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

The fishery, demographic size structure and oocyte development of dolphinfish, *Coryphaena hippurus*, in Venezuela and adjacent waters*

FREDDY AROCHA[1], LUIS A. MARCANO[2], ASDRUBAL LÁREZ[2], DOUGLAS ALTUVE[2] and JOSE ALIÓ[2]

[1]Instituto Oceanográfico de Venezuela, Universidad de Oriente Apartado de correos no. 204, Cumaná 6101 Venezuela
E-mail: farocha@sucre.udo.edu.ve
[2]Centro de Investigaciones Agricolas y Pesqueras, FONAIAP. Cumaná, Venezuela

SUMMARY: Dolphinfish, *Coryphaena hippurus*, is a widely distributed epipelagic species that migrates seasonally in different areas of the oceans. In Venezuelan and adjacent waters it is fished commercially mainly by artisanal fishermen using surface longline and gillnet. Information on effort, location, catch at size, weight and sex determination from 1991 to 1997 was used to determine the seasonality of the demographic structure of dolphinfish off Venezuela. A total of 4876 specimens were measured and sexed from port sampling and observer-covered trips in longline vessels. Oocyte development and spawning season were estimated from samples collected in observer-covered trips on board longline vessels. The seasonality of dolphinfish off Venezuela appears to show two different size groups: one arriving at the end of the first quarter comprised of large mature individuals that will spawn in May, and one arriving at the beginning of the third quarter comprised of smaller specimens that will spawn in October-November. Sex ratio at size was significantly biased towards females in all quarters for smaller specimens (<100 cm FL), while males were predominant in larger size classes (>120 cm FL). Oocyte development revealed an indeterminate spawning pattern, as shown by the asynchronous oocyte development in the material examined. A reproductive strategy is proposed based on the seasonal movement pattern of dolphinfish off Venezuela, which is used to ensure recruitment success due to the prevailing environmental conditions off the Venezuelan coasts.

Key words: *Coryphaena hippurus*, dolphinfish, size structure and seasonality, sex ratio at size, oocyte development, Venezuela.

INTRODUCTION

Dolphinfish, *Coryphaena hippurus* L., 1758, is a mid-size, fast-swimming, epipelagic oceanic species that migrates seasonally in different areas of the oceans and is widely distributed throughout the tropical, subtropical and temperate oceans between 40°N and 40°S (Palko *et al*., 1982). In the North Atlantic Ocean, spawning occurs in the warm waters of the western central Atlantic and in the Mediterranean Sea (Beardsley, 1967; Oxenford and Hunte, 1986; Massutí and Morales-Nin, 1997).

In Venezuelan waters, dolphinfish occurs seasonally. It has been caught as by-catch in the tuna longline fishery since early 1960 (Nemoto, 1968) and by the recreational fishery since the late 1950s (Jaen and Jaen, 1994). In late 1980, the demand for, and economic importance of, this species began to grow, inducing the artisanal fleets to start targetting dolphinfish. This situation became more evident in the northeastern region, where most of the artisanal surface longline fleet is based, which shifted fishing

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operations to target dolphinfish during the season of higher relative abundance (Marcano *et al*., 1997). At present, it is one of the most important large pelagic fish landed by the artisanal fishermen in terms of weight and revenue.

There is little information about the biology of dolphinfish in the southern Caribbean. Preliminary studies in Venezuela have indicated that most of the landings (90%) take place between March and August, with May and June as peak months (Marcano *et al*., 1997). It was also observed that sex ratio favored females in two areas of the Venezuelan coasts. In the present paper, we re-analyze and update the data used by Marcano *et al*. (1997) to propose a seasonal movement pattern that may be related to a reproductive strategy of dolphinfish in the waters off Venezuela.

METHODS

Dolphinfish data on effort, location (Lat., Long.), catch at size, weight and sex determination were collected during 1991-1997 from port sampling and observer-covered trips in surface longliners. Data from port sampling included samples from the fishing village of Playa Verde (La Guaira area), where the gillnet catch is landed, and samples from Margarita Island, where most of the artisanal surface longline catch is landed. Data were also obtained from the observer-covered trips in the tuna and swordfish longline fishery.

Sex ratio at size was estimated based on 3469 females (20-160 cm FL) and 1407 males (40-170 cm FL) caught in Venezuelan and adjacent waters. The sex ratio data were based on the proportion of females partitioned into four quarters for all years combined. The proportion of female data was fitted using a locally weighted regression smoother (S-plus, 1997) and 95% binomial confidence intervals were also estimated.

Dolphinfish gonads are a delicacy among fishermen and is very difficult to obtain gonad samples with information on the fish. The gonad samples for this study were obtained from four observer-covered trips on artisanal longline vessels during May, June, October-November and December 1995. Information on location, size and weight of fish was recorded, but only one pair of mature gonads was collected. Thus, no estimates on GSI were possible. Staging and measurement of whole oocytes were determined from sectioned ovaries of 8 females. Each ovary section was thawed and a random sample of the whole section was analyzed. Over 300 oocytes for each ovary sample were measured at random using a video analyzing system linked by a video camera to a dissection microscope, and frequency size distributions of oocyte diameter were later estimated. Because the oocytes were basically spherical, the orientation of the oocytes with respect to the line of measurement was random.

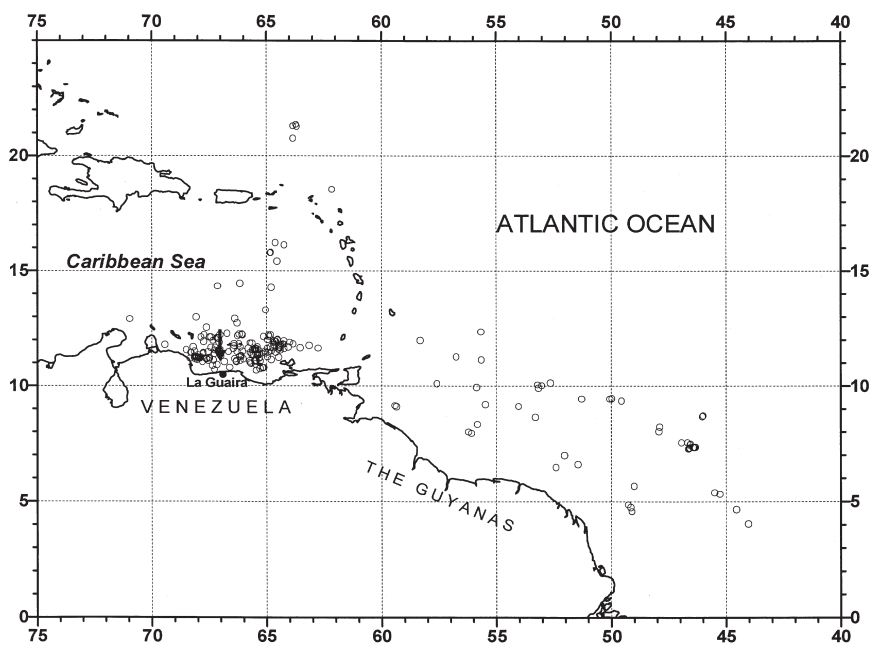

FIG. 1. – Spatial distribution of dolphinfish off Venezuela and adjacent waters based on locations of longline sets where dolphinfish catch was recorded and specimens were measured and sexed (open circles represent a minimum of one individual). Arrow showing submarine mountain.

RESULTS

The fishery

Dolphinfish is fished commercially off the coasts of Venezuela over deep water (>200 m) using gillnets and surface longline, and is also caught as by-catch by the tuna and swordfish longline fishery in the Venezuelan EEZ and adjacent waters (Fig. 1). It occurs in Venezuelan waters during the entire year, but its relative abundance is very seasonal.

The gillnet fishery is localized in a small fishing village (Playa Verde) in the La Guaira area located on the central coast (~67°W). There are 28 gillnet vessels operating in this area; these vessels are small artisanal 8 to 10 m wooden boats equipped with 48-75 HP outboard engines. This fleet performs daily trips with no refrigeration of the catch. The nets are fished overnight (from 18:00-20:00 until 5:00-6:00) with the float line 12 to 15 m below the surface; total net lengths range between 500 and 1500 m, and the average mesh size varies from 38 to 63 mm. The fishing is conducted year round, targeting medium to large pelagic fish species. It is concentrated in and around "el Placer de La Guaira", a sea mount rising up to 200 m from the surface which was established as a Marine Protected Area (MPA) to exclude commercial longlining. The dolphinfish catch by this fishery showed a steady increase as the result of the increase in the number of trips during the monitored period (1991-1997). However, the CPUE has remained level at around 3 kg/trip (Table 1).

The artisanal surface longline fishery that targets dolphinfish is based on Margarita Island, located off the northeastern coast. The fleet consists of 85 wooden (8 and 14 m) vessels, equipped with a central diesel engine of 25 to 150 HP, and no electronic gear until 1996. These vessels are also equipped with live fish holds to keep live bait (mainly sardine and jack mackerel depending on the target species). This fleet performs 8 to 10 day trips and deploys 200 to 400 hooks per set. The fishing is conducted during the daytime in 3 to 4 hour sets. The fleet concentrate their effort around Venezuela's offshore island group located about 100-250 km off the central and eastern coasts, including the area off La Guaira. The catch reported by this fishery showed a steady increase from 1991 to 1995 as a result of the increase in the fishing effort geared to target dolphinfish (Table 1), resulting in a steady increase in the CPUE from 4.3 to a maximum of 23.0 kg/100 hooks. The last two years of the time series showed a decline in the catch as well as in the CPUE, accompanied by small reductions in the fishing effort when compared to the trend in previous years. This situation may be the result of under-reporting catch and fishing effort during these last two years, when a considerable proportion of the fleet shifted landing ports and started fishing illegally in the MPA off La Guaira.

The dolphinfish caught as by-catch in the tuna and swordfish longline fishery represent a small fraction of the total catch from this fishery, but represent 15% of the total sampled dolphinfish catch in the area. Similar to the other fisheries, the catch reported by this fishery showed a steady increase that has doubled in the last two years (Table 1). The information on catch location has revealed the extent of the spatial distribution of dolphinfish (Fig. 1) and the size composition of the catch by this fleet has showed that it catches mostly larger specimens (>90 cm FL) in the Venezuelan EEZ and off the Guyanas.

TABLE 1. – Total reported dolphinfish landings for Venezuela from 1985 to 1997. Sampled catch, effort and CPUE for the gillnet fishery, artisanal, and Tuna and SWO (tuna and swordfish) longline fishery during the sampling period of 1991-1997.

	Venezuela	Gillnet fishery (La Guaira)			Artisanal longline fishery			Tuna and SWO longline fishery		
	Total Landings (MT)	Sampled Catch (MT)	No. trips	CPUE kg/trips	Sampled Catch (MT)	No. hooks	CPUE kg/100 hooks	Sampled Catch (MT)	No. hooks	CPUE kg/100 hooks
1985	17	-	-	-	-	-	-	-	-	-
1986	11	-	-	-	-	-	-	-	-	-
1987	2	-	-	-	-	-	-	-	-	-
1988	18	-	-	-	-	-	-	-	-	-
1989	6	-	-	-	-	-	-	-	-	-
1990	50	-	-	-	-	-	-	-	-	-
1991	190	2	1417	1.4	13	303848	4.3	9	1961693	1.2
1992	208	4	1389	3.0	10	337089	3.0	3	1648112	1.1
1993	243	4	1495	3.0	20	568310	4.0	4	2949418	0.3
1994	274	5	1475	3.4	93	650515	14.3	6	3366636	0.4
1995	447	7	1301	5.3	95	411630	23.0	10	3164000	0.9
1996	560	8	2524	3.0	64	501974	13.0	21	2398500	1.3
1997	697	10	2472	4.0	90	528115	17.0	23	2504412	1.3

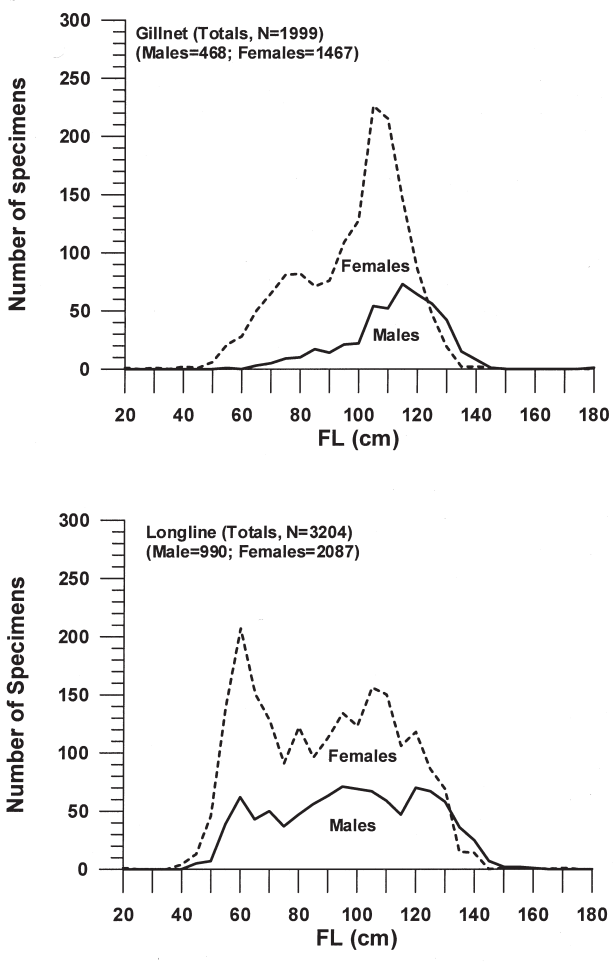

FIG. 2. – Size frequency distributions by sex of dolphinfish sampled catch in the artisanal gillnet fishery off La Guaira area and in the longline fishery recorded from 1991 to 1997.

The total reported landings of dolphinfish in Venezuela reveals the growing importance of this species in the Venezuelan markets during the last seven years (Table 1). Landings showed an uneven increase from 1985 to 1990. Thereafter, a steady increase in the landings is observed, from 190 TM in 1985 to 697 TM in 1997. The rising trend in the 1990's is the result of the high value of this species in the fish markets of the main cities of Venezuela.

Demographic size structure and seasonality

The general demographic size structure of dolphinfish showed marked differences between the two fisheries and between sexes (Fig. 2, Table 2). In the longline fishery, two size groups represented the majority of the specimens, one large group of between 50 and 70 cm FL and a less abundant one of between 90 and 130 cm FL. In contrast, the size composition in the gillnet fishery shows larger specimens (100-130 cm FL) for both sexes.

The seasonal demographic size structure showed marked differences between fisheries (Table 2). In the longline fishery during the first two quarters most of the females and males consisted of specimens of between 90 and 130 cm FL (Fig. 3). During the third quarter, the fishery selected smaller specimens of between 50 and 80 cm FL. Small females continued to be selected during the fourth quarter, while males were represented by two size groups, one consisting of small individuals and one of larger specimens (110-130 cm FL). The seasonal size structure in the gillnet fishery showed a similar pattern to the longline fishery for the first and second quarters (Fig. 3). The third quarter was dominated by 100-130 cm FL specimens of both sexes. Small size females (50-90 cm FL) were better represented during the fourth quarter, whereas males were better represented by larger individuals (110-140 cm FL).

Sex-ratio

Examination of the seasonal sex ratio at size by quarters, based on the proportion of females, showed that there is a significant predominance of females for specimens between 45 and 110 cm FL as revealed by the shapes of the locally weighted regression curves (Fig. 4). The proportion of females tends to fluctuate above 70% for size classes between 45 and 105 cm FL in all quarters. Females appeared to be most favored for the

TABLE 2. – Mean, standard error (s.e.) and sample size values (n) by quarter for size distributions of the dolphinfish sampled catch obtained by the longline and gillnet fishery.

	Longline fishery						Gillnet fishery						All gears combined					
	Males			Females			Males			Females			Males			Females		
	Mean	s.e.	n	Mean	s.e.	n	Mean	s.e.	n	Mean	s.e.	n	Mean	s.e.	n	Mean	s.e.	n
Jan-Mar	104.2	2.01	106	95.8	1.46	184	110.3	1.53	115	99.3	0.95	301	107.3	1.26	221	98.0	0.81	485
Apr-Jun	96.2	1.19	202	93.1	0.82	451	112.2	0.87	145	103.8	0.54	528	102.9	0.89	347	98.9	0.50	979
Jul-Sep	84.9	1.91	190	74.3	1.20	373	110.2	1.41	117	94.6	0.99	360	94.5	1.48	307	84.3	0.86	733
Oct-Dec	92.1	1.59	277	75.5	1.01	513	105.8	2.30	91	78.7	1.10	278	95.5	1.36	368	76.6	0.76	791

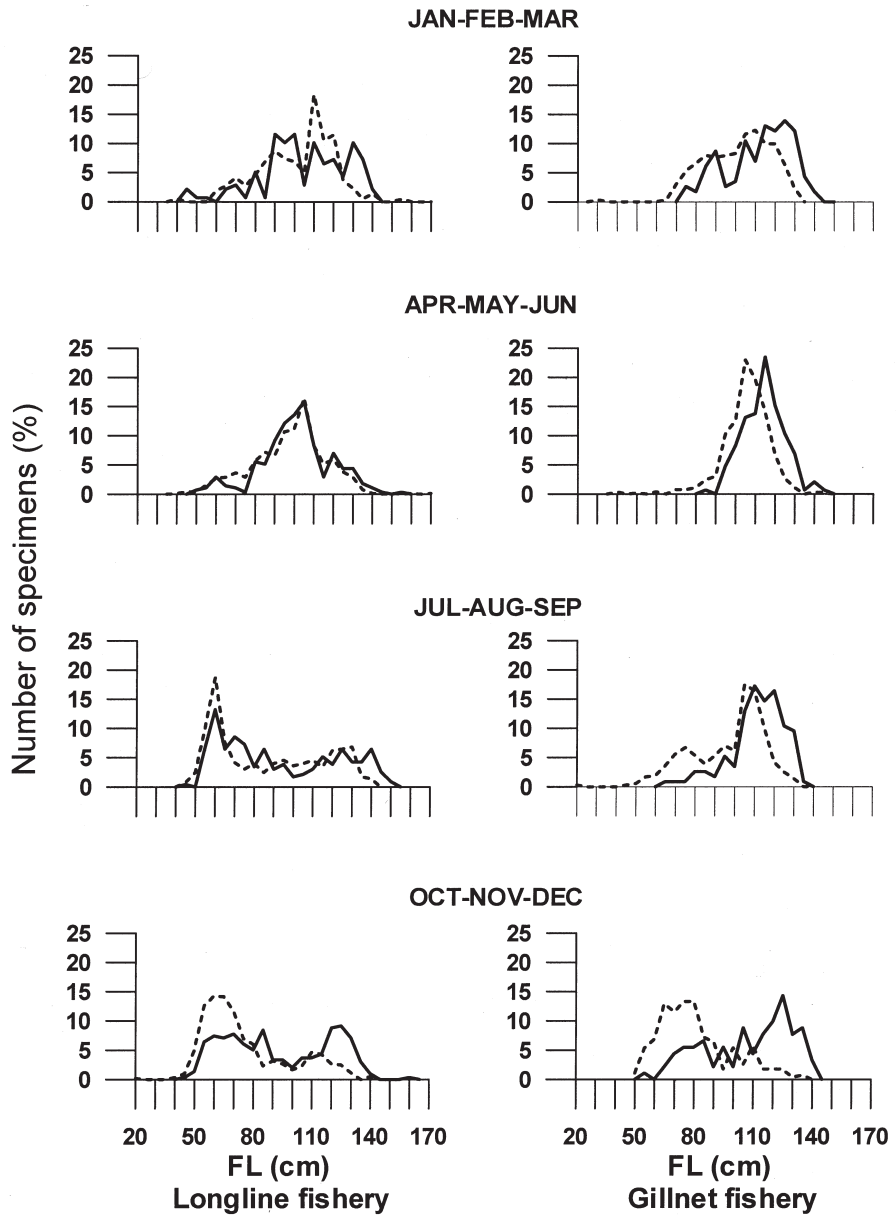

FIG. 3. – Quarterly size frequency distribution by sex of dolphinfish sampled catch by gear (gillnet and longline) recorded from 1991 to 1997 (dashed lines represents females, solid lines represents males).

smaller size classes (<80 cm FL) with proportions above 70%. In specimens of 80 cm to 110 cm FL, the proportion of females leveled around 70% for the first three quarters of the year. In the fourth quarter, the proportion of females varied between 50% and 70% in mid-size classes (80-110 cm FL), but with a higher degree of uncertainty due to the broader binomial confidence intervals. Thereafter, a significant reduction in the number of females for size classes beyond 110 cm FL is observed throughout the four quarters, thus favoring the proportion of larger males (>120 cm FL) throughout the year.

Oocyte development and spawning season

Eight mature female dolphinfish specimens were used to describe the type of oocyte development. The females used to construct the oocyte size frequency distributions ranged in size from 70 cm to 121 cm FL. All oocyte distributions showed at least three groups of oocytes (Fig. 5); the first group consisted of oocytes smaller than 200 μm, the second of oocytes between 300 and 700 μm, and the third of oocytes between 750 and 1000 μm. The first group (<200 μm) is formed by perinucleolar oocytes, which appear transparent and are considered the per-

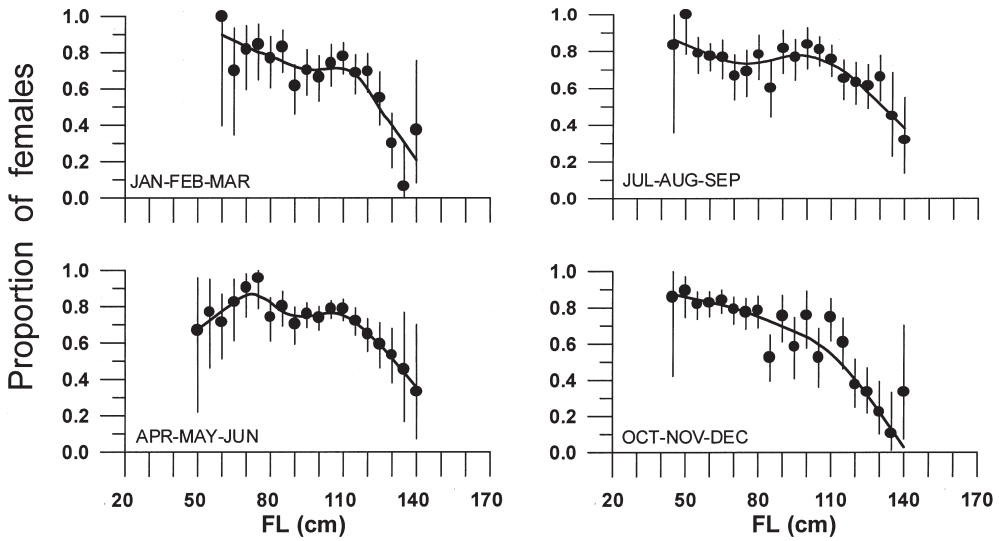

FIG. 4. – Quarterly proportion of female dolphinfish at size for all gears combined. The solid lines represent the locally weighted regression curves and the vertical lines represent 95% binomial confidence intervals.

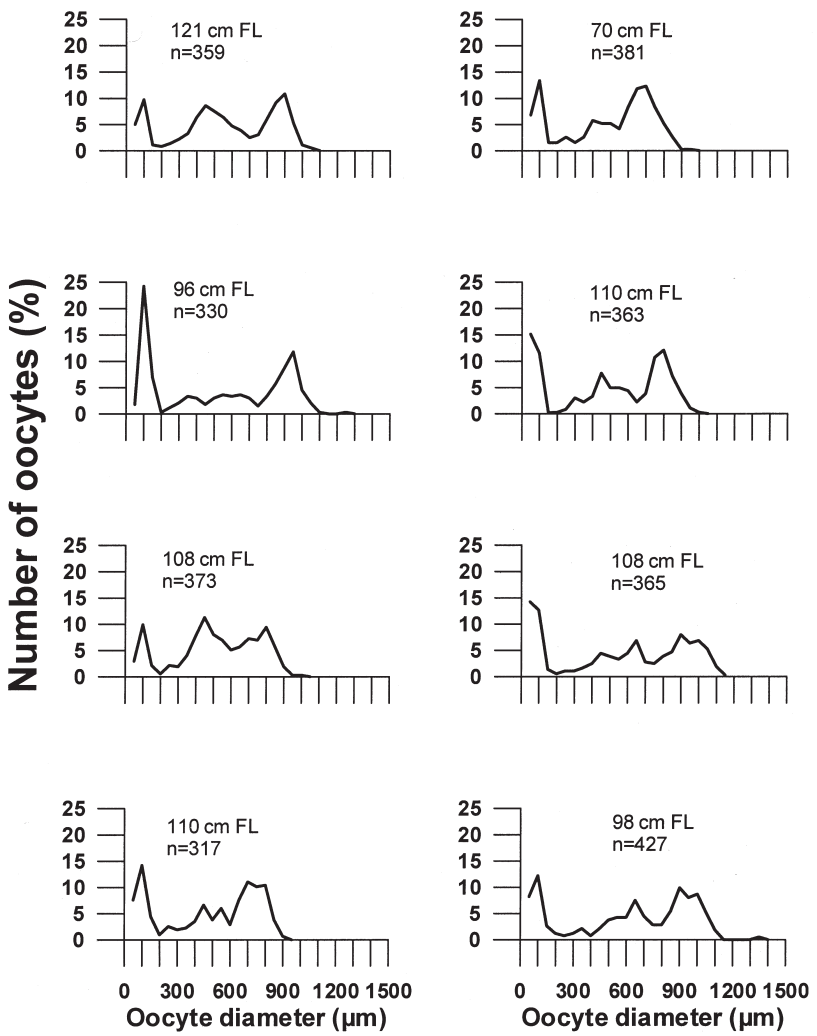

FIG. 5. – Individual dolphinfish oocyte size frequency distributions showing different developmental stages of whole oocyte obtained from 8 female gonad samples

manent stock of oocytes. The second group (300-700 μm) is formed by pre-vitellogenic and early vitellogenic oocytes, which appear with numerous small lipid droplets in the periphery of the nucleus in pre-vitellogenic oocytes (<400 mm), while in early vitellogenic oocytes (400-700 μm) the small lipid droplets cover the total interior of the oocyte. The third group consists of late vitellogenic oocytes (750-1000 μm), which appear with a few large lipid droplets surrounding the nucleus. As the oocytes in this size range grow, the lipid droplets coalesce gradually to form a single droplet observed in larger oocytes (900-1000 μm). No hydrated oocytes were observed in any of the samples.

Based on the incidence of mature gonads (with vitellogenic oocytes) in 21 sampled female ovaries obtained during four observer-covered longline trips in 1995, the dolphinfish spawning season off Venezuela appeared to be during May and October-November, when most of the female gonad samples had advanced vitellogenic oocytes.

DISCUSSION

The seasonality of dolphinfish off Venezuela appears to show two different size groups arriving at different time periods. The first group, comprised of specimens >90 cm FL, starts to arrive at the end of the first quarter. By the second quarter, most of the specimens caught by both types of gear are large mature specimens ready to spawn during that quarter, as observed by the incidence of females with mature oocytes in May. The second group, comprised of smaller specimens (50-80 cm FL) and formed mostly by females that will spawn during the beginning of the fourth quarter, arrive through the northeastern region by the beginning of the third quarter. This group gradually reaches the central coast region until it is fully distributed along the Venezuelan oceanic waters by the fourth quarter, as represented by the bimodal size frequency distribution of both gears during that period of time.

The movement pattern presented here contrasts with what was proposed by Oxenford and Hunte (1986), who suggested (for the southern stock) a northward movement along the Antillean Islands arc. It appears that there are at least two groups of dolphinfish in the Caribbean. The group found in the Venezuelan oceanic waters does not seem to follow the movement pattern suggested by Oxenford and Hunte (1986), as most of the Venezuelan catch is taken when the "Antillean group" is moving north. The possibility of a westward movement of the "Venezuelan group" is difficult to discriminate because of the lack of information on the abundance of dolphinfish catches in the western Caribbean (Colombia, Panama and Costa Rica), which prevents us from suggesting a movement in that direction. A southeastern movement along the South American coast may seem possible due to the catches observed in August and September around 8 to 9°N and the common catches observed from January to February further south (4-7°N). However, the data for the South American coast is insufficient to provide a workable hypothesis. Another possibility is to consider a generalized north-south movement of a broadly distributed population with a seasonal onshore-offshore movement, similar to what Mahon and Mahon (1987) proposed, but there are still insufficient data to offer solid conclusions.

The results given here showed that the proportion of females is favored for size classes <100 cm FL in well over 60% throughout the year, while large males (>120 cm FL) tend to be favored during all quarters. This seems to correspond to what has been observed in other areas like off Cape Hatteras, USA (35°N), where Rose and Hassler (1974) found a different proportion of sexes at size and it has been attributed to the hypothesis of differential schooling and feeding patterns between large and small dolphinfish. However, in spawning areas off Puerto Rico and off east African waters females predominate over the males, which suggests a pre-spawning migration of females (Erdman, 1956; Williams and Newell, 1957). The predominance of females in all quarters off Venezuela and of spawning females in the second and fourth quarter, suggests that the difference in sex ratio observed is due to reproductive behavior.

The oocyte development presented in our study showed the distinct absence of a hiatus between the permanent stock of oocytes and the group of maturing oocytes, as well as the overlap of oocyte size frequency distributions in each of the development stages. These findings lead us to propose that dolphinfish has an indeterminate spawning pattern. This type of spawning pattern involves an asynchronous oocyte development, as seen by the presence of all types of oocytes in mature fish without a clear distinction between stages of oocytes in the size frequency distributions (Hunter *et al*., 1985). Thus, it can be inferred that new oocytes are being recruited from the stock of perinucleolar oocytes (or imma-

ture oocytes). Estimates of fecundity in species with an indeterminate spawning pattern must be based on the number of mature oocytes that are to be released in the immediate spawning batch, *i.e.*, the number of hydrated oocytes times the number of spawnings during the spawning season (Hunter and Macewicz, 1985). In this study, no hydrated oocytes were observed in any of the gonads sampled, so no batch fecundity estimates could be produced. These observations contrast with earlier studies (Beardsley, 1967; Goldberg and Tresierra, 1985; Oxenford and Hunte, 1986; Massutí and Morales-Nin, 1997), which have estimated fecundity relationships based on mature counts of oocytes > 0.6 mm (i.e. late vitellogenic oocytes and later stages). Estimates of batch fecundity including late vitellogenic oocytes and ovulated hydrated oocytes in species with an indeterminate spawning pattern produce biased estimates of fecundity, because they over-estimate batch fecundity.

The seasonal pattern presented by dolphinfish in the waters off Venezuela appears to indicate a reproductive strategy. A basic trait in a reproductive strategy of teleost fishes is to spawn in a time and area where the availability of suitable prey is maximized and the risk of predation on the progeny is minimized. Dolphinfish arrive and spawn in Venezuelan oceanic waters at a time when favorable conditions for prey availability are ensured by the environmental conditions present in the area.

Biological productivity on the Venezuelan shelf is highly correlated with wind-induced upwelling during the peak of the dry season (March-May) and river runoff from the Orinoco during the peak of the rainy season (July-November) (Muller-Karger and Varela, 1990). High concentrations of phytoplankton originating from the previously mentioned environmental conditions are found on the shelf and off the shelf areas in the northeastern region of Venezuela (Muller-Karger and Varela, 1988). These high concentrations of phytoplankton sustain regionally important pelagic and demersal resources. Dolphinfish arriving during the peak of the upwelling season will find a sufficient food supply for gonad development that will ensure successful spawning at the end of the upwelling season. Offspring may survive on prey availability produced by high concentrations of phytoplankton originating from calm periods after the upwelling season, when the phytoplankton cells bloom in highly stratified shallow layers and produce what is termed the Gran effect (Mann, 1992). The second group, which arrives at the beginning of the third quarter, will continue to take advantage of prey availability in the area (Anon., 1989) for gonad development. Newly hatched dolphinfish in October-November will ensure survival based on the biological production originated by the Orinoco river, which discharges considerable amounts of nutrients into the southeastern Caribbean (Muller-Karger and Varela, 1990). It can be concluded from these observations that dolphinfish off Venezuelan waters can spawn over a protracted spawning season and ensure recruitment success due to the prevailing environmental conditions in the area.

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