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BIOLOGY AND FISHERY OF DOLPHINFISH AND RELATED SPECIES. *E. MASSUTÍ and B. MORALES-NIN (eds.)*

Review of dolphinfish biological and fishing data in Japanese waters*

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SUMMARY: The dolphinfish (*Coryphaena hippurus*) performs seasonal migrations into adjacent waters of Japan, where it is exploited by several fisheries. The annual dolphinfish landings in Japan have tended to decrease in recent years. Between 1993 and 1995, the mean annual catch was 9962 metric tonnes. This total catch corresponded to the following fishing methods: set net fishery 24.9%, skipjack pole and line fishery 21.2%, surrounding net fishery (which is mainly comprised of the "shiira-zuke" fishery) 12.9%, longline fishery 10.2%, other angling fisheries 10.3%, and other fisheries 20.5%. In the "shiira-zuke" fishery, fishermen catch dolphinfish and other fishes gathering around bamboo rafts (called "tsukegi") with a purse seine net. Major fishing grounds of this fishery are situated in the western Japan Sea and off the south Pacific Japanese coast. The use of floating FADs to create productive fishing areas is of ecological interest. In this paper we describe this fishery, and review the biological characteristics of dolphinfish with regard to ecology and fishing conditions.

Keywords: Dolphinfish, *Coryphaena hippurus*, Fisheries, Biology, Western Pacific.

INTRODUCTION

In the Pacific Ocean, the dolphinfish (*Coryphaena hippurus*) is found year round in waters within latitude 30º (Kojima, 1964a). From early summer to autumn, this species performs seasonal migrations into the adjacent seas of Japan, where it is the target of important fisheries.

Surface migratory fishes such as dolphinfish, skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*) are well known to gather under floating objects like driftwood and floating seaweed. The Japanese "shiira-zuke" fishery captures mainly dolphinfish which gather under bamboo rafts (called "tsukegi") set on the sea surface. Although the use of FADs (Fish Aggregation Devices) in unused offshore areas, with surface migratory fishes as targets, has attracted attention over the years, much remains unknown about the gathering mechanism or the fish collecting effect of these FADs. Several studies in Japanese waters have examined biological aspects of the "shiira-zuke" fishery (e.g. Kojima, 1955, 1956, 1960a, 1960b, 1961, 1963a, 1963b, 1964b, 1966a, 1966b, 1967, Ida *et al.*, 1967; Sakamoto and Taniguchi, 1993).

Here we review information on dolphinfish fisheries in Japanese waters, as well as data on the biology of this species in the area. In particular, we review the ecological aspects and fishing conditions (fishing data, seasonal changes, length distribution, growth, feeding habits and fish community associated with "tsukegi") of the "shiira-zuke" fishery.

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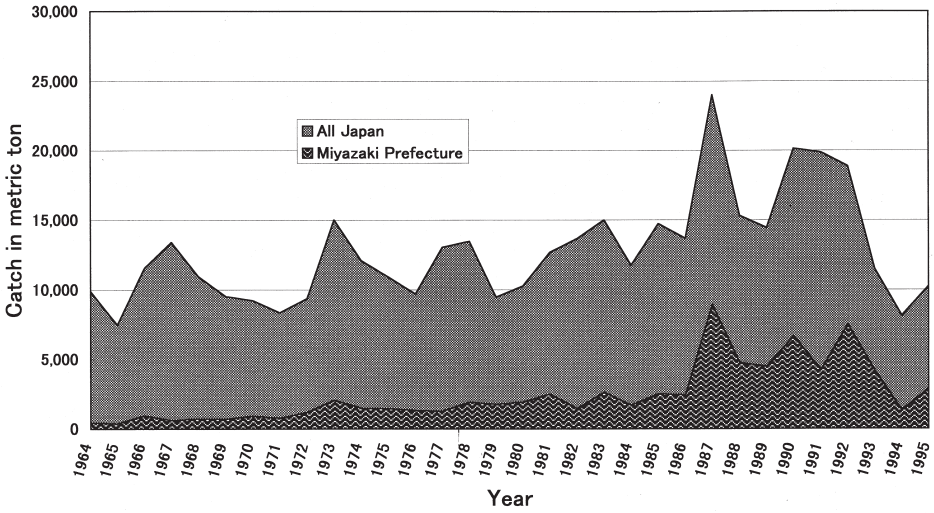

FIG. 1. – Historic catch data series of dolphinfish in all of Japan and in Miyazaki Prefecture.

PRODUCTION TRENDS

The annual catches of dolphinfish in Japan tended to increase from 1964 to 1987 (Fig. 1). Following a peak catch of 24019 metric tonnes in 1987, the annual catch decreased in 1988-1989. In recent years (1993-1995) the mean annual catch of dolphinfish has been 9962 metric tonnes, with a mean annual value of ¥1785 million. This overal trend is consistent with that seen in Miyazaki Prefecture, a major dolphinfish fishing area (Fig. 1). The recent mean annual catch (1993-1995) in Miyazaki Prefecture has been 2775 metric tonnes of dolphinfish,

TABLE. 1. – Annual catches (metric tons) of dolphinfish by regions in adjacent waters of Japan. Statistics based on home ports.

Sea region	1989	1990	1991	1992	1993	1994	1995
Hokkaido	110	285	105	131	15	102	61
North Pacific	457	630	1006	1502	39	85	85
Middel Pacific	1362	2214	4509	1512	860	912	1238
South Pacific	6849	10111	9136	10205	6007	2469	4782
North Japan Sea	575	1043	710	634	155	537	811
West Japan Sea	2145	2337	1172	1654	1686	1252	1122
East China Sea	2919	3509	3210	3226	2707	2777	2088
Seto Inland Sea	10	16	21	8	27	9	15
Total	14427	20145	19869	18872	11496	8143	1024

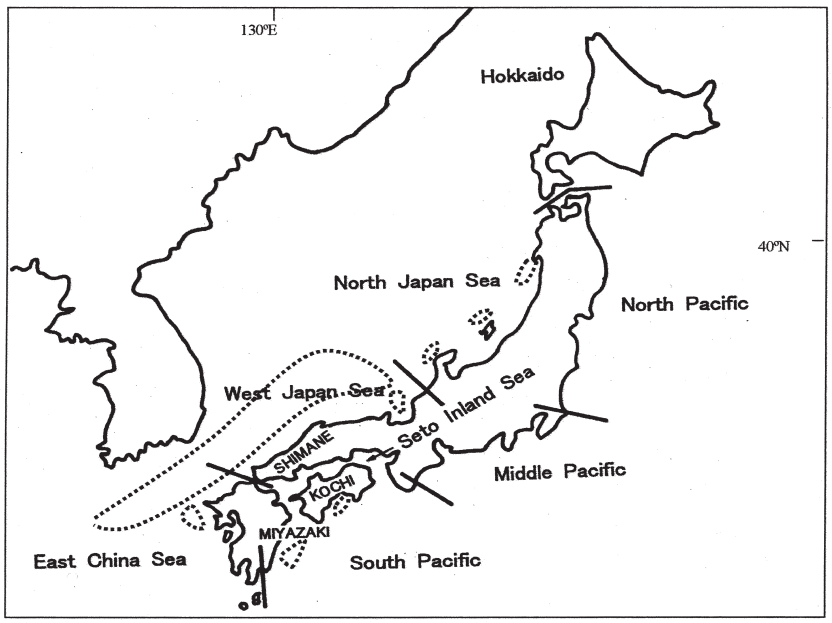

FIG. 2. – Regions of adjacent waters of Japan and distribution of "shiira-zuke" fishing grounds (dotted areas).

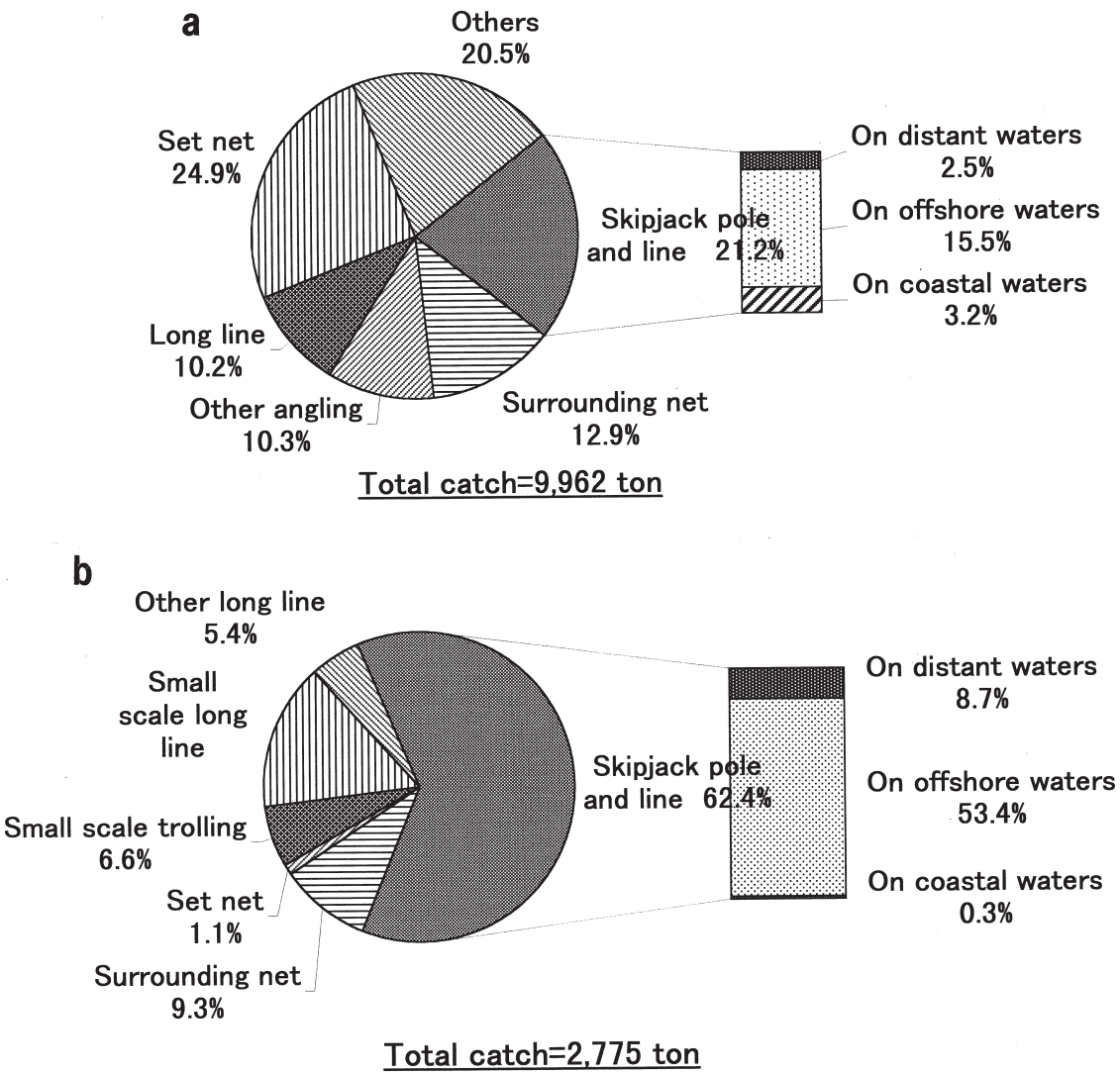

FIG. 3. – Mean annual catch (1993-1995) of dolphinfish by fishing methods in Japan (a) and in Miyazaki Prefecture (b). The percentage of dolphinfish catches by fishing area in the skipjack pole and line fishery is also shown.

with a mean annual value of ¥603 million. Annual catches of dolphinfish by regions (Fig. 2) from 1989 to 1995 (Table 1) indicated that the South Pacific and East China Sea are responsible for two thirds of Japan's total production.

Mean annual catch (1993-1995) of dolphinfish by fishing methods in Japan and in Miyazaki Prefecture are given in Fig. 3. The most important portion of dolphinfish is caught in the skipjack pole and line fishery. Its major offshore fishing areas, where dolphinfish is captured as by-catch, change with seasonal migration of skipjacks (Fig. 4). Other important fisheries for dolphinfish are the surrounding net fishery, which is comprised mostly of the "shiira-zuke" fishery, the set net fishery and the longline fishery.

The seasonal pattern of dolphinfish landings in seven major markets of Miyazaki Prefecture from 1993 to 1995 is shown in Fig. 5. Although dolphinfish is captured all year round, about 70% of the catch is landed from April to June.

FISHING METHODS AND FISHING AREAS

In the trolling line fishery, 1-5 metric ton vessels use cutriggers to tow 2 main surface lines and several subsurface lines, each bearing 1 to 3 hooks and artificial baits. They operate from June to August between 5 and 30 miles from shore (Yamaguchi, 1977). The longline fishery uses 3-10 metric ton vessels which deploy 10-16 Km of multihook, sub-

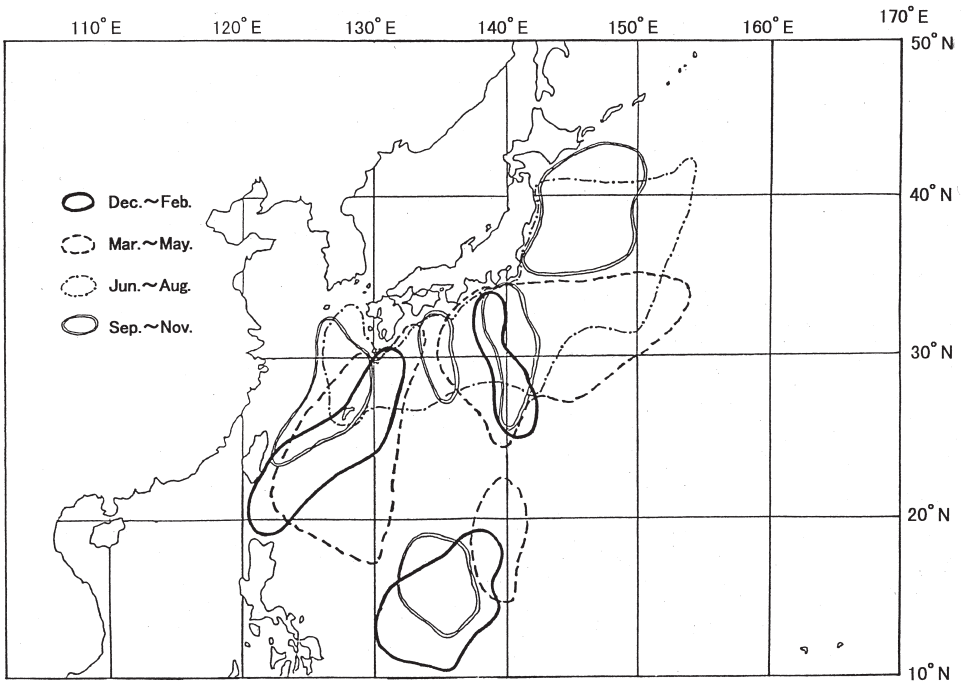

FIG. 4. – Seasonal fishing grounds of the skipjack pole and line fishery in offshore waters of Japan. Data source: "Adjacent Sea Skipjack and Tuna Fishery" by the Japan Fisheries Association and National Association Adjacent Sea Skipjack and Tuna Fishery (1989).

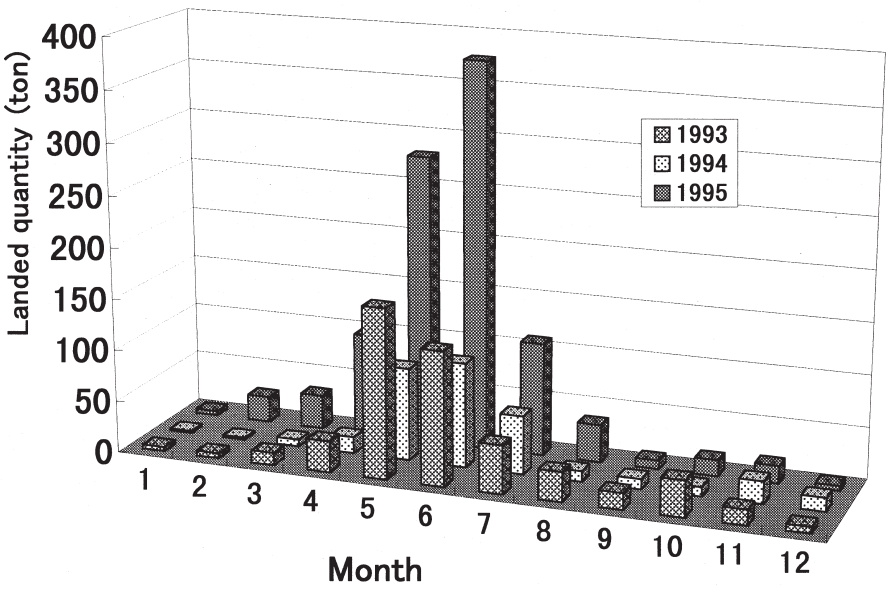

FIG. 5. – Monthly distribution of dolphinfish landings in seven major markets of Miyazaki Prefecture from 1993 to 1995.

surface (9-12 m depth) longlines. They also operate between 5 and 30 miles from shore between May and July (Kaveda, 1995).

In the "shiira-zuke" fishery, anchored bamboo rafts (called "tsukegi") are used, and dolphinfish and other fishes gathering around are caught with a purse seine net. The "shiira-zuke" fishery is a traditional fishery targetting mainly dolphinfish, although in recent years the fishery captured mainly amberjack (*Seriola lalandi*) along the west coast of East China Sea. Major fishing grounds (Fig. 2) are situated in the western Japan Sea (Shimane Prefec-

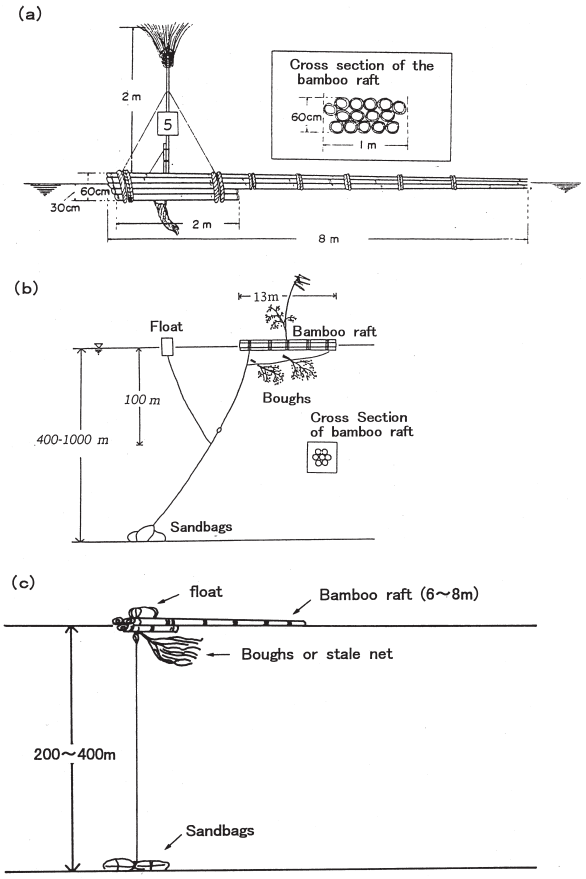

FIG. 6. – Design of "tsukegi" (bamboo raft for dolphinfish used in the "shiira-zuke fishery) typical of Shimane (a), Kochi (b) and Myyazaki (c) districts.

ture) and off the Japanese coast in the western Pacific (Miyazaki and Kochi Prefectures). The use of anchored FADs restricts the fishing grounds to relatively shallow waters over the continental shelf, and to areas without strong currents. In the Kochi district, they are situated 30-40 miles off the shore and over 1000 m depth. During the fishing season (June-November) more than 2000 "tsukegi" may be set over this area, and to avoid the excessive competition for sea space, the setting line of respective "tsukegi" is decided by lottery every year, such that in principle a vessel will only operate along the assigned line, except in cases of co-operation with other vessels.

The designs of the "tsukegi" typical of the Shimane, Kochi and Miyazaki districts are shown in Fig. 6. In the Kochi and Miyazaki districts, a green wood of bayberry is tied below the "tsukegi", because fishermen consider that this "darkness" (the bush) has a crucial effect on aggregation of dolphinfish, and replace the bayberry branches once or twice a month to prevent the falling and browning of leaves. The purse seine net used is about 180 m long on its buoy side. The net height is approximately 10.5 m in the bag and 3.3 m in the wings. The mesh size is approximately 3 cm in the bag and 6 cm in the wings. Vessels operating in the "shiira-zuke" fishery are between 5 and 18 metric tons and have 45-140 horse power. A single boat's crew usually consists of 2 persons.

The fishing operation around each "tsukegi" is carried out as follows. Mackerel slice are scattered as chum, whilst baits of rainbow runner (*Elagatis bipinnulata*) and buller mackerel (*Auxis rochei*) are towed, and artificial mongrel mackerel (*Acanthocybium solandri*) and dolphinfish (tubular streamers made of cloth) are used to lure the gathered fishes out from under the "tsukegi". The purse seine is then cast around the lure school. Reactions to the chum differ between species. For example, compared to the dolphinfish, rainbow runner and greater amberjack (*Seriola dumerili*) are much more difficult to lure away as a school. Catchability also differs between species, and dolphinfish cannot escape the purse seine by cruising vertically like some other fish (e.g. skipjack, yellowfin tuna and mongrel mackerel). These species are not easily captured by purse seine nets, and have to be caught by piercing with a hook or harpoon.

TABLE 2. – Fishes taken around "tsukegi" by the "shiira-zuke" fishery along Kochi Prefecture during June through November 1985 (from Sakamoto and Taniguchi, 1993).

Species	Length(cm) Range	Mode	Sample size
Elagatis bipinnulata	16.7-79	29-30	422
Seriola quinqueradiata	34	-	1
Seriola rivoliana and *S. dumerili*	15.6-48	24-26	256
Seriola lalandi	35	-	1
Naucrates ductor	23.5, 27.5	-	2
Decapterus macarellus	18-45	22-24	176
Kaiwarinus equula	19	-	1
Caranx sexfasciatus	25.5	-	1
Uraspis helvola	14.5-29.2	20-22	167
Carangoides orthogrammus	18-28	24-28	21
Carangoides ferdau	21.5	-	1
Coryphaena hippurus	27-130	48-50	1111
Lobotes surinamensis	25.5-49	47	7
Kyphosus lembus	14-33	-	18
Kyphosus cinerascens	9-25.5	12-13	5
Oplegnathus fasciatus	15.5	-	1
Oplegnathus punctatus	16	-	1
Acanthocybium solandri	44-136	80-90	136
Katsuwonus pelamis	25.5-35.5	26-27	43
Auxis rochei	35-37	-	3
Thunnus albacares	25-63	38-40	23
Thunnus alalunga	33-44	-	6
Aluterus monoceros	12-46.5	36-38	197

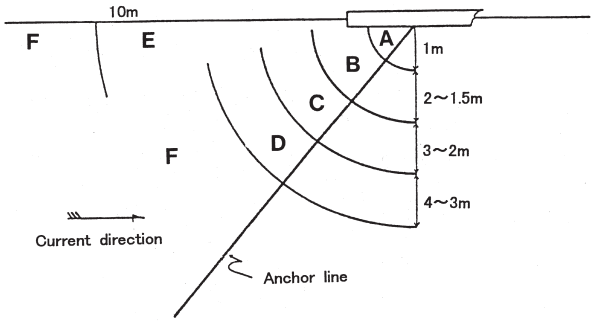

FIG. 7. – Spatial distribution of fish species around "tsukegi" in the Shimane Prefecture (from Kojima, 1966c).

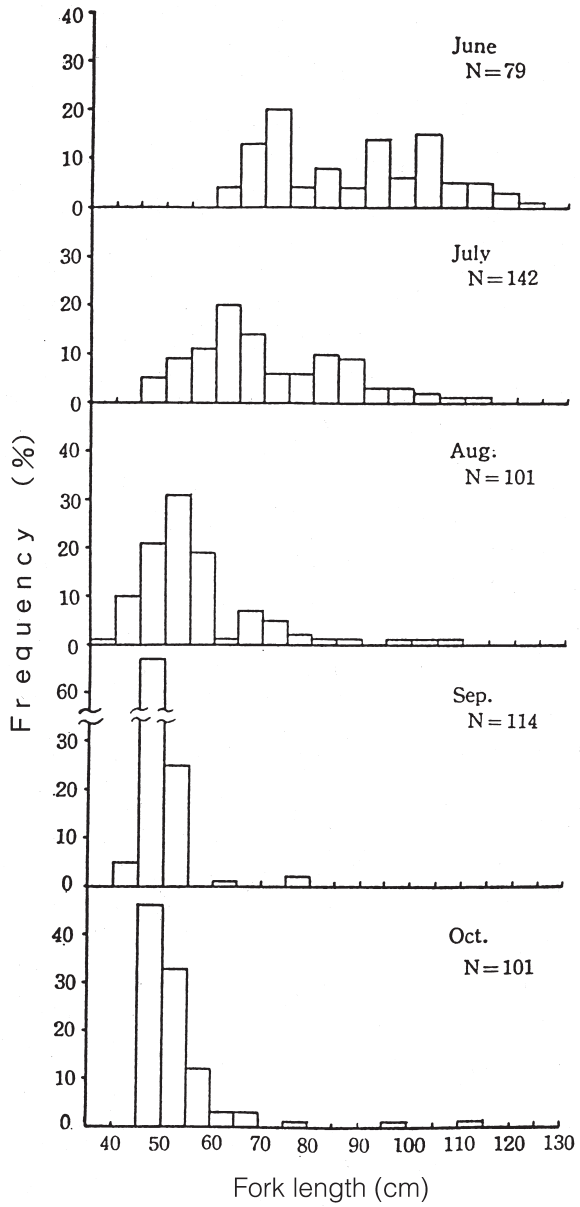

FIG. 8. – Monthly size distributions for dolphinfish caught by the "shiira-zuke" fishery in the western Japan Sea off Shimane Prefecture during the 1964 fishing season (from Kojima, 1966b).

"TSUKEGI" FISH AGGREGATIONS

Table 2 shows the species composition of "tsukegi" fish aggregations. The absence in the catches of small fishes that are thought to be beneath the "tsukegi" is most likely a result of their not being vulnerable to the fishing method and gear. Because catchability differs clearly between species, the results obtained might not reflect faithfully the actual ratios of species and quantity of fishes gathering around the "tsukegi".

However, these data allow the identification of much of the fish fauna gathering around the "tsukegi". Dolphinfish was overwhelmingly the most numerous species, followed by *Elagatis bipinnulata*, *Seriola dumerili*, *Seriola rivoliana*, *Aluterus monoceros*, *Decapterus macarellus*, *Urasois helvola* and *Acanthocybium solandri*. Body length ranged widely from *Kyphosus cinerasecens* of 9 cm to *A. solandri* of 136 cm. *Thunnus albacares*, *Thunnus alalunga*, *S. dumerili*, *S. rivoliana*, and *E. bipinnulata* were found to gather around the "tsukegi" as young immature fish.

The spatial distribution of fishes around the "tsukegi" has a characteristic pattern (Fig. 7). Dolphinfish usually swim about 10-15 m up current from the "tsukegi", and are seldom seen in any other place. All the fish attracted to "tsukegi" tend to stay parallel to it, gathering either around the anchor line or the head of the raft against the current. Among the various species schooling about the raft, the smallest was *Girella punctata* of about 5 cm in length. Fishes staying at the "tsukegi" are those which have grown enough to resist the current.

BIOLOGICAL DATA

The monthly size distribution of dolphinfish caught in the western Japan Sea (Fig. 8) shows that early in the season (June) schools are composed mainly of large fishes of more than 60 cm fork length (FL), and after August they are mainly composed of small fishes of about 50 cm FL. Based on Kojima (1966a, 1966b), dolphinfish larger than 55 cm FL were fully mature, so this seasonal variation in size represents the appearance of spawning schools (older fish) and feeding schools (young fish).

Simmilar trends can be observed in the southern Pacific Japanese coast (Fig. 9), where large size fish (over 80 cm FL) were identified as the main group

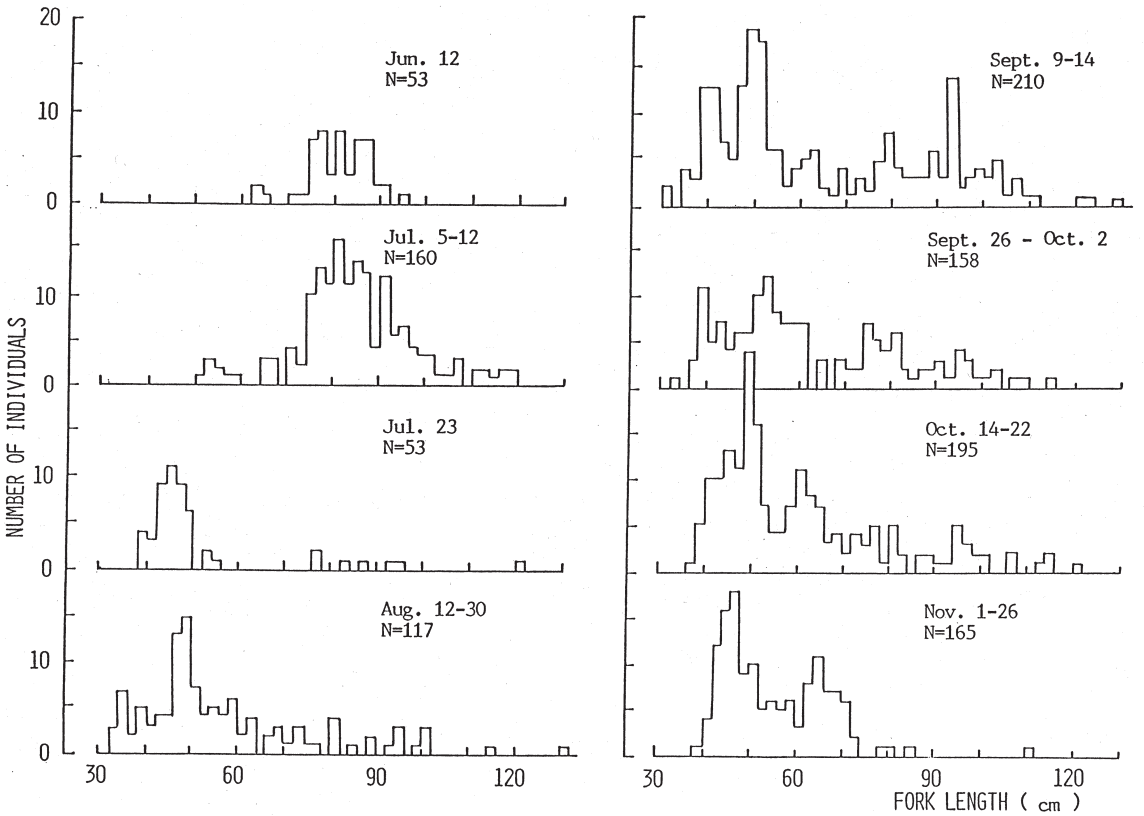

FIG. 9. – Monthly size distributions for dolphinfish caught by the "shiira-zuke" fishery in the southern Pacific Japanese coast off Kochi Prefecture during the 1985 fishing season (from Sakamoto and Taniguchi, 1993).

until the middle of July, and small size fish (45-50 cm FL) became the main group after late July. This pattern is consistent with that reported in the Japan Sea, except for the occurrence of a well defined large size group in July, which appears relatively often until late October. Furthermore, the modal length of about 45 cm FL in late July increases over the months to about 65 cm FL in November. From September to October, individuals with a mode of 40-50 cm FL appear, and in November the size distribution is clearly bimodal.

In Japanese waters, dolphinfish reach about 38 cm FL by the first year, 68 cm FL by the second year, 90 cm FL by the third year, 108 cm FL by the fourth year and 122 cm FL by the fifth year. However, growth rates observed in reared specimens were higher, and in the aquarium young specimens of 45 cm and 0.5 Kg were grown to the size of 123 cm and 16.6 Kg in 9 months (Masuda *et al.*, 1975). Furthermore, of 36 young dolphinfish between 35 and 50 cm total length (TL) collected in September-October 1975 and kept in a big tank at 22.8-25.4°C, 11 specimens survived until April 1976, at which time they had increased in length to about 100 cm TL (Soichi, 1978).

Feeding habits of dolphinfish have been extensively studied in Japanese waters. From 1103 specimens between 35 and 105 cm in length captured in the Japan Sea, Kojima (1961) found that fishes made up 85% of the food items by frequency of occurrence and 95% by weight. The food items appeared, for the most part, to fall into two size groups: 2-4 cm (e.g. *Stephanolepis cirrhifer*, *Engraulis japonicus* and *Upeneus bensani*) and 10-15 cm (e.g. *E. japonicus*, *Sardinops melanostictus* and flyingfishes). The same author concluded that the diet of dolphinfish changes during the early development (Kojima, 1966c). Thus, juveniles up to 4 cm TL mainly feed on Copepoda, and thereafter they begin to feed on other juvenile fish such as *Cololabis saira*, *Seriola quinqueradiata*, *Girella punctata* and *Stephanolepis cirrhifer*. Young fish >18 cm TL feed mainly on pelagic juvenile fishes such as *E. japonicus*, *U. bensasi* and flyingfishes.

Similar results were obtained by Sakamoto and Taniguchi (1993) from adult dolphinfish captured by the "shiira-zuke" fishery in the western Pacific Japanese coast. From 575 samples, 306 individuals were detected to contain food. Fishes were overwhelmingly the most numerous group in the stom-

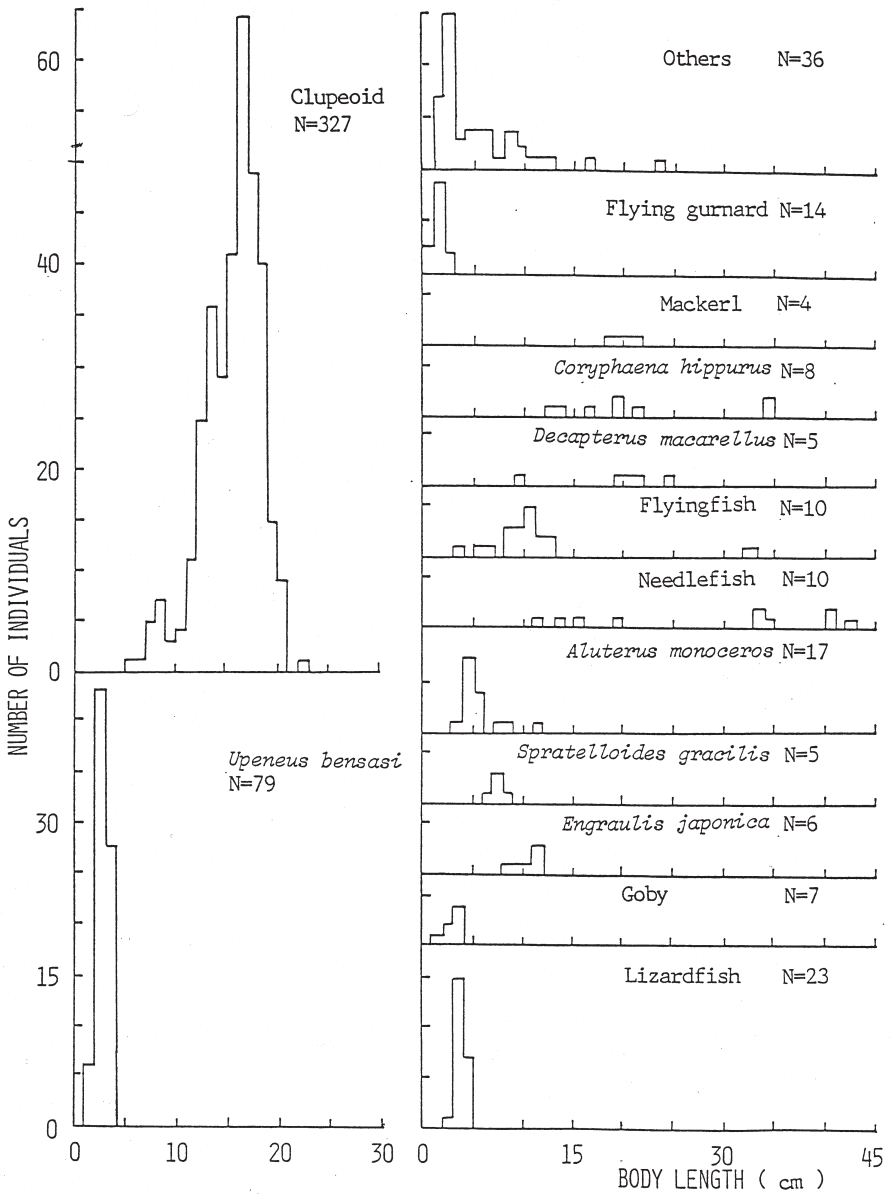

FIG. 10. – Body length composition of each food item found in the stomach contents of dolphinfish caught by "shiira-zuke" fishery off Kochi Prefecture in 1985 (from Sakamoto and Taniguchi, 1993).

ach contents, accounting for 86.7% of the total number of prey items and 98.4% of the total weight; clupeids (including *S. melanostictus*, *Etrumeus teres*, *E. japonicus* and other unidentifiable species) were the most frequenct preys, occurring in 68% of all stomachs. In total, fishes from 24 families and 35 species were identified as prey of dolphinfish, with *S. melanostictus* occuring in 51% of all stomachs containing food and accounting for 63.8% of the total weight of prey items. The next most frequently occurring species was *U. bensasi*, which was found in 11.8% of all stomachs and accounted for 13.5% of all prey items by number and 0.2% by weight. It was found that prey size varied widely, from 1 cm to about 35 cm (Fig. 10), but size distribution of prey was distinctly bimodal: one mode below 4 cm and the other around 15-20 cm, which was consistent with the former knowledge in the Japan Sea (Kojima, 1961).

The diet of dolphinfish varied during its ontogenic development (Fig. 11). The smaller the body length class was, the more juvenile fish occurred in the stomach contents. Inversely, the bigger the predator was, the more large size prey appeared. By groups, clupeids were important in all size classes of dolphinfish. For invertebrate prey, crustaceans were

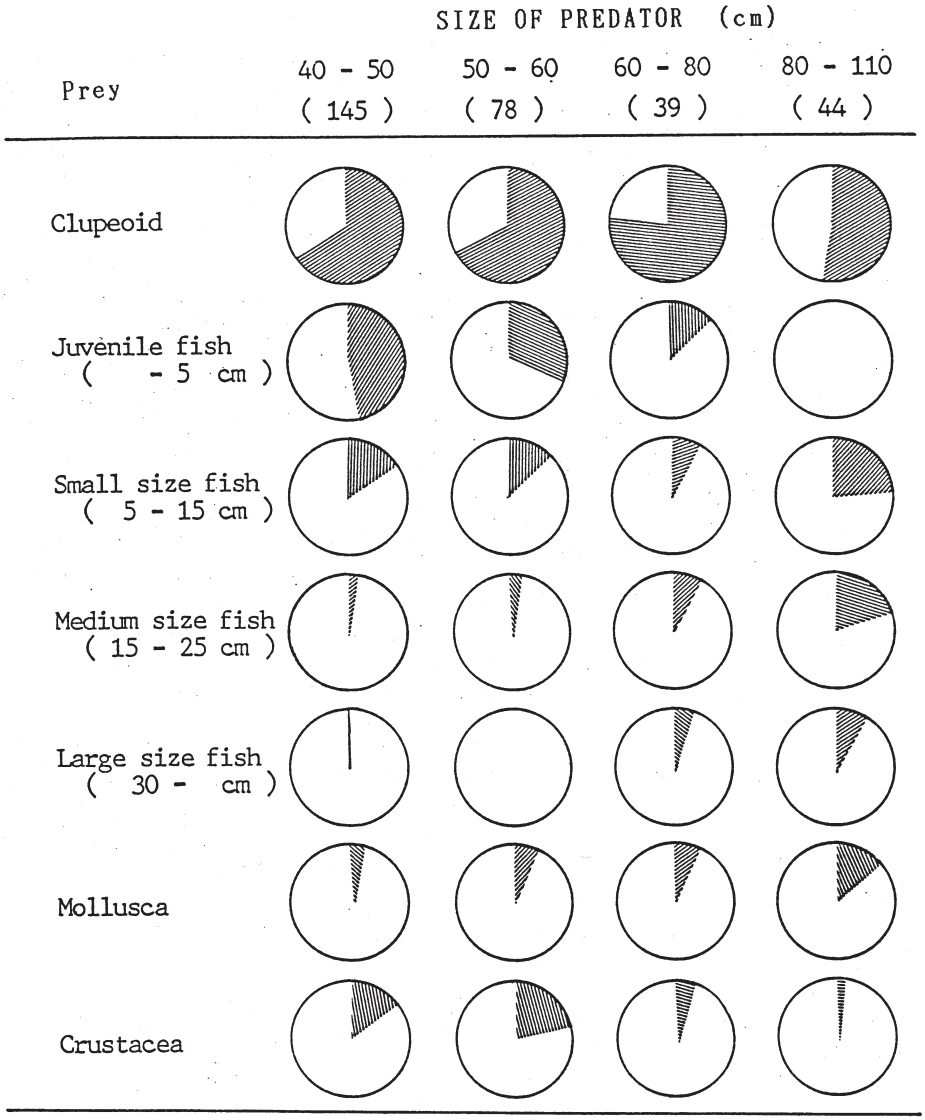

FIG. 11. – Frequency of occurrence (as percentage) for selected prey items of dolphinfish, stratified by predator size, off Kochi Prefecture in 1985 (from Sakamoto and Taniguchi, 1993).

found more frequently in fish of smaller size, and molluscs occurred more often in the stomachs of fish of larger size. Daily changes in feeding activity have been analysed by Sakamoto and Taniguchi (1993). The comparison of degree of digestion of stomach contents between dolphinfish caught in the morning and in the afternoon indicate that dolphinfish feed more actively in the morning than in the afternoon.

Seasonal changes in the diet of dolphinfish have also been observed. In most of the stomachs analysed from the Japan Sea, medium sized fish exceeded juveniles in amount (Kojima, 1963b). Nevertheless, species composition of medium sized fish in the stomachs changed 2 or 3 times within each of the three fishing seasons considered. During this period of alternation, medium sized fish decreased while juveniles increased in amount. Based on the above observations, it can be considered that dolphinfish feed mainly on medium sized fish, but sometimes on juveniles when the primary food becomes scarce. In the southern Pacific Japanese coast (Sakamoto and Taniguchi, 1993), clupeids occurred with high frequency over all seasons (Fig. 12). Nevertheless, juvenile fish (<5 cm length) appeared with high frequency in August and September, and small sized fish (5-15 cm length) occurred with high frequency from June to September. Molluscs occurred frequently in June and August, and crustaceans appeared from August to

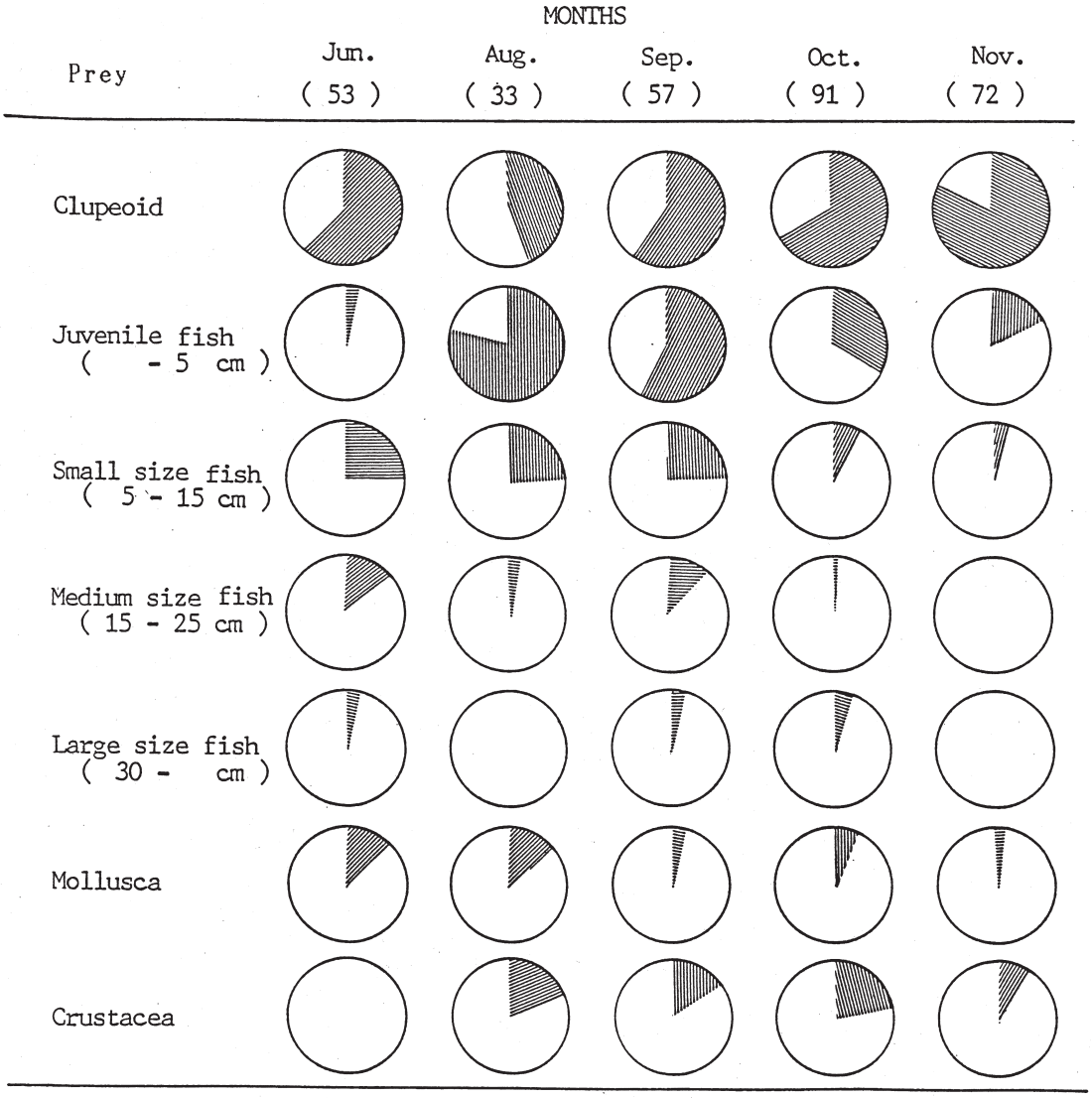

FIG. 12. – Frequency of occurrence (as percentage) for selected prey items of dolphinfish, stratified by month, off Kochi Prefecture in 1985 (from Sakamoto and Taniguchi, 1993).

October. In any case, prey selection of dolphinfish was basically not strong, and dolphinfish can be defined to be opportunistic feeders that catch preys which live near the very surface and in sizes they can catch. Thus, these seasonal changes in the diet of dolphinfish may be related to changes in the prey environment and to a different size composition of the dolphinfish population.

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