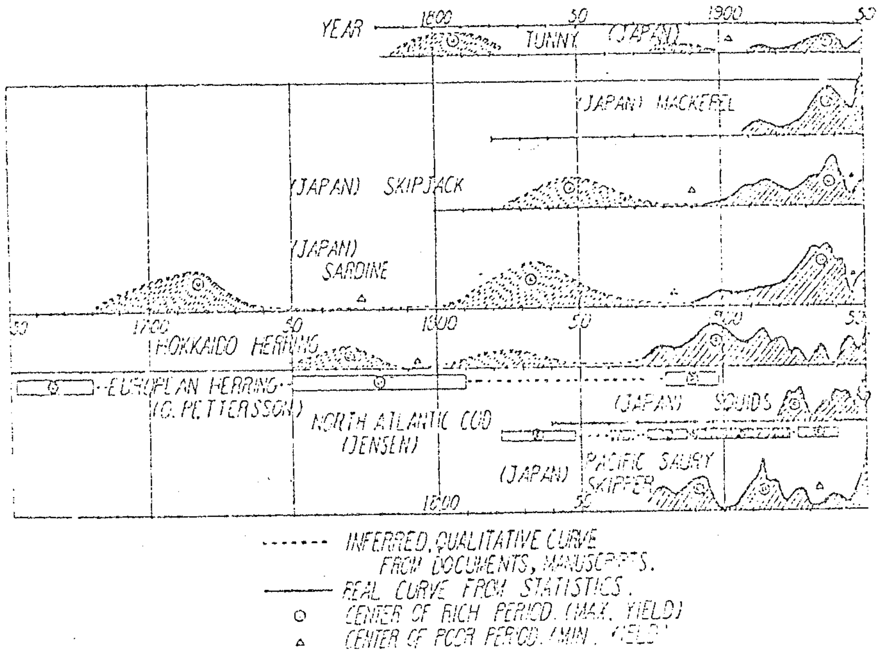
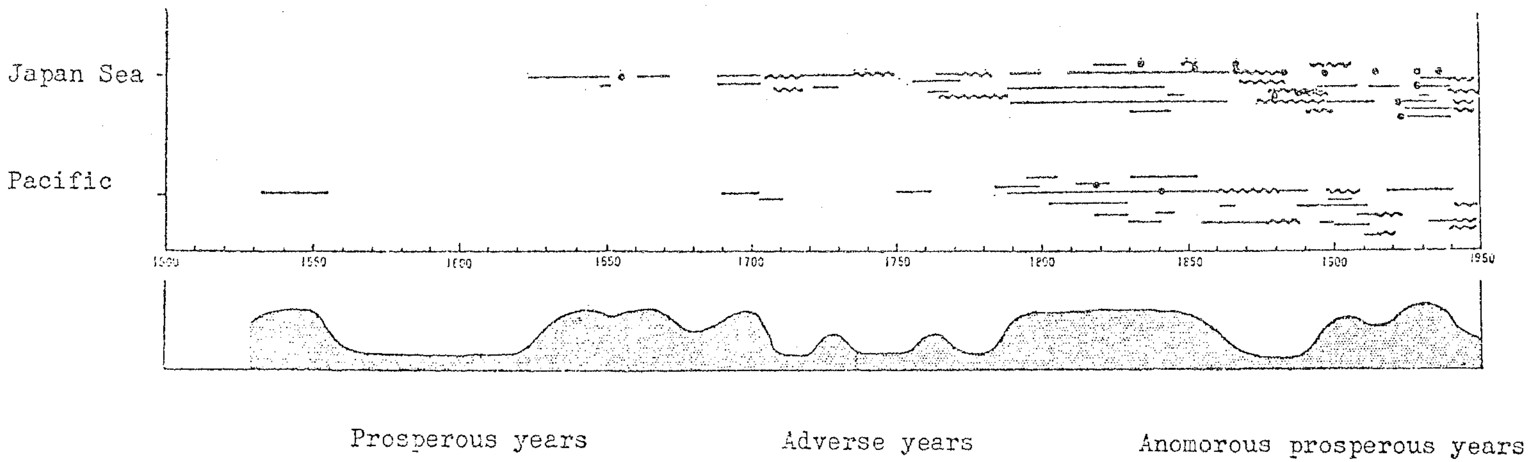



Fig. 1. Surmised long-term change in catch of bluefin tuna and some other species in the waters adjacent to Japan.

After Uda (1952), left panel, and Ito (1962), lower panel.



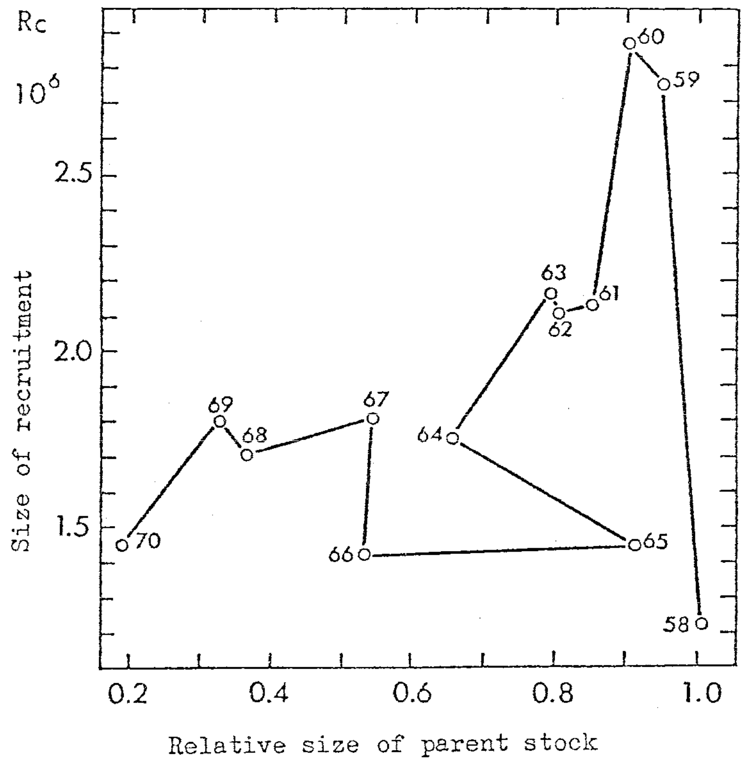



Fig. 2. Stock-recruitment relation of southern bluefin tuna, 1958-59 - 1970-71 seasons.

After Hayasi (ms).

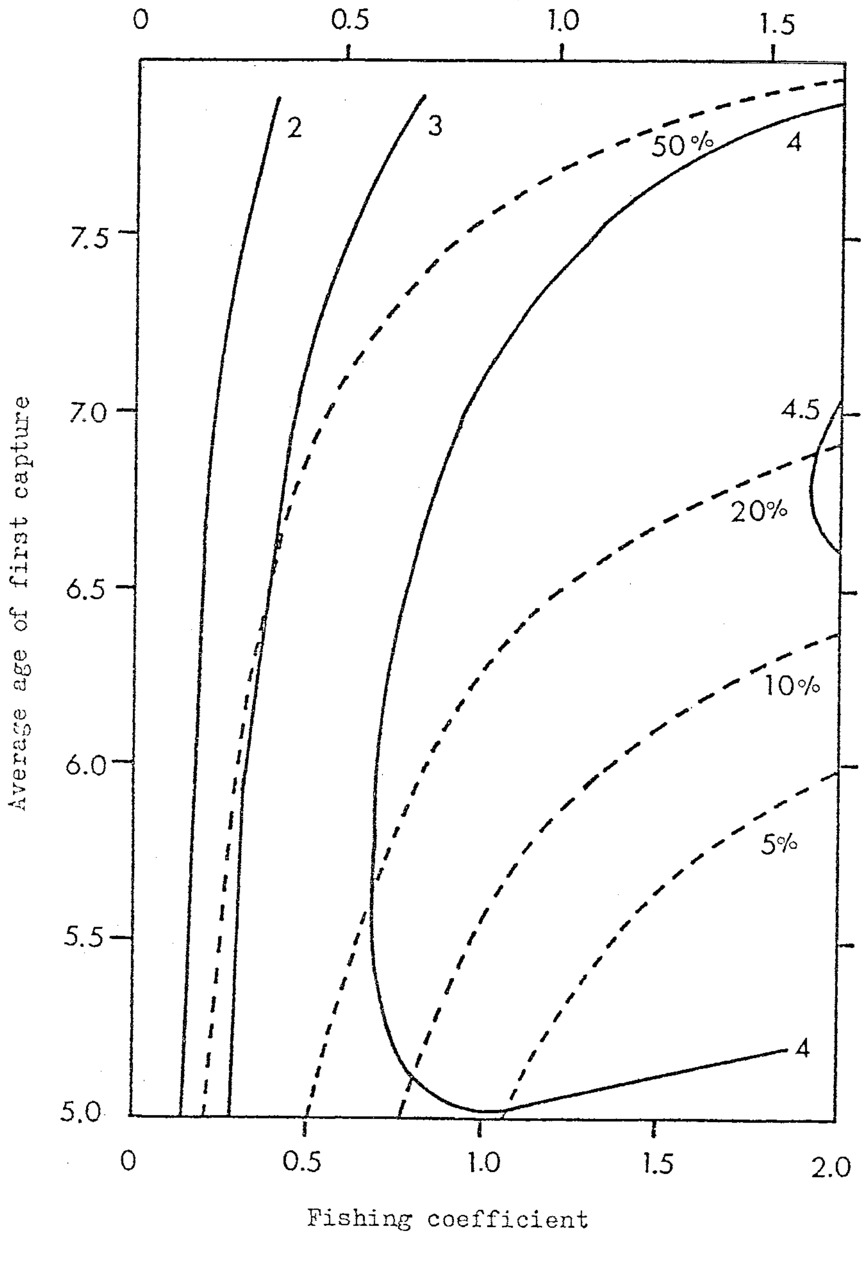



Fig. 3. Isometric curves of yield in 10,000 tons and relative stock fecundity in percent of southern bluefin tuna.

Modified from Hayasi (ms).