TOURNAMENT FISHING EFFORT ESTIMATES AND REPRODUCTIVE DYNAMICS OF THE DOLPHINFISH, *CORYPHAENA HIPPURUS*, L. IN PUERTO RICO

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ABSTRACT

Fishing effort and biological data were colected at fifteen tournaments throughout Puerto Rico from November, 1990, to July, 1992, in order to document the recreational importance of the dolphinfish, Coryphaena hippurus, L. Average catch per unit of effort varied from 0.035 to 0.55 fish/boat-hour. The tournament sponsored by the La Parguera Nautical Club was the most consistent and successful one on the Island. The average catch per unit of effort at this tournament varied from 0.14 to 0.55 fish/boat-hour over a ten year period. Dolphinfish samples from Puerto RicoÕs south coast were significantly larger and heavier than those collected from the north coast. Most females caught were aggregated (schools) under debris or Sargassum spp. The female to male ratio was approximately 2.3 to 1. Histological description of dolphinfish gonad samples, the Gonosomatic Index, and oocyte frequency measurements suggest an annual spawning period extending from September to June; with distinct spawning peaks in March and June. the smallest mature individual caught measured 400 mmFL. No differences in minimum size class of sexual maturity (50% criteria) between coastal areas could be detected from the sampled population. Batch fecundity fluctuated between 219,670 and 1,548,457 eggs per ovary weight. When reproductive traits data collected during this study were compared to similar data collected in other studies, it appears that population stock differences may not be as obvious as previously believed. However, more detailed information on *C. hippurus* biology and fishing effort should be recorded for proper fishery dynamics parameters analysis and assessment of population stocks.

INTRODUCTION

Since the early 1950's, Puerto Rico has been developing a national, as well as an international, reputation in sportsfisheries (Erdman, 1956; Bird, 1963; Griffith et al, 1988; Berríos et al., 1989). The potential for the socio-economic development of a Marine Recreational Fisheries (MRF) in Puerto Rico has been addressed in the past by several authors (Schmied, 1987; Campos and Mu–oz-Roure, 1987; Griffith, et al. 1988). However, these authors acknowledge the under-utilization of the available infrastructure and manpower (such as boat ramps and skilled fishermen) and that basic information on the biology of local fisheries resources is scarce. Only Griffith et al. (1988) documented that dolphinfish were ranked within the top five most desirable fish species by sportfishermen interviewed in Puerto Rico and the U. S. Virgin Islands. Erdman (1956) reported on the seasonal abundance of dolphinfish caught in Puerto Rico, mainly from October to May. Recently, recreational shorefisheries and billfish tournaments have been the only local marine sportfishing activities surveyed. Berr'os et al. (1989) have briefly described several of the species caught during these activities. Among the incidentally-caught species mentioned was the dolphinfish (*Coryphaena hippurus*, L.).

The worldwide tropical and subtropical distribution of *C. hippurus* has been well documented (Kojima, 1956; Lozano-Cabo, 1961; Beardsley, 1967; Lewis and Axensel, 1967; Wang, 1974; Palko et al., 1982; Golberg, 1985). In the northwest-central Atlantic, dolphinfish support commercial and sportfisheries (Erdman, 1956; Beardsley, 1967; Rose and Hassler, 1969). Many Caribbean countries presently recognize the recreational and commercial importance of dolphinfish as a fisheries resource (Erdman, 1977; Gibbs and Collette, 1959; Wolf, 1974; Oxenford and Hunte, 1987). The migratory pattern of the dolphinfish has been suggested to occur based mainly on the marked seasonality observed in catch data collected throughout the western Atlantic (Palko et al., 1982). Oxenford and Hunte (1986) hypothesized the annual migratory pattern of two different dolphinfish populations in the eastern Caribbean and Central Atlantic regions. Based mainly on catch data collected throughout the Caribbean basin, growth characteristics, age and size at sexual maturity, egg size differences and perhaps, some genetic variation, they concluded that there is a northeastern and a southeastern dolphinfish stock. The suggested northeastern stock would migrate northwest from Puerto Rico from December to February reaching the Bahamas, Florida and the Carolinas in June and July; then turning towards Bermuda in July and August and heading south to the virgin Islands and Puerto Rico by November. Meanwhile, the southeastern stock migratory path would originate off Grenada in February and March, proceed north along the Lesser Antilles, and arrive off the Virgin Islands by

April to May; then continuing eastward into the Atlantic and turning south to Grenada. This speciesÕ migratory behavior expands its population boundaries to multinational levels, stressing the need for cooperative fisheries management efforts to ensure the proper utilization and development of what may be shared stock populations (Mahon, 1987). Puerto Rico seems to be in the pathway of both of the proposed two population stocks hypothesis. One of the objectives pursued during this study was to histologically describe the annual reproductive cycle, minimum size of sexual maturity of females, and spawning frequency and female fecundity. These reproductive traits were compared to previous studies to further examine the two-stock hypothesis.

The dolphinfish, *Coryphaena hippurus* is the target species for many sportfishermen and several tournaments in Puerto Rico. However, its abundance, based on present day tournaments, landings and historical records was unknown prior to this study. In spite of its sportfishing importance and implications on MRF development, no basic biological data on dolphinfish have been consistently gathered in the past. Therefore, a preliminary assessment of data available from dolphinfish tournament records was performed and a protocol for monitoring future tournaments was developed.

Historical landings data for this species was previously presented for the purpose of establishing its usefulness in determining fluctuations in abundance, catch per unit of effort and potential biological impact of the recreational exploitation (Pérez and Sadovy, 1991; Pérez et al., 1992).

METHODS AND MATERIALS

Tournament Survey

The Puerto Rico Sportfishing Association (PRSA) provided billfish tournament schedules for 1990 through 1992. All marine sportfishing clubs on these schedules were contacted prior to and during billfish tournaments. Personal interviews with tournament organizers and club members provided basic information on the dates and sites at which each local club-sponsored dolphinfish tournament occurred.

Subsequently, each club sponsoring a dolphinfish tournament was contacted and the organizers interviewed to determine the existence and extent of past tournament records. In addition to historical tournament data assessment, a protocol or log table, was developed to help gather basic biological data and fishing effort information from monitored dolphinfish tournaments. The biological information collected on the dolphinfish included their weight in kilograms (kg) and pounds (lbs.), total length (TL), fork length (FL) and standard length (SL) in millimeters, and their sex. Since *C. hippurus* have been

reported to travel in groups, as well as alone, a fish behavior column was incorporated in the log table to gather data related to the prevailing conditions under which each fish was caught. Fishing effort data included: total number of boats and fishermen, official fishing hours, and total number of dolphinfish landed during the tournament. Additional information related to fishing effort (such as fishing technique, boat name, fishing time, a number of lines and hooks, hook size, and type of bait) were recorded whenever possible.

During the first dat of each dolphinfish tournament the organizers were contacted and the number of fishermen and boats competing and the official fishing time schedule were recorded. The total number of dolphinfish caught and/or reported were recorded after the tournament. Participants were approached as they returned at the end of each day, either at their docking area or at the weighing station, to be interviewed regarding the fish they caught. Occasionally, time limitations of departing fishermen constrained the interviews to the most relevant questions (such as fish measurements). When possible, all fish caught by a particular boat were weighed and measured. After each tournament, the biological data gathered in the log table were tabulated separately from the fishing effort information. Subsequently, all fish measurements recorded were combined to show the size frequency distribution and associated variability. Also, regression analysis was performed to determine the relationships between lengths (TL, FL, and SL) in millimeters and weight (Wt) in grams. To check if differences existed between sex for size frequency distribution, and male and female mean sizes, a Kolmorov-Smirnoff Test and a Student T-test (Sokal and Rohlf, 1981) were performed, respectively.

The total pounds landed and weight size frequency distribution for each tournament monitored were tabulated. Since most historic records on dolphinfish tournaments kept by the clubs have been reported as pounds (lbs), we also followed the convention of reporting all landings data as pounds to facilitate comparison of these data.

Reproduction Dynamics

To address the reproduction dynamics of dolphinfish in Puerto Rico, gonad samples were collected from dolphinfish examined during billfish and dolphinfish tournaments. When tournaments were not scheduled for a particular month, samples were gathered from cooperating sportfishermen, commercial fishermen, and Fishery Research Laboratory research vessels.

The minimum requirement of 15 gonads per month was exceeded for most of the year. When intact gonads were obtained and weighed in the field, the Gonosomatic Index (GSI) was calculated. Then, a small portion was preserved

in Davidson's fixative for posterior histological analysis and the rest frozen for oocyte diameter measurements and fecundity analysis. Tissues were strained using Eosin and Hematoxylin, following the procedures outlined by Coolridge and Howard (1979).

Ten samples were prepared for histology to compare cellular development throughout the gonad lobules. Two sections (i.e. transverse and longitudinal) from three gonadal areas (the anterior, central and posterior region of the lobules) were prepared. Preliminary observations showed no major differences between sections. This was performed since standardization of gonad sample collection was difficult due to their market value as a delicacy. Thereafter, samples were taken from the central area of the lobules, when possible. Otherwise, the anterior lobules were collected and the proximal slice (3 mm wide) preserved for histological purposes. Despite efforts to collect samples representative samples could not be obtained between the July-August period, due to the low and irregular catching rate of dolphinfish at that time.

Moe's (1969) descriptions for the identification of oocyte stages were followed to define four female dolphinfish stage-maturation categories (Table 1) and photographs for each stage described are provided (Plates 1-6). We established the fork length (mmFL) size class where 50% of the females had become mature, and the size at first maturity using histological criteria described on Table 1. The histological descriptions of Grier (1981) and Murphy and Taylor (1990) were the criteria used to define the male dolphinfish stage-maturity categories (Table 2). For the reproductive dynamics of the species, this report emphasized the female stage-maturation description.

Oocyte diameter measurements were made using the smallest to the largest vitellogenic oocyte observed which ranged from 0.26 mm to 1.56 mm. Chatterji and Ansari (1982) measured similar oocyte diameters in Indo-Pacific dolphinfish, ranging from 0.25 to 1.58 mm. Mito (1960) described dolphinfish eggs collected from the Sea of Japan as colorless, buoyant, spherical in shape, measuring between 1.2 and 1.6 mm. and having a single light yellow oil globule. Soichi (1978) described C. hippurus fertilized eggs as transparent, spherical, buoyant, and measuring between 1.40 and 1.65 mm in diameter. oocyte diameter measurements from Puerto Rico correspond with the general oocyte measures and descriptions for dolphinfish made in these studies.

Hunter et al. (1985) explained how annual fecundity is seasonally undetermined in temperate and tropical fishes with multiple, serial or heterochronal spawning, and discussed batch fecundity as the only useful measurement tool available. He defined batch fecundity as the number of hydrated oocytes produced in one spawning batch. The Hunter et al. (1985)

oocyte size-frequency method was used in the present study to estimate dolphinfish batch fecundity. This method accounts for the most advanced modal group of oocyte classes (i.e. largest oocytes) present in the oocyte size frequency distribution. for the size frequency distribution oocytes were always measured along their longest axis. To standardize the procedure, the largest oocyte modal group recognized were larger than 0.80 mm. Whole gonads were weighed to the nearest 0.01 g. A subsample accounting for 0.05% of the total gonad weight was reweighed to the nearest 0.1 mg, and all oocytes larger than 0.80 mm were counted. Batch fecundity (Y) was estimated for each gonad sampled as follows:

$$Y = n \times Wtg / Wts$$

Where, n = number of hydrated and/or largest oocytes counted,

Wtg = whole gonad weight in grams, and

Wts = subsample gonad weight in grams.

The Gonosomatic Index (GSI), which is defined as the ratio of ovary weight divided by somatic weight (fish weight without its gonads) was calculated. Although ovary weight increases faster with fish length than with somatic weight, GSI combined with histology can be used to provide a crude index of spawning frequency and duration of the spawning season (Hunter et al., 1985; Hunter and Macewics, 1985).

RESULTS AND DISCUSSION

Overview of Offshore Sportfishing

To date, there are fourteen marine sportfishing clubs and four marinas recognized by the Puerto Rico Sportfishing Association (PRSA) around Puerto Rico (Mr. Casellas, PRSA, pers. comm., 1990). Each club holds an annual billfish tournament officially sponsored by the PRSA. Since these are internationally recognized tournaments, records are kept by the PRSA. However, smaller tournaments described as local, interclub or invitational are not sponsored by the PRSA and their target species are mostly other fish besides billfish. Some of these tournaments target large dolphinfish as the main species.
Anglers target dolphinfish during most of the year. However, most fishermen interviewed agreed that fishing effort increases during seasons when dolphinfish are more abundant. The high quality of dolphinfish meat is one of the reasons most angler's target this species. Between November 1990 and July 1992, fifteen dolphinfish tournaments were held. During personal communications with the club leaders it was found that most tournament records were scattered or had

been lost. It was also learned that some sportfishing clubs have been sponsoring dolphinfish tournaments for the past two decades. However, no records were provided or available. In addition, some of these club sponsored tournaments are not held every year, making it more difficult to keep track of these events. The exception to the rule is the Lar Parguera Nautical Club (CNP), which has kept most of their catch and effort records since 1983 (Table 3).

Tournament Records and Fishing Effort Estimates

During the 1990 and 1992 period project personnel visited a total of 21 billfish and fifteen dolphinfish tournaments. Each year the La Parguera Nautical Club (CNP) holds an islandwide dolphinfish tournament in April or May. The timing of this tournament coincides with the maximum seasonal abundance of bullhead dolphinfish in coastal waters (pers. comm. Dr. Ram'rez, CNP secretary, 1990). All tournament records available since 1983 were kindly made available for use in the present study by the CNP. Most records included tournament time schedules, number of participating boats and fishermen, and individual fish weights. These tournaments attracted an average of 93 (sd=40.87) sportfishermen and 25 (sd=8.51) boats every year. Estimates of CPUE varied from 0.14 to 0.55 fish/boat-hr. over the ten year period (Table 3). For these tournaments, yearly average weight varied from 17.24 to 27.7 lbs. (Table 4). Size frequency distribution for each year by weight class are shown in Figure 1. When compared with other club tournaments for 1991 and 1992, La Parguera CPUE shows a tenfold difference on catching success (Table 5). For the 1991 and 1992 period, the average fish weight for all tournaments held on the south coast was 21.33 lbs (sd=3.65, n=8) and 16.14 lbs. (sd=2.34, n=5) for the north coast (Table 5). Also, fish caught on the southern coast tended to be significantly heavier than fish caught on the north coast ($p<0.01$). Similarly, average fork length (mmFL) was significantly greater ($p<<0.001$) in fish collected from the south coast (Table 6).

Biological and Fishing Data

The size frequency distribution of the 916 fish measured during this project is shown in Figure 2; fork length (mmFL) sizes ranged between 358 and 1479 mm, with an overall mean size of 946 mm (sd=189). Gear selectivity and the purpose of sportfishing tournaments accounts for the size range of the data in which larger fish predominate. The largest fish were caught during March and June (Figure 3). Accordingly, a greater variability in mean size ranges was observed for the other months. This variability may be related to the presence of

young individuals, who seem to arrive later in the year, during August to December, along with some scattered older individuals.

When the size frequency distribution for sexed fish were compared (Figure 4), they were found to be significantly different (K-S test: Critical D (.05) = 0.0996<0.185 Observed D). The average male size tended to be larger than the female ($p<<0.001$). The sex proportion tended to be predominantly female, with an average 2.3:1 ratio, irrespective of the coastal area.

Interviewed fishermen have reported catching dolphinfish from less than half a mile to more than 30 miles offshore (Figure 5). Consistent with literature cited (Palko et al., 1982), sportfishermen reported dolphinfish closer to shore in areas with a narrower insular shelf where rivers, transporting large amounts of effluent and debris, are present. The gear used in fishing for dolphinfish consists mainly of fishing rods using 30 and 80 pound test lines with one hook per line while the vessel is trolling (Table 7). Hook sizes vary from 3/0 to 10/0, with a 28.76% preference for the 7/0 hook size. Approximately 74% of the sportfishermen preferred using dead fish as bait over other bait types. Availability of fresh bait throughout the year could account for this bait type preference. However, dolphinfish is well known for its voracious and indiscriminant feeding habits (Gibbs and Collette, 1959; Beardsley, 1967; Rose and Hassler, 1974). Observation of dolphinfish stomach contents,'in situ', revealed several species of juvenile pelagic and reef fishes, (e.g., Balistidae, Monacanthidae) as well as adult *Cypselurus sp.* and invertebrates. The highest percent of dolphinfish caught (61.07%) were reported to be schooling under Sargassum spp. mats or floating objects (Table 8). The biological data collected during the course of this project, suggest that females were found in schools under debris 24.43% of the time. Solitary males seem to be found in clear open water more often than females. In addition, sportfishermen found dolphinfish where sea birds and/or water color changes related to depth contours or plankton were present.

In general, the average size of dolphinfish varied significantly depending on coastal area and sex. Larger fish were caught on the south coast rather than the north coast, which is in agreement with the postulated difference in size for the proposed southern population stock theory (Oxenford and Hunte, 1987). Most studies have reported males to be larger than females (Beardsley, 1967; Rose and Hassler, 1969; Oxenford and Hunte, 1987), which is related to sexual dimorphism.

The sex ration observed in this study favored females 2.3 to 1, which could be a reflection of higher catchability (Gibbs and Collette, 1959) since females were found to predominate under flotsam. This sex ration coincides with

previous reports for Puerto Rico (Erdman, 1977). The high percentage of young mature females caught under floating debris and Sargassum spp. has been related to food search strategies (Kojima, 1956; Palko et al., 1982). Also, data collected by Ida et al. (1967) suggest that larger floating objects attract more fish than smaller ones.

Generally, Caribbean Sea surface currents tend to move toward the northwest with some seasonal changes in velocity (Wust, 1964; Molinari et al. 1980). While reports on wind speed and direction were not available, most sportfishermen interviewed on the south coast agreed that dolphinfish were most likely to be caught when southeastern winds prevailed. These winds are generally stronger between April and May on the south coast (Mr. Micky Amador, La Parguera sportfisherman, pers. comm., 1991) when the dolphinfish tournaments are held.

Florida commercial dolphinfish catch data consisted of smaller-sized fish; averaged length 592.8 mmFL (sd=167, n-92). Based on Rick Beaver's (Florida Dept. of Natural Resources) experiences, fishermen used selective gear to catch small dolphinfish (i.e., approximately 2 lbs) since this was the most marketable fish size. Conversely, Barbadioan fishermen target large dolphinfish to maximize their effort while fishing for the flying fish, Cypselurus melanurus (pers. comm. Mr. Colvin Taylor, Barbados Fisheries division, 1991). In addition, from data collected by Oxenford and Hunte (1987), the mean weight of individual dolphinfish caught by the recreational fishermen fluctuated between approximately 4.5 kg (sd=1.5) and 9.5 (sd=3). Interestingly, recruitment sizes for this fishery seem to vary from country to country, which may account for the average size differences in dolphinfish repored from Florida and Barbados. Also, the known migratory behaviour and the size structure of the dolphinfish cohorts may be related to the seasonal landings repored by different countries along its pathway (Oxenford and Hunte, 1986).

To facilitate future comparisons from one measurement to another by other authors, the logarithmic relationships were calculated from all the data collected for this report (Table 9).

Reproduction Dynamics

Oocyte size frequency distribution for various dolphinfish sampled during the present study exhibited an heterogeneous oocyte size class composition, irrespective of month or fish size (Figure 6; Plates 2, 4). At least two spawnings occurred during each season. This is consistent with previous studies showing a protracted and multiple spawning behavior in C. hippurus

(Gibbs and Colette, 1959; Beardsley, 1967; Golberg, 1985; Oxenford, 1985; Pérez and Sandovy, 1991; Soichi, 1978).

Analysis of histologically processed samples collected between September 1990 and May 1992 suggest a female minimum size class of maturity of approximately 900 mmFL based on a 50% criteria (Figure 7). No differences in the minimum size class were observed when the data were compared by coast. Oxenford (1985) described a similar maturity size class for dolphinfish from Barbados. The smallest mature female measured during the present study was approximately 400 mmFL. However, analysis of additional females smaller than 600 mm will be needed in order to establish the minimum size of maturation (Table 10). Although there are mature females present throughout most of the year (Figure 8), when monthly GSIÕs were calculated they revealed spawning peaks in March and June (Figure 9). From a total of 300 females examined using the stage-maturation classification scheme described previously, 95% were considered mature (Table 11). This is consistent with previous observations by Erdman (1977) of the percentage of mature females within the dolphinfish population. Erdman (1956), observed female gonads with the most advanced stage of development during February in Puerto Rico. In other studies, peak spawning activity in dolphinfish has been found to occur between May and June in Barbados (Oxenford, 1985), July and August in North Carolina (Gibbs and Collette, 1959), and January and March in Florida (Beardsley, 1967). Golberg (1985), found that all C. hippurus collected off the Peruvian coast in June during the 1983 El Ni–o event were adults (i.e. evidence of vitellogenesis) and observed postovulatory follicles, which are only detectable within 48 hours of spawning, in 11.6% of the individuals. Shcherbachev (1973), stated that dolphinfish is an 'intermittent spawner' year-round in tropical waters and confines its spawning activity to the warmer seasons on the periphery of their distribution range.

When dolphinfish female samples were sorted by coastal region in Puerto Rico, the northwest coast showed mature individuals at 500 mmFL and the south coast at approximately 400 mmFL. Again, these measurements represent the smallest individual collected in those areas. Angler interviews confirmed the presence of large schools of juvenile dolphinfish along the north coast from October to December and along the south coast from February to March. Therefore, the collection of more dolphinfish individuals less than 600 mmFL in Puerto Rico will be critical to more accurately estimate the minimum size class of dolphinfish at maturity. Nevertheless, when the present data are compared with similar data from other regional studies, they suggest that population stock differences may not be as obvious as previously believed (Table 12). The size of dolphinfish at first maturity for specimens collected on

the south coast of Puerto Rico seems to be similar to those reported for Florida (Beardsley, 1967), contrary to observations by Oxenford and Hunte (1986) in Barbados.

Whole gonads were collected immediately before and during the hypothesized peak spawning season in Puerto Rico. Based on the histological descriptions given in Table 1, most of the females were mature but between spawning periods (Plate 4). Nevertheless, batch fecundity estimates calculated for a total of 25 individuals (sizes ranging from 616 mmFL to 1193 mmFL) varied between 219,670 to 1,197,870 hydrated oocytes per ovary weight. Batch fecundity had a positive correlation ($r^2=0.46$) with dolphinfish fork length (Figure 10). The low correlation factor between the logarithmic values for fecundity and length may be related to the protracted spawning season of the species and the variability in fecundity between mature females (Chatterji and Ansari, 1982; Oxenford, 1985).

CONCLUSIONS

The importance of sportfishing for dolphinfish in Puerto Rico has been underestimated prior to this study. During the two year period covered by this investigation, fifteen different dolphinfish tournaments around Puerto Rico were visited. The La Parguera fishing effort records, and yearly variations on the size frequency distribution through the years derived from them, suggested the existence of high-low abundance periods that may be related to recruitment success and migration patterns. Gear selectivity (such as line and hook) aimed toward larger fish predominates in Puerto Rico. To properly asess population stocks, tournament organizers were encouraged to keep complete yearly fishing records of their activities. However, periodic monitoring efforts are recommended to provide a reliable database for use in developing appropriate management options. The data presented in this report only begins to touch upon the local sportfishing activity of dolphinfish occurring in Puerto Rico. Nevertheless, it provides a firm foundation upon which to develop an extensive database and future monitoring efforts of this important sportfishery.

The rapid growth rate of dolphinfish (Beardsley, 1967; Oxenford and Hunte, 1986), together with an extended, multiple spawning behavior and maturation at small sizes, indicates that recruitment over-fishing of this species is unlikely. Nevertheless, schooling behavior of sexually matured individuals are more vulnerable to fishing pressure which may affect the population stocks.

The present study suggests that there are no major differences in reproductive traits between the northern and southern dolphinfish population stocks in west-central Atlantic Ocean. Oxenford and Hunte (1983) noticed that

the northern dolphinfish population mature at a younger age and smaller size than does the southeastern population stock and that there may be genetic differences between the two populations. The scope of this study did not consider other variants such as age and growth or genetic variability, as analyzed by Oxenford and Hunte (1986). However, recent analysis of otolith daily growth bands on dolphinfish collected in Puerto Rico, suggested no differences between growth patterns of the Puerto Rico and Barbados stocks (Rivera, 1994). Preliminary electrophoresis tests performed on dolphinfish from Barbados and Florida suggested little gene flow between the proposed two stocks (Oxenford and Hunte, 1986), but suggested that this genetic variability may be related to latitudinal clinal variations. Levington (1982), mentions temperature as one of the possible factors producing clinal variations.

The available commercial landings data showed annual bimodal abundance peaks (Pérez and Sadovy, 1991) and differences in the average size of dolphinfish between coastal areas around Puerto Rico (Pérez et al., 1992), suggesting the presence of two population stocks in this region. Nevertheless, more detailed information on fishing effort is needed to better assess these population stocks. Caribbean Sea current patterns suggest an alternate westerly route of migration for the southern dolphinfish population. This new pathway suggests that the southern stock population visits the U. S. Virgin Islands and southern Puerto Rico during April and May and eventually migrates either southwest into the Caribbean Sea or westward into the Gulf of Mexico. While migration patterns of dolphinfish in the west-central Atlantic Ocean and Caribbean Sea regions may be quite complex, international cooperation should be encouraged in ordre to facilitate proper utilization of these resources. The regional importance of dolphinfish as a fishery resource and its potential as a Marine Recreational Fishery has been demonstrated in the present study. Actually, the Puerto Rico Department of Natural Resources is developing mechanisms to monitor the recreational fishing activities throughout the island.

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Plate 1: Photomicrograph of an immature dolphinfish ovary. Notice the thin ovary wall (ow), compact lamellae (L), previtellogenic (Pv), and the few vitellogenic (V) oocytes (Bar=1mm; Specimen measured 492 mmFL and weighed 2 kg; collected on October 6, 1991 at Club Naœtico de MayagŸez).

Plate 2. Photomicrograph of a mature inactive dolphinfish ovary. Early vitellogenic oocytes with a thin zona radiata (Zr) begin to predominate the field of view. (Bar=1mm; Specimen collected on Nov. 14, 1991 at La Parguera, Lajas, measured 625 mmFL and weighed 2.5 kg.)

Plate 3. Photomicrograph of a mature active dolphinfish ovary. Hydrated oocytes (H) predominates the field of view. Observe the presence of several stages of prvitellogenic (Pv) and vitellogenic oocytes. (Bar=1mm; Specimen collected on Feb. 9, 1991 at CangrejoÕs Yacht Club, measured 909 mmFL and weighed 5.75 kg.)

Plate 4. Photomicrograph of a mature dolphinfish female caught between spawning periods. Notice the large oocytes with a thick zona radiata (Zr), disorganized appearance, thick ovary wall (ow), and few atretic oocytes (*). (Bar=1mm; Specimen collected on May 4, 1991 at Club Naœtico de Parguera, measured 920 mmFL and weighed 5 kg.)

Plate 5. Photomicrograph of an early post-spawning dolphinfish. Notice the presence of atretic bodies (*), muscle bundles (mb) and thick ovary wall. (Bar=1mm; Specimen collected on May 4, 1991 at Club Naœtico de Parguera, measured 764 mmFL and weighed 2.9 kg.)

Plate 6. Photomicrograph of a late post-spawning female. Only previtellogenic oocytes in a loose disorganized ovary are present. (Bar=1mm; Specimen collected on Jan. 31, 1991 at la Parguera, measured 910 mmFL and weighed 4.5 kg.)

Table 1. Maturation Description of Coryphaena hippurus Females (Oocyte stages corresponds with those of M. Moe, 1969)

FEMALES

Maturity stage	Description
1. Immature (Plate 1)	Small diameter gonad lobules are bright orange, neither eggs nor blood vessels visible macroscopically.

Microscopic description: Oocytes stages 1 and 2 (previtellogenic) and perhaps, a few oocytes early stage 3. Lamellae looks compact within a thin muscular tunica (i.e. ovary wall). Small blood vessels surround ovary walls and there is no evidence of prior spawning (i.e. disorganized and loose appearance of ovary, muscle bundles, oocytes stage 4 or atretic bodies).

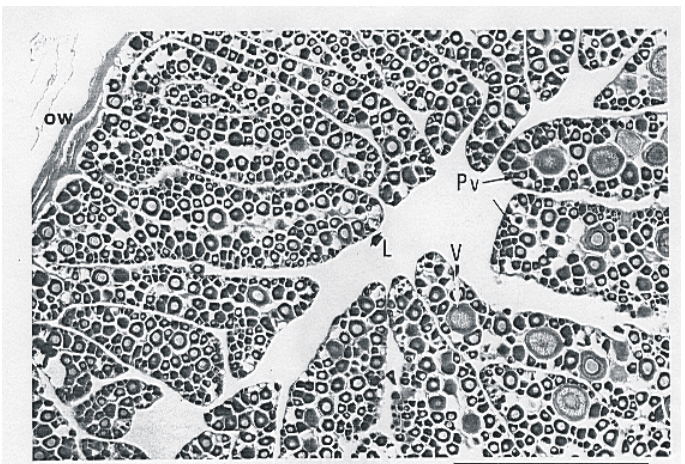

Plate 1. Photomicrograph of an immature dolphinfish ovary. Notice the thin ovary wall (ow), compact lamellae (L), previtellogenic (Pv), and the few vitellogenic (V) oocytes (Bar= 1mm; Specimen measured 492 mmFL and weighed 2 kg; collected on Oct. 6, 1991 at Club Naútico de Mayagüez.).

II. Mature — Turgid gonad lobules are round and orange
Inactive — color, eggs and small veins visible macroscopically.

Microscopic description: First time spawners have compact ovaries with oocytes in stages 2, 3, maybe a few early stage 4 and a thin muscular tunica. Oocyte stage 3 (i.e. early vitellogenic) begin to predominate the field of view (i.e. 400x). If previous spawning occurred, ovary show a slightly disorganized appearance oocytes stage 3 predominates a few atretic oocytes may be present. Also, muscular tunica seems slightly thicker than in immature gonads.

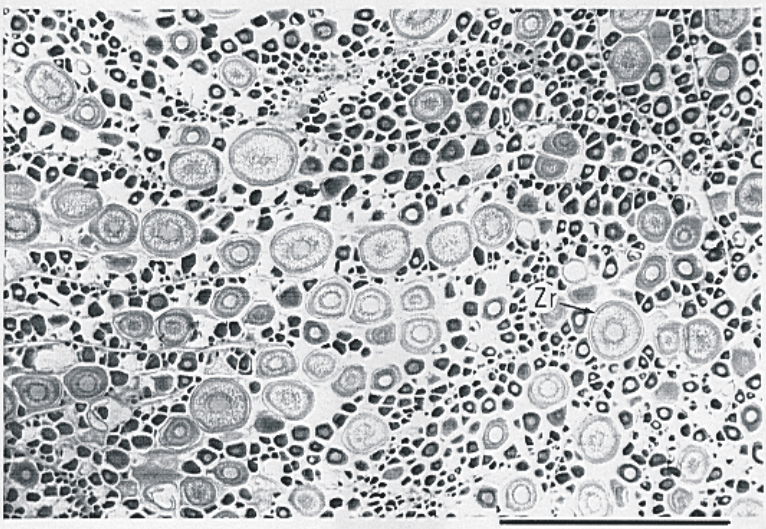

Plate 2. Photomicrograph of a mature inactive dolphinfish ovary. Early vitellogenic oocytes with a thin zona radiata (Zr) begin to predominate the field of view. (Bar= 1mm; Specimen collected on Nov. 14, 1991 at La Parguera, Lajas, measured 625 mmFL and weighed 2.5 kg.)

III. Mature Active Gonad lobules could be completely turgid or slightly flaccid with pale orange or yellow color. Large translucent eggs visible through ovary wall with large blood vessels surrounding the ovaries.

Microscopic description: Oocytes stages 1, 2, 3 and 4 present. Ripe gonads are completely turgid and mid to late stage 4 dominates the field of view by more than 50% (i.e. 400x). Some hydrated oocytes and postovulatory follicles may be observed. Ocytes stage 4 have distinctive thick zona radiata. Muscular tunica is thin (Plate 3).

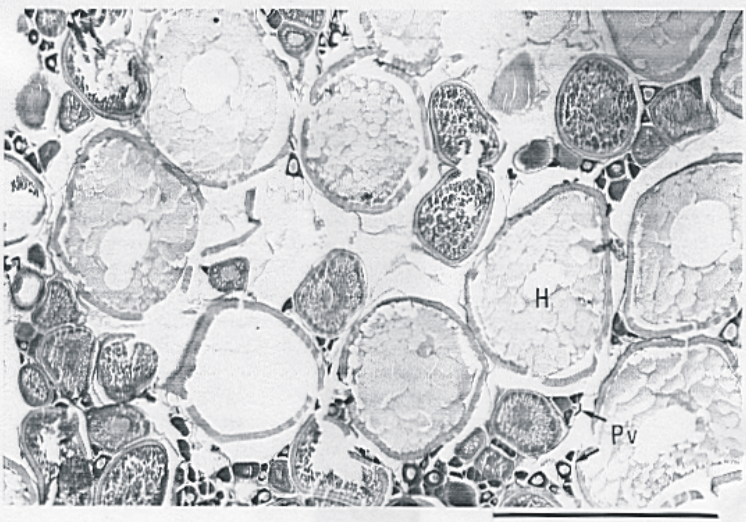

Plate 3. Photomicrograph of a mature active dolphinfish ovary. Hydrated oocytes (H) predominates the field of view. Observe the presence of several stages of previtellogenic (Pv) and vitellogenic oocytes. (Bar= 1mm; Specimen collected on Feb. 9, 1991 at Cangrejo's Yacht Club, measured 909 mmFL and weighed 5.75 kg.)

When female is between spawns, gonad lobules are slightly flaccid and healthy oocytes in late stages 3 and mid 4 may be equally abundant. The muscular tunica gets thick and scattered degenerated oocytes could be observed in a disorganized ovary (Plate 4).

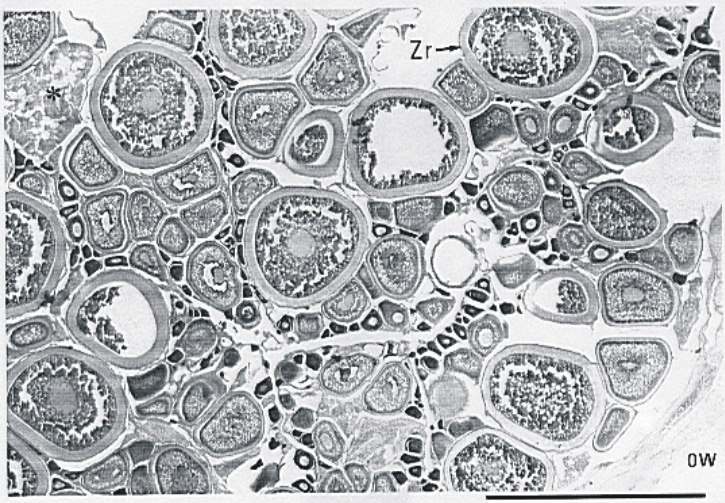

Plate 4. Photomicrograph of a mature dolphinfish female caught between spawning periods. Notice the large oocytes with a thick zona radiata (Zr), disorganized appearance, thick ovary wall (ow), and few atretic oocytes (*). (Bar= 1mm; Specimen collected on May 4, 1991 at Club Naútico de Parguera, measured 920 mmFL and weighed 5 kg.)

IV. Post- spawned.Gonad lobules completely flaccid and reduced in diameter. Blood vessels present.

Microscopic description: In early postspawners, many healthy oocytes stage 3 with stretic oocytes stage 4 are observed (Plate 5). In later postspawners, oocytes stage 1 and 2 predominate, scattered atretic oocytes stage 3 and 4 may be present (Plate 6). Many atretic oocytes are present in several degeneration stages.

Stretched muscular tunica, looks slightly thin like immature ovary but, large compressed blood vessels surrounds the ovary walls. Disorganized and muscle bundles across ovary are present.

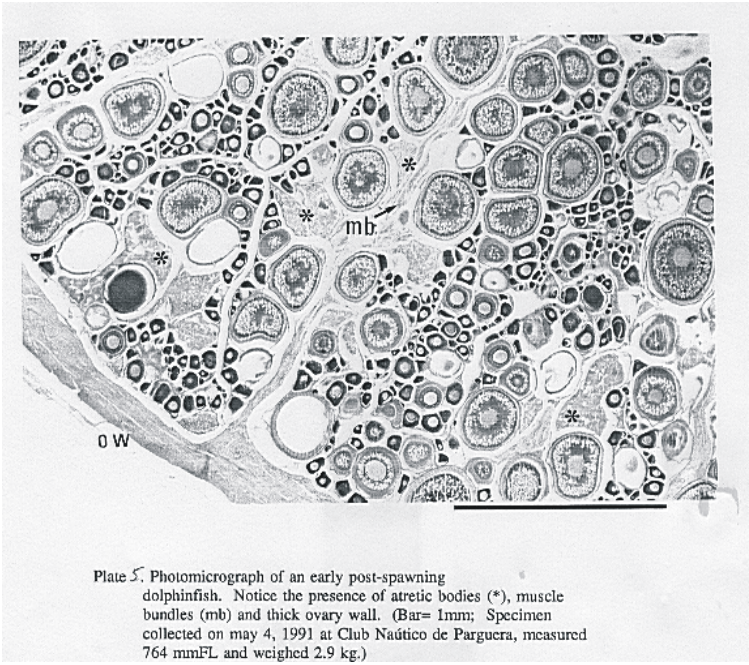

Plate 5. Photomicrograph of an early post-spawning dolphinfish. Notice the presence of atretic bodies (*), muscle bundles (mb) and thick ovary wall. (Bar= 1mm; Specimen collected on may 4, 1991 at Club Naútico de Parguera, measured 764 mmFL and weighed 2.9 kg.)

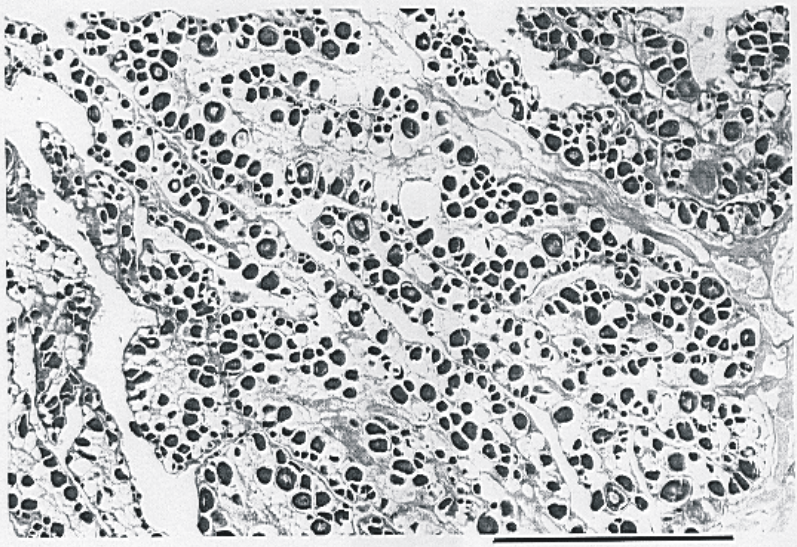

Plate 6. Photomicrograph of a late post-spawning female. Only previtellogenic oocytes in a loose disorganized ovary are present. (Bar= 1mm; Specimen collected on Jan. 31, 1991 at la Parguera, measured 910 mmFL and weighed 4.5 kg.)

Table 2. Maturation Description of Coryphaena hippurus Males (Description from: Grier, 1981 and Murphy and Taylor, 1990)

MALES
Maturity stages Description

1. Mature Testes lobules are laterally compressed (narow),

Inactive firm and shows some convolutions. Color may vary with freshness of sample. Most samples collected to date have a dark pink/brown appearance. No milt extrudes when cut or squeezed.

Microscopic description: Crypts of spermatogonia and early spermatogenesis develops together around each seminiferous tubule. Gonad small and compact. Few or no sperms are present.

II: Mature Testes lobules are narrow. They could be small (or ripe)and compact like immature testes or have convolutions. Tissue feels soft. Milt may extrudes when cut or slightly squeezed. Color varies from pale pink to white.

Microscopic description: The seminiferous tubules are cysts in several stages of spermatogenesis. Throughout the testes, the cysts have the sinuses partially or totally full of spermatides and/or sperm. Seminiferous tubules closer to the central or efferent ducts are connected and elongated, partially or totally full of spermatozoa.

III. Spent Testes are flaccid with dark pink/brown color. They may be confused with immature testes.

Microscopic description: Disorganized appearance and elongated cysts. Crypts of spermatocytes and spermatides are present, but most seminiferous tubules and sinuses are empty and some have remnants of sperms. Some spermatogonia may be observed.

Table 3. La parguera Nautical Club dolphinfish tournament data and estimated catch per unit of effort (CPUE). [***, no date]

Tournament Year	CPUE No.Fish/ Boat hr.	Number Fishermen	Number Boats	Fishing Hours	Number C.hippurus	Lbs. caught
1983	0.48	49	16	18	138	1200.00
1984	***	***	***	***	***	***
1985	0.46	57	15	18	125	2103.75
1986	0.16	100	25	18	72	1606.50
1987	0.14	116	29	18	72	1476.25
1988	***	***	***	***	***	***
1989	0.31	38	19	18	106	3021.00
1990	0.29	88	22	18	115	3366.00
1991	0.55	133	34	18	338	5510.50
1992	0.35	163	41	18	256	4726.50 present.

Table 4. Weight frequency distribution of *C. hippurus* caught in Parguera Nautical Club tournaments

Weight Class (lbs)	1985	1986	1987	1989	1991	1992
0	0	0	0	0	0	0
2.5	0	0	0	0	0	0
5	0	0	0	0	2	4
7.5	1	2	0	1	4	4
10	12	3	4	5	8	16
12.5	37	1	6	0	19	27
15	33	9	13	4	47	51
17.5	2	5	10	4	70	51
20	6	17	3	7	67	25
22.5	2	7	8	4	38	20
25	11	7	9	22	19	13
27.5	1	6	3	16	9	12
30	5	4	4	9	6	8
32.5	1	6	1	11	4	8
35	2	0	7	5	4	9
37.5	0	1	3	7	2	2
40	4	0	0	3	2	1

42.5	1	1	0	2	0	2	
45	3	0	0	1	1	2	
47.5	0	0	0	1	0	0	
50	0	1	1	0	0	0	
52.5	0	1	0	0	0	1	
55	0	0	0	0	0	0	
57.5	1	0	0	2	0	0	
60	0	1	0	1	0	0	
62.5	0	0	0	1	0	0	
65	0	0	0	1	0	0	
Average	17.24	22.31	21.1	27.7	18.32	18.46	
s.d.	9.39	9.29	8.39	10.49	5.59	7.79	
Minimum		6	6.5	10	6	3.5	4
Maximum		56.5	58	47.8	63.5	43	51

Table 5. Catch data for several *Coryphaena hippurus* tournaments around Puerto Rico during 1991 and 1992. [***, no data; CNSJ, San Juan Nautical Club; CNA, Arecibo Nautical Club; CYC, Cangrejos Yacht Club, Carolina; PYC, Ponce Yacht Club; CNG, Guayama Yacht Club; APP, Ponce Fishing Association; CNES, Club Nautico Esmeralda de Sur, Patillas; CNP, Parguera Nautical Club, Lajas; CNB, Boquer—n Nautical Club, Cabo Rojo]

North Coast

	CNSJ	CNSJ	CNA	CNA	CYC	CYC		
Fishing Date		26-27Jan	8-9Feb	27Jan	15Dec	9-10Feb	29Feb-1Mar	
	1991	1992	1991	1991	1991	1992		
Fishing Hours Per Boat			16	17	7	7.5	19.5	17
Number of Boats	29		16	20	16	35	20	
Number of Fishermen			112	64	57	46	108	80
Number of *C. hippurus*			158	33	5	15	51	12
Fish per Boat Hours			0.341	0.121	0.036	0.125	0.075	0.035
Fish per Fishermen Hours			0.088	0.032	0.0175	0.043	0.024	0.009
Total pounds C. hippurus caught				1435	***	87.6	310.1	436.2
199.5								
Average weight of fish	12.69	***		17.5	19.4	14.5	16.6	
Standard Deviation	4.9		***	4.7	11.6	5.2	6.7	
Weight of largest fish			41	***	22	51	28.6	28

C. hippurus average weight (sd) for the north coast 16.14 (2.34)

South Coast

	PYC	APP	CNES	CNES	CNP	CNP	CNG	
Fishing date		28-19Mar		21-22May		20-21April		1-12April
4-5May	25-26April		10-11Nov					
		1992	1992	1991	1992	1991	1992	1990
Fishing Hours per Boat			18.5	19	18.5	19	18	18
18								
Number of Boats		15	17	25	23	34	41	12
Number of Fishermen		60	65	96	88	133	163	48
Number of *C. hippurus*		21	14	74	50	338	256	16
Fish per Boat Hours		0.076	0.043	0.16	0.114	0.55	0.35	0.074
Fish per Fishermen Hours			0.019	0.011	0.042	0.029	0.14	0.09
0.019								
Total pounds *C. hippurus* caught				567	351	1218.5	874	5510.5
4726.5	166.31							
Average weight of fish caught				27	27	16.44	20.81	l8.32
18.46	11.09							
Standard Deviation		8.4	9.5	6.62	13.3	5.6	7.8	12.2
Weight of largest fish caught				41	47	***	55	43
51	46.5							

C. hippurus average weight (sd)
for the south coast 21.33 (3.65)

Table 5. Catch data for several *Coryphaena hippurus* tournaments around Puerto Rico during 1991 and 1992. [***, no data; CNSJ, San Juan Nautical Club; CNA, Arecibo Nautical Club; CYC, Cangrejos Yacht Club, Carolina; PYC, Ponce Yacht Club; CNG, Guayama Yacht Club; APP, Ponce Fishing Association; CNES, Club Nautico Esmeralda de Sur, Patillas; CNP, Parguera Nautical Club, Lajas; CNB, Boquer—n Nautical Club, Cabo Rojo] (continued)

	West Coast				
	CNB	CNB			
Fishing Date	28-Apr	5-Apr			
	1991	1992			
Fishing Hours per Boat		9.5	8		
Number of Boats	29	38			
Number of Fishermen		110	150		
Number of *C. hippurus* caught			39	52	
Fish per Boat Hours		0.142	0.171		
Fish per Fishermen Hours		0.037	0.043		
Total pounds C. hippurus caught			857.34	949.3	
Average weight of fish caught				22	20.6
Standard Deviation	8.5	11.8			
Weight of largest fish caught		42	57.25		

C. hippurus average weight (sd)
for the west coast 21.3(0.98)

Table 6. Average *C. hippurus* fork length (FL) data collected from 1990 to 1992 by coastal region

	North coast	South coast	West coast
Sample size	158	528	230
Average FL(mm)	920	978	891
std. dev.	173	177	209
minimum	445	358	428
maximum	1288	1479	1432

Table 7. Percents and ranks of fishing gear used in *C. hippurus* tournaments monitored between 1991 and 1992.

line(lbs)	Percent	Rank
15	1.03	6
20	6.19	4
30	44.33	1
40	0	***
50	37.11	2
75	2.06	5
80	7.28	3

#hook/line	Percent	
1	1.43	2
2	98.57	1

#hook size	Percent	Rank
3/0	1.37	6
4/0	1.37	6
5/0	0	***
6/0	21.92	2
7/0	28.76	1
8/0	21.92	3
9/0	19.18	4
10/0	5.48	5

Bait type	Percent	Rank
dead	73.61	1
live	4.17	4
artificial	2.78	2
dead w/teaser	19.44	3

Table 8. Percent and rank of *C. hippurus* behavior patterns observed by sportfishermen in Puerto Rico during 1991 and 1992.

Behavior A: 1 = fish in school
2 = fish alone
3 = fish alone with other species of fish

Behavior B: 1 = fish under debris in open water
2 = fish caught in clear open water

	Behavior					
Percent	A	B	Percent	Sex	Percent	Rank
	1	1	36.64	male	12.21	2
61.07				female	24.43	1
	1	2	24.43	male	8.39	2
				female	14.50	1
	2	1	12.21	male	5.34	2
32.82				female	6.87	1
	2	2	20.61	male	11.45	1
				female	9.16	2
	3	1	4.58	male	1.53	2
6.11				female	3.05	1
	3	2	1.53	male	0.76	***
				female		

Table 9. Conversion equations used in determining weight, length, and recundity relationships for *C. hippurus* in Puerto Rico. [N, sample size; df, degrees of freedom; SE, standard error of coefficient]

Variable	Equation	Independent					
Dependent variable	Independent	logy = a + b logx					
y	x	a	b	r2	N	df	SE
range							
Weight (b)	Standard Length (mm)	-4.80	2.93	0.95	670	668	0.03
338-1323							
Weight (g)	Total Length (mm)	4.79	2.83	0.95	204	202	0.05
420-1600							
Weight (g)	Fork Length (mm)	-4.52	3.49	0.95	852	850	0.027
381-1479							
Male Weight (g)	Fork length (mm)	-4.75	3.62	0.96	261	259	0.043
490-1479							
Female weight (g)	Fork length (mm)	-4.24	3.36	0.95	591	589	0.031
445-1310							
Fecundity (#eggs/ ovary weight)	Fork length (mm)	-6.22	3.98	0.49	24	22	0.859
445-1310							

		y = a + bx					
		a	b	r2	N	df	SE
Standard length (mm)	Fork length (mm)	14.0454	0.9253	0.98	332	330	0.0064
358-1474							

Table 10. Percent frequency of mature *C. hippurus* females in each size class (including mature inactive, and postspawn).

FL(mm)	Frequency Immature	Percent Cumulative Mature	Cumulative Mature	Cumulative Mature
350	0	0	0	0.00
400	0	1	1	0.36
450	2	1	2	0.72
500	4	2	4	1.43
550	4	8	12	4.30
600	1	12	24	8.60
650	0	12	36	12.90
700	0	9	45	16.13
750	0	12	58	20.79
800	0	21	70	25.09
850	0	38	91	32.62
900	0	31	129	46.24
950	0	27	160	57.35
1000	0	25	187	67.03
1050	0	27	212	75.99
1100	0	13	239	85.66
1150	0	12	252	90.32
1200	0	10	264	94.62
1250	0	4	274	98.21
1300	0	1	278	99.64
1350	0	0	279	100.00
1400	0	0	279	100.00
1450	0	0	279	100.00
1500	0	0	279	100.00
n=	11	279		

Table 11. Number of females per maturation stage. (***, no samples, N, number of samples)

		Maturation Stages			
Month	N	I	II	III	VI
JAN	31	0	0	30	1
FEB	31	0	1	30	0
MAR	21	0	0	21	0
APR	43	2	5	36	0
MAY	19	1	0	18	0
JUN	20	0	0	20	0
JUL	0	***	***	***	***
AUG	1	0	0	1	0
SEP	24	6	4	14	0
OCT	40	9	7	21	3
NOV	37	2	5	28	2
DEC	33	1	4	28	0
n=	427	29	130	262	6

Table 12. Comparison of reproductive traits in *C. hippurus* from previous studies [mm, millimeters; mmSL, standard length in millimeters; FL, fork length; (), standard deviation; S, south coast; N, north coast]

	Florida	Barbados	Puerto Rico	
	Beardsly (1967)	Oxenford and Hunte (1986)		Present Study
Size at first maturity (mmSL)	324	610		384
Size class at maturity (50% criteria)	450mmFL	850mmFL		900mmFL
Mature egg size range (mm diameter)	1-1.7	0.86-1.00	0.85-1.56	N&S
Mean mature egg (mm diameter)	1.3	0.97	1.096 (0.040)S 1.1095(0.063)N	
Spawning season	Extended	Extended	Extended	

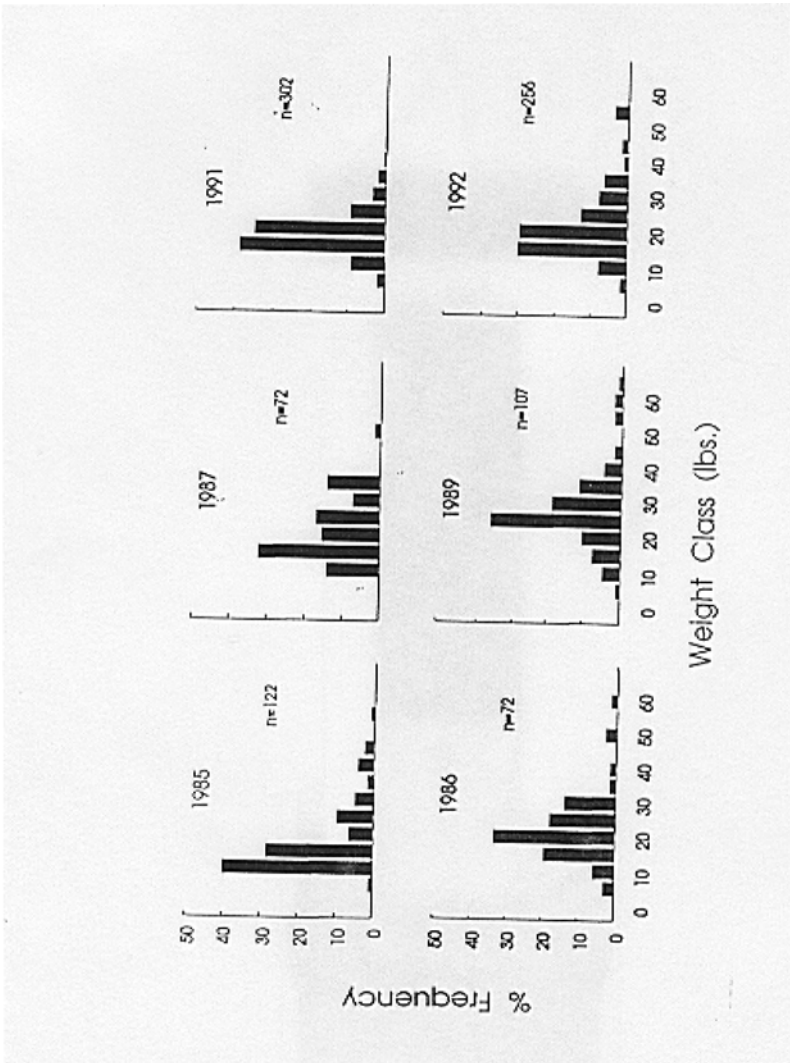

Figure 1. Weight frequency distribution *C. hippurus* from La parguera Nautical Club tournaments

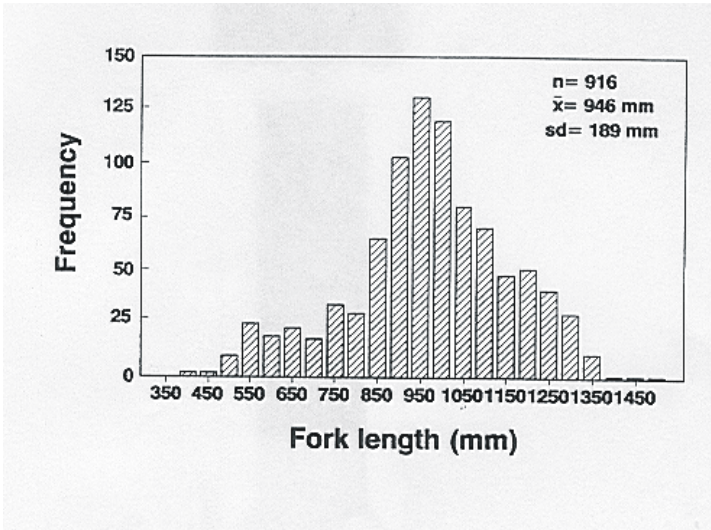

Figure 2.Size frequency distribution *C. hippurus* measured between 1990-1992

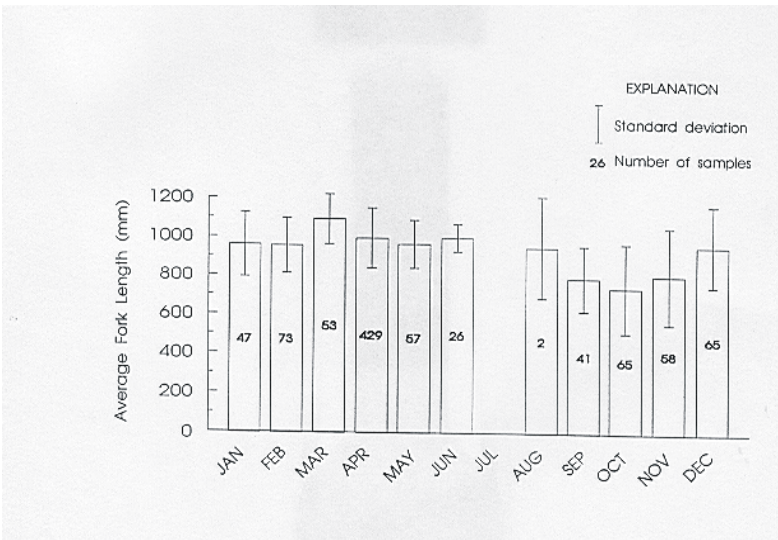

Figure 3. Monthly average size for *C. hippurus* between 1990-1992

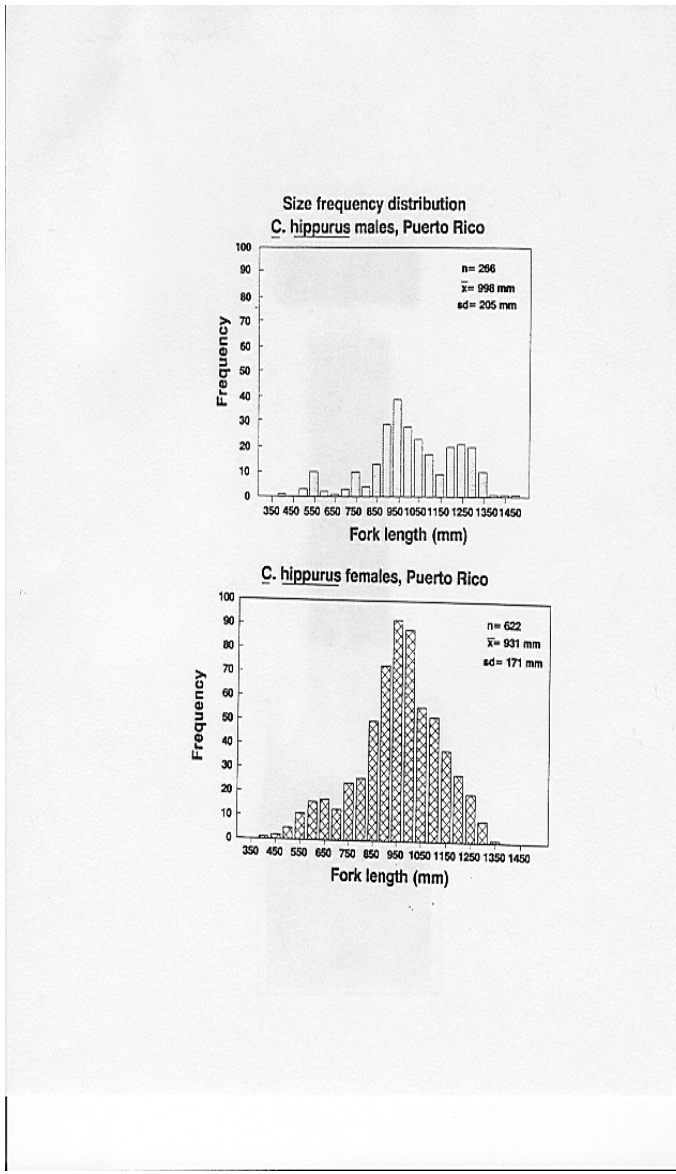

Figure 4. Male and Female dolphinfish size frequency distribution

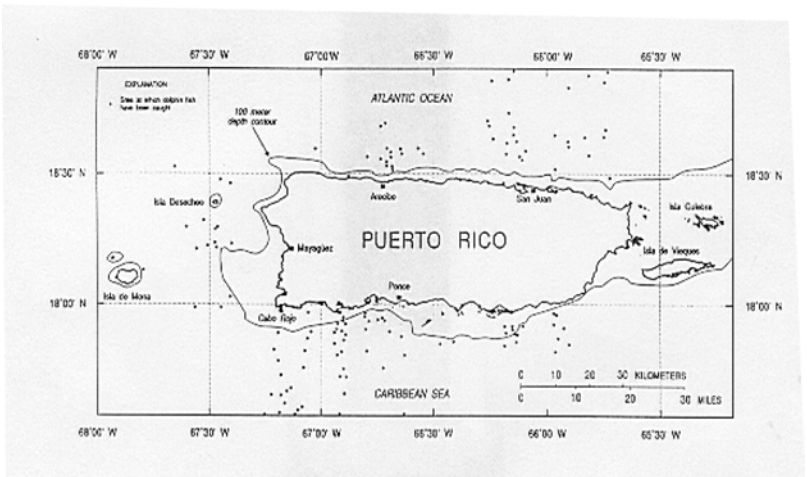

Figure 5. Puerto Rico map showing locations where dolphinfish were caught

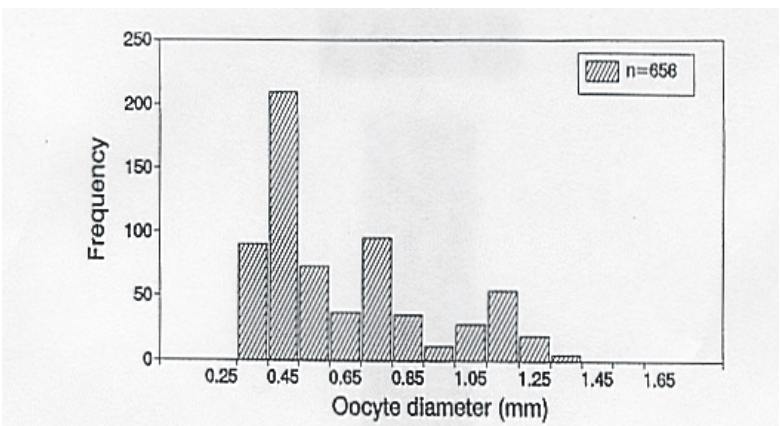

Figure 6. Oocyte diameter frequency distribution of *C. hippurus* in February.

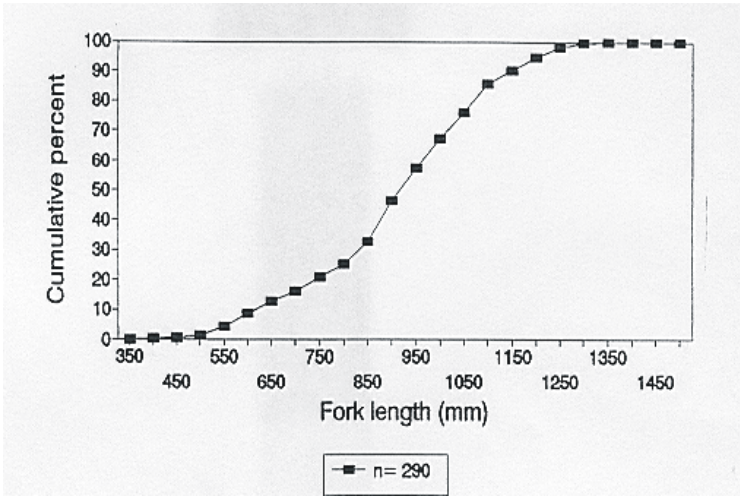

Figure 7. Percent frequency of mature *C. hippurus* females on each fork length size class

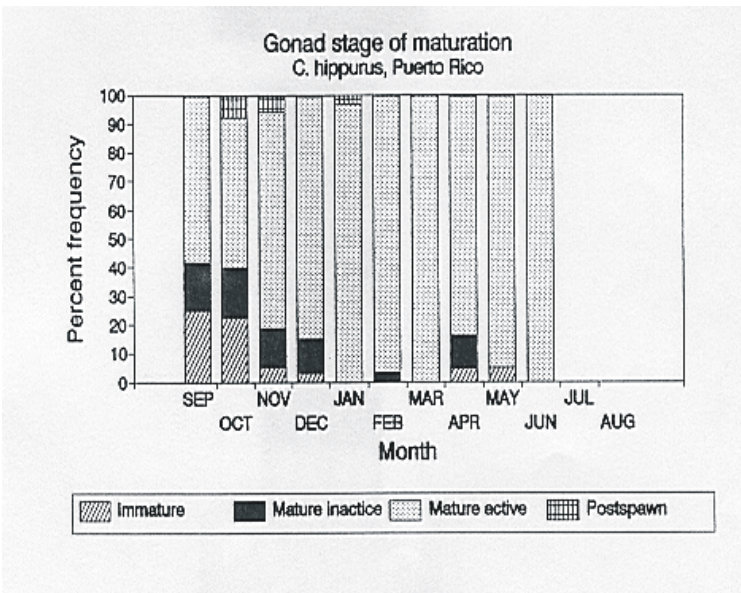

Figure 8. Percent frequency of *C. hippurus* females on each maturation stage

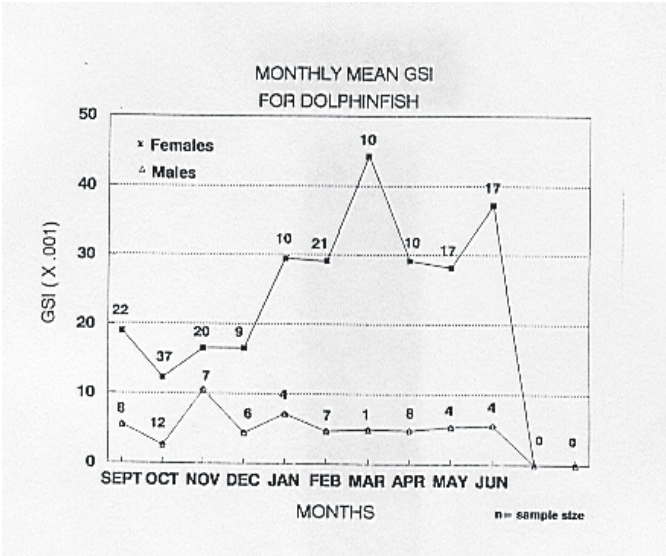

Figure 9. Mean Gonosomatic Index (GSI) per month for *C. hippurus*

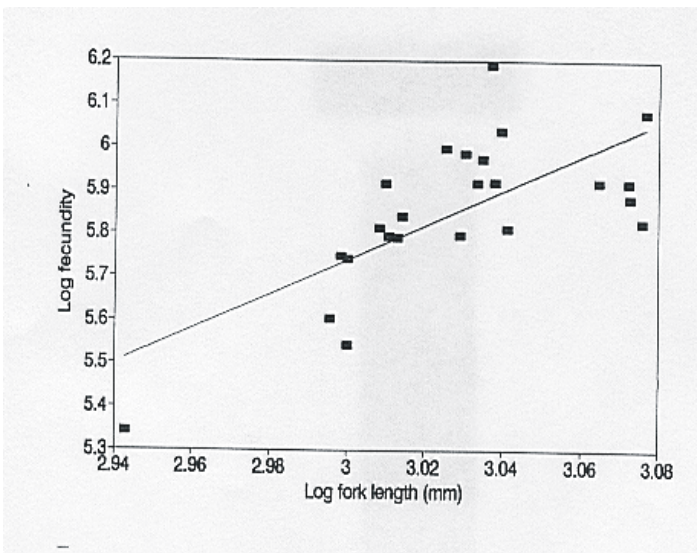

Figure 10. fecundity vs. length relationship for females of *C. hippurus* in Puerto Rico