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

Fisheries and biology of *Coryphaena hippurus* (Pisces: Coryphaenidae) in the Pacific coast of Colombia and Panama*

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SUMMARY: The fisheries and biology of the dolphinfish *Coryphaena hippurus* were studied between August 1994 and December 1996, using data obtained from the fishery fleet that operates in the area known as Panama Bight. The data showed a seasonal pattern of total catches with peaks from December through April and a total catch during three years of 1322.30 t., demonstrating the migratory pattern of the species. Based on the sex ratio (1 male: 0.96 female) and the reproductive index, the migration was spawning related. The diet is based on fishes (Exocoetidae, Scombridae, and Signathidae), mollusks (Loliginidae) and crustaceans (Portunidae). The relationship of fork length (fl) and total weight for the species was modeled based on the equation $Wt = 0.0224 \times (fl)^{2.78}$ reflecting allometric growth. The frequency histograms showed lengths between 29 and 197 cm of fork length (35 and 238 cm of total length) with a mode around 105 cm and average length of 98.21 cm. The growth parameters were $L_\infty = 194$ cm, $K = 0.91$ cm/year and $t_0 = -0.1049$. Data on C. *equiselis*, the other species of the same family, are reported.

Key words: Fisheries, biology, dolphinfish Coryphaenidae, Pacific Ocean, Colombia, Panama.

INTRODUCTION

The dolphinfish, *Coryphaena hippurus* (Linnaeus, 1758), a migratory pelagic fish with a world distribution and a relatively fast growth, usually lives on oceanic and tropical coastal waters with temperatures over 21°C (Scherbachev, 1973). One of the stocks occurs in the area of the Panama Bight, extending from the Ecuador to Costa Rica along the west coast of Central America. It is being exploited mostly in Ecuador (Patterson and Martinez, 1991), with captures of 11600 t in 1990, estimated at $US 29 million on the US market (Scott, 1992). Rubio (1987) classified the species as a coastal, pelagic and oceanic fish commonly found on surface continental and insular waters and off the continental shelf.

The species is considered an important fisheries resource on the Pacific coast of Colombia, since it is one of the dominant fish obtained from the artisanal and industrial fleet landings, together with sharks, marlins and groupers (Zapata, 1993). Currently, its annual catch contribution is less than that of tuna but more than that of shrimp. The catches of *Coryphaena* represented a total of 1322.30 t between 1994 and 1996, being the second most important resource on the Pacific coast of Colombia after the snapper (Lutjanidae) and above sharks (Carcharhinidae), which are simultaneously cap-

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tured. The latter has as local name: toyo blanco *Carcharhinus falciformis* (Bribon, 1939) and *Carcharhinus limbatus* (Valenciennes, 1839); madrecazones, *Carcharhinus leucas* (Valenciennes, 1839); toyos, *Carcharhinus porosus* (Ranzani, 1839); tintoreras, *Galeocerdo cuvieri* (Peron and Lessueur, 1822); and toyo tinto *Alopias vulpinus* (Bonnaterre, 1788) (Acevedo, 1994). On the Pacific coast of Colombia, the dolphinfish species is captured by the industrial fishery, especially by the shark fleet using surface nets at night, between 54 and 108 km offshore. However, during some periods it is captured by the grouper fleet, since these vessels exhibit seasonal changes to surface line, as well as by sport fishermen.

The family Coryphaenidae includes two species, *Coryphaena hippurus* and *Coryphaena equiselis* (Linnaeus, 1758). The present study examined the fleet landings in different harbors of the Pacific coast of Colombia, and principally the biology of *Coryphaena hippurus* in the Panama Bight, between August 1994 and December 1996. The main goal was to evaluate the fishery statistics, reproduction, growth and food habits of the species.

MATERIALS AND METHODS

Samples were collected during 16-day periods from the industrial fleet targetting shark, which uses surface nets (mallador). In addition, samples from the grouper fleet that use surface lines were obtained for a total of 24 continuous samples between August 1994 and December 1996, with the exception of September and October 1994, and July, October and November 1996. For each catch, characteristics of the vessels, equipment, and fishing areas were obtained. Capture per unit effort (CPUE) is expressed as Kg/day taking into account total catches on the Pacific coast of Colombia during each month and divided by the number of days that the fleet is offshore. The percentages of capture per species were estimated based on the number of individuals of each species multiplied by its average weight. For each animal, data of fork length (fl), total weight (tw), eviscerated weight (we), and weights of stomach (stw), liver (lw) and gonads (gw) were obtained.

The diet was determined using contents from 228 stomachs collected between December 1994 and December 1995. The following indexes were estimated (Vegas, 1977):

- Coefficient of emptiness (E): % of total empty stomachs/total stomachs.
- Index of repletion (IR): stomach weight/total fish weight.
- Prey frequency index (F): number of total fishes with a specific prey/total number of examined fishes.
- Index of relative abundance (A): % of total weight of specific prey/total weight of all ingested preys.
- Percent number (CN): % of total number of individuals with the specific prey/total number of total ingested preys.
- The food coefficient Q= CN*A (Gherbi Barre, 1983) was used to classify the food type as: 1) principal Q>1500; 2) occasional 800<Q<1500; 3) replacement 400<Q<800; and 4) rare Q<400.

Reproduction was studied based on the sex ratio, the gonadic index (GI), the hepatosomatic index (HI) and the condition factor (K) according to Vazzoler (1981). GI reflected the different reproduction stages. HI indicated the contribution of the liver in the production of gametes and other metabolic activities (Gherbi-Barre, 1983).

Growth was estimated using fork length (fl) and total weight (tw) according to Pauly (1989). Monthly size histograms were used to estimate average length of capture for *Coryphaena hippurus*. The parameters L_∞, K and t_0 were calculated using these data and applying Pauly's (1983) integrated method together with the computer program FISAT (Gayanilo *et al*., 1994). t_0 was obtained using the following equation (Pauly, 1983):

$$\text{Log } (-t_0) = -0.3922 - 0.2752 \text{ Log } L_\infty - 1.038 \text{ Log } K$$

L_∞ was also estimated based on the maximum length (L_{max}), using Pauly's equation where $L_\infty = L_{max}/0.95$. For *Coryphaena equiselis*, the size histograms were also based on fork length (fl).

Catch data were obtained from the "fishery report", used for the National Fisheries and Aquaculture Institute (INPA), Zapata (1992). It provides the industrial and artisanal catches from the main harbors (Buenaventura, Tumaco and Bahia Solano) on the Pacific coast of Colombia. Most of the catch in the region is processed on board, and arrives at the harbor gutted. Thus, the study calculated the conversion factors for gutted to whole weight by linear regression analysis. A linear regression analysis was performed to obtain the conversion equation. Likewise, a regression analysis was performed to

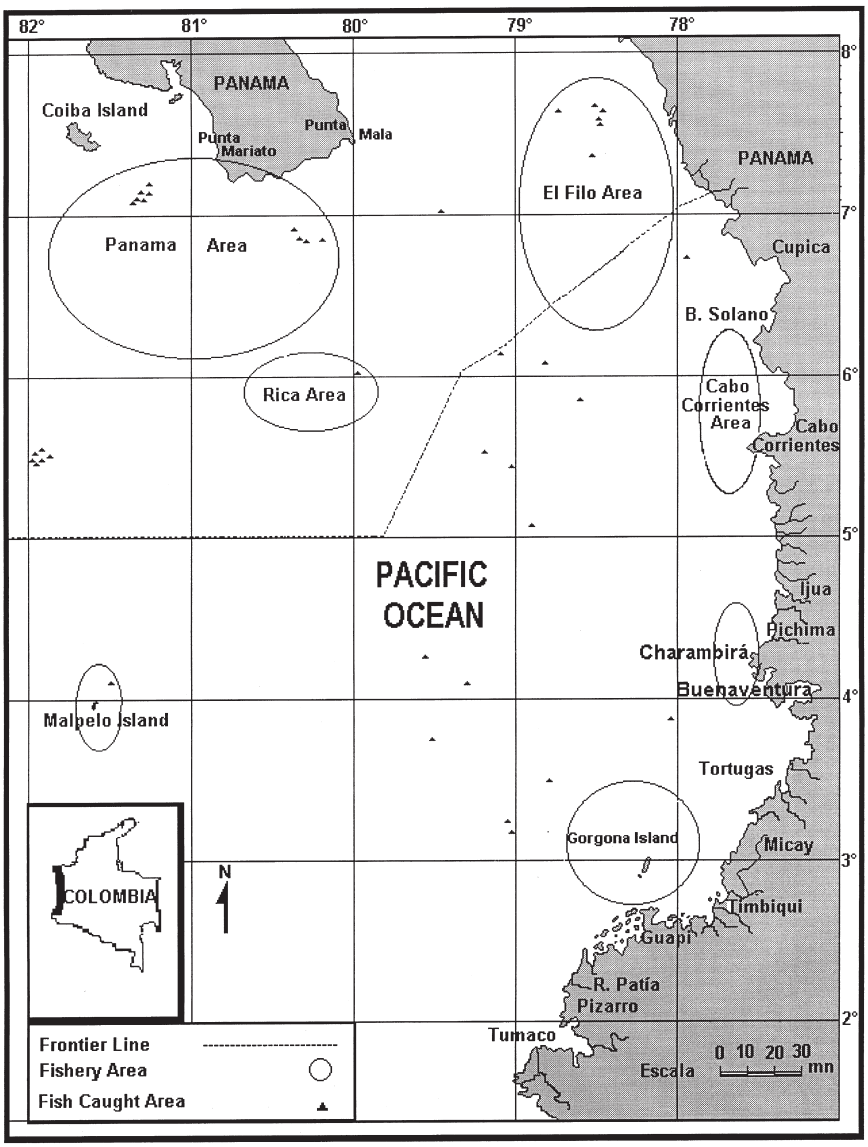

FIG. 1. – Map of the study area showing the main fish areas of the shark float during the sampling period of August 1994 and December 1996.

obtain the relationship between total length (TL) and fork length (FL). Finally, the species composition of all the catches was obtained.

RESULTS

Fishing areas and techniques

The surface fishing net has an average length of between 1500 and 4200 m, a height of 15 m and a mesh size of 11 inches. At the top, there is a series of buoys and plastic drums separated by approximately 2 fathoms (3.6 m), and bordered with lamps for illumination. The bottom net is bordered with circular lead weights (4-6) each fathom. This type of net is commonly used for shark fishing. The ships arrive at the fishing areas and start activities in late afternoon. They leave the net fishing during the night. Early the following morning, the catch is brought on board for processing. In the case of long-line vessels, the line has a total length of about 3.6 km and 1400 to 1500 hooks. This fishery uses bait such as *Euthynnus lineatus* (Scombridae); *Cetengraulis mysticetus* (Gunther, 1866), *Anchoa* spp. and *Anchovia macrolepidota* (Engraulidae) and the squid *Loligo* sp. Long-line fishing is done early in the morning beginning at 6 am for about 4 to 6 hours.

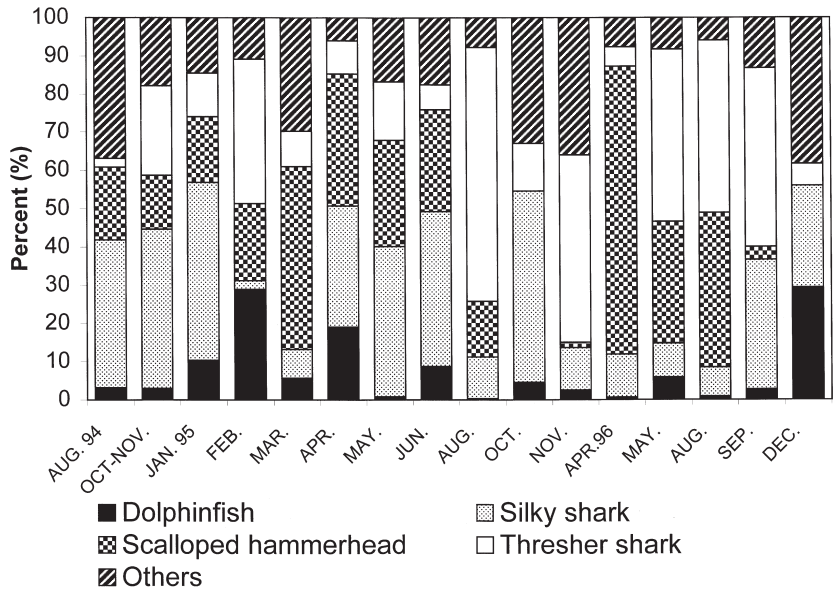

FIG. 2. – Capture composition of *Coryphaena hippurus* and associated species during the study period.

The vessels are equipped with GPS and echo sounders, which are helpful for detecting the fish schools. The most common fishing area of the shark fleet is the north region of the Panama Bight, since it has registered the highest shark catches and associated dolphinfish.

The most important fishing areas (Fig. 1) are: Cabo Corrientes (5°30' to 6°10'N, 77°30'W to 78°00'W). El Filo, on the boundary with Panama. The Panama area (6°00' to 7°00'N, and 80°00' to 82°00'W). Zona Rica, an area no more than 500 m deep dominated by rocky substrata is a difficult area to set the long-line, and is characterized by a high abundance of sharks. Malpelo and Gorgona Islands, both national parks, are potential areas for the resource. The Charambira area on the continental shelf is characteristically deeper than 1000 m due to a geologic fault running parallel to the Pacific coast line (Zapata *et al.*, 1997).

Catches

Of 3505 *Coryphaena* studied, only 0.83% were *Coryphaena equiselis*. Consequently the statistical

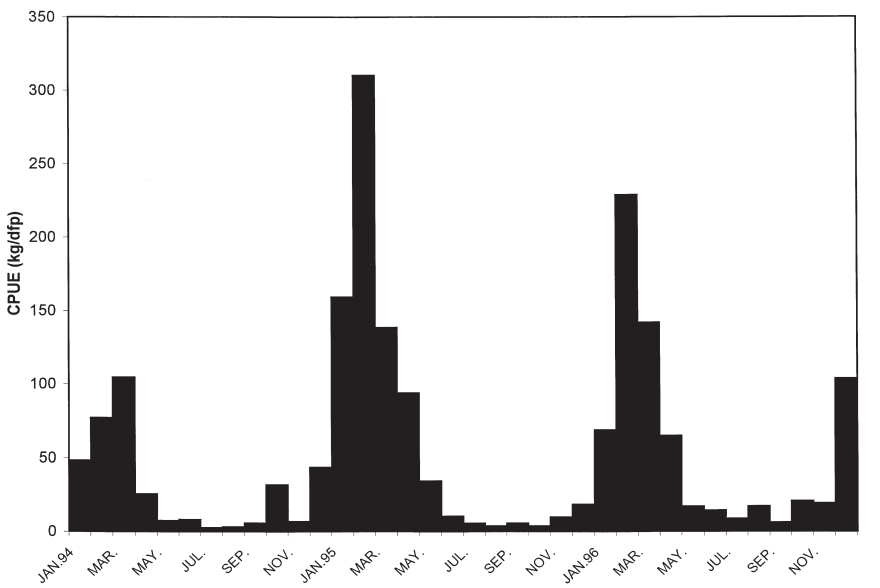

FIG. 3. – CPUE for *Coryphaena hippurus* during the study period.

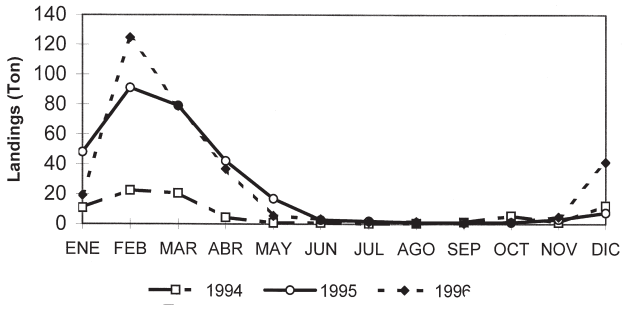

FIG. 4. – Total landings for the dolphinfish in Buenaventura (Pacific Coast of Colombia) in 1994, 1995 and 1996.

analysis was focused on *C. hippurus*. The highest catches occurred from December to February and in April (Fig. 2). A relationship was observed between these peaks and the migration of the species into the Colombian Pacific waters. Shark species such as *Sphyrna lewini* (Griffth and Smith 1834) were common at the beginning of the year (March-April) and from August through November "toyo tinto" were caught. The capture per unit effort (CPUE) was highest during February 1995 and February 1996 with average values of 310.01 and 228.70 Kg/day respectively (Fig. 3).

TABLE 1. – Artisanal and industrial catches of dolphinfish on the Pacific coast of Colombia 1994-1996 (SN: surface net; LL: long-line).

	Vessel number		Industrial Catches		Artisanal	Total
	SN	LL	SN	LL	Catches	(kg)
1994	20	18	36027	71529	234116	341672
1995	27	18	68721	238129	125198	432048
1996	31	16	116346	262744	169491	548581

Landings

The total landings of *Coryphaena hippurus* from the artisanal and the industrial fleet during 1994, 1995 and 1996 came to 1322.30 t. The artisanal long-line catches contributed 39.99%, while the industrial catch (43 vessels) equipped mostly with surface net contributed 60.00% of the total catches

TABLE 2. – Associated species taken during the capture of *Coryphaena hippurus*.

FAMILY	Scientific Name	Common name	Classification
Istiophoridae	*Istiophorus albicans*	Marlin negro	Commercial
	Tetrapturus audax	Marlin negro	Commercial
	Makaira indica	Marlin blanco	Commercial
	Makaira mazara	Marlin azul	Commercial
Xiphidae	*Xiphias gladius*	Pez espada	Commercial
Scombridae	*Katsowonus pelamis*	Barrilete	Commercial
	Euthynnus lineatus	Patiseca	Commercial
	Auxis rochei	Maduro	None commercial
	Thunnus albacares	Aleta amarilla, albacora	Commercial
Mobulidae	*Manta birrostris*	Manta raya	Semi-commercial

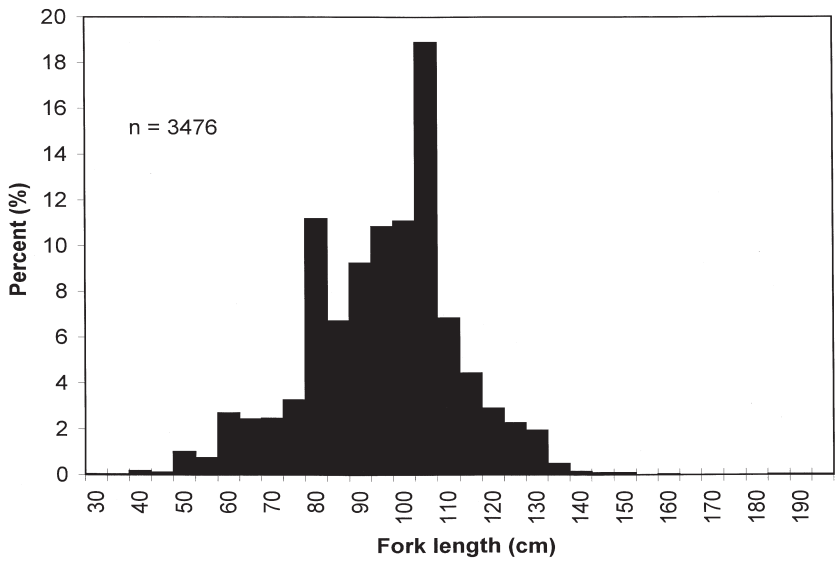

FIG. 5. – Size frequency histograms for *Coryphaena hippurus* in August 1994 and December 1996.

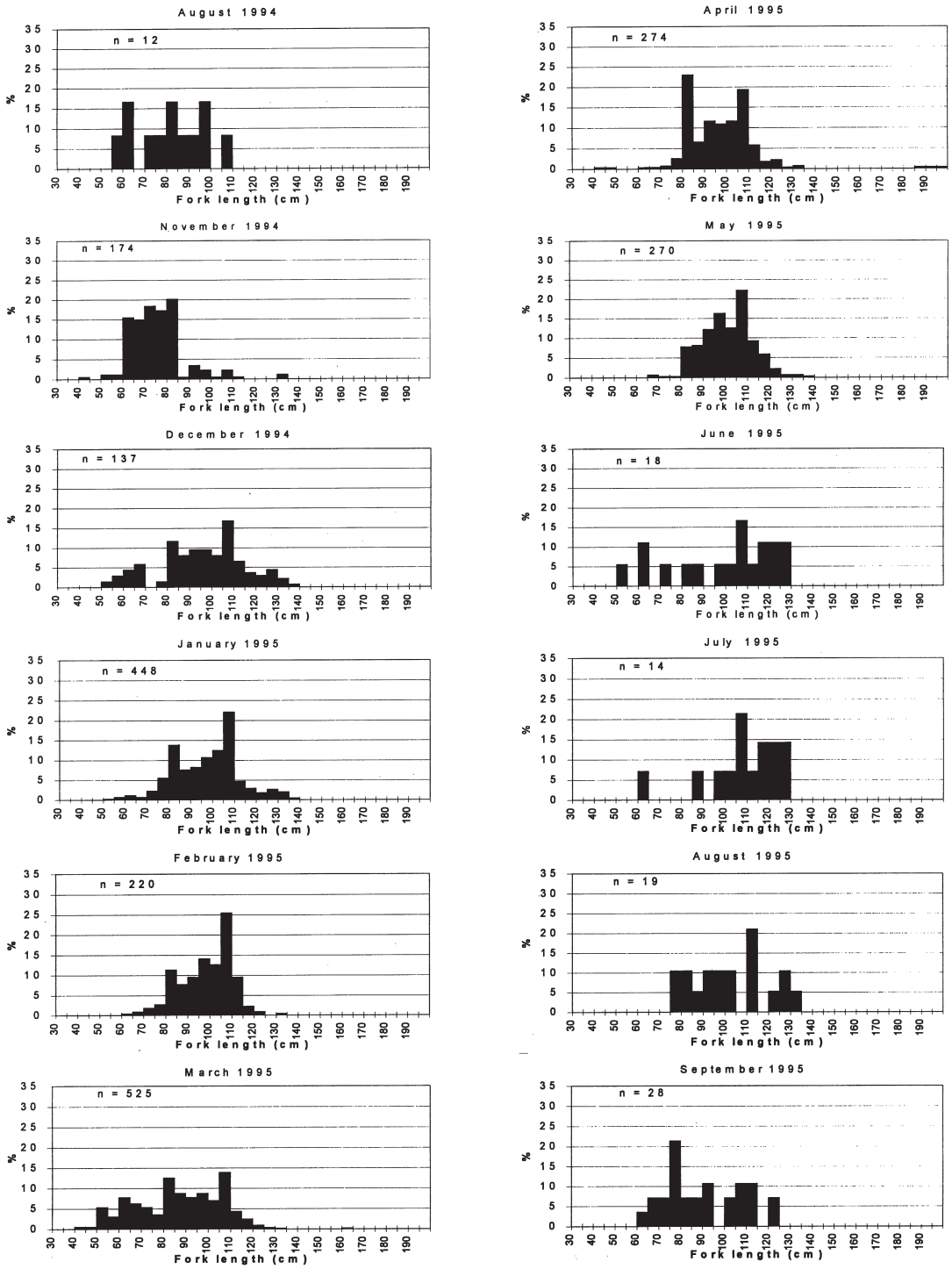

FIG. 6. – Monthly size frequencies of *Coryphaena hippurus* in August 1994 and December 1996.

(Table 1). The highest peak was during the period December-April (especially February) in the north area of the Panama bight, with a total of 91.72% of the total fish catches (Fig. 4). The companion species of the dolphinfish catches are listed in Table 2. Istiophoridae dominated this fauna, and were relatively abundant in the net.

The size composition of *Coryphaena hippurus* ranged from 29 to 197 cm fl with a mode of about 105 cm (Fig. 5). The monthly size frequency

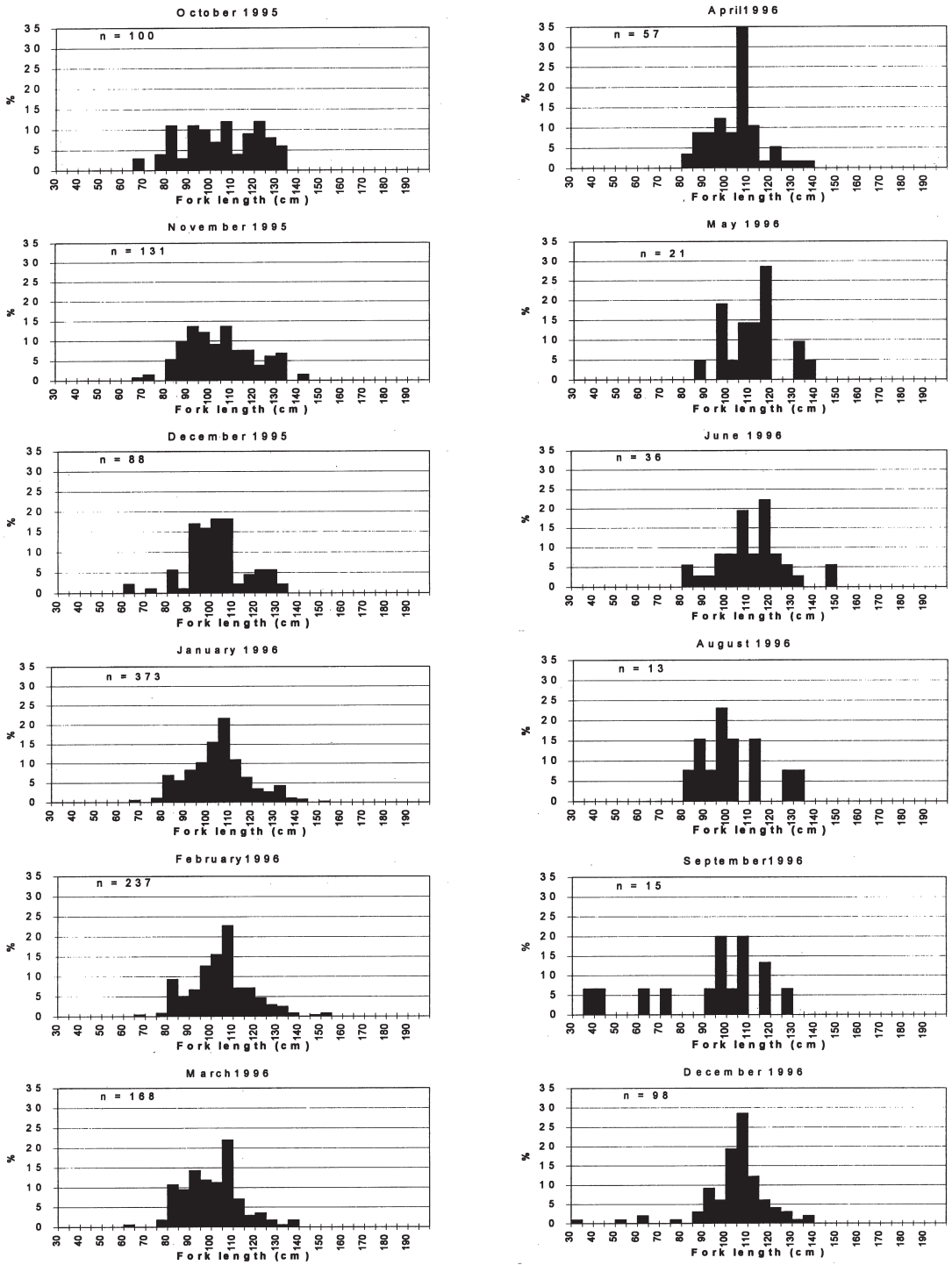

FIG. 6. (Cont.) – Monthly size frequencies of *Coryphaena hippurus* in August 1994 and December 1996.

showed a stable mode in the interval of fl = 105 cm, while smaller individuals (30-50 cm) were found especially from September to December and March to April. Larger individuals (185 cm) were observed in April 1995 (Fig. 6).

The average length of individuals in field samples and catches measured at processing places was 98.21 cm, which was close to that obtained in 1995 (115.55 cm of Tl) (Lasso, 1996). This value converted to fork length was 95.65 cm. *Coryphaena*

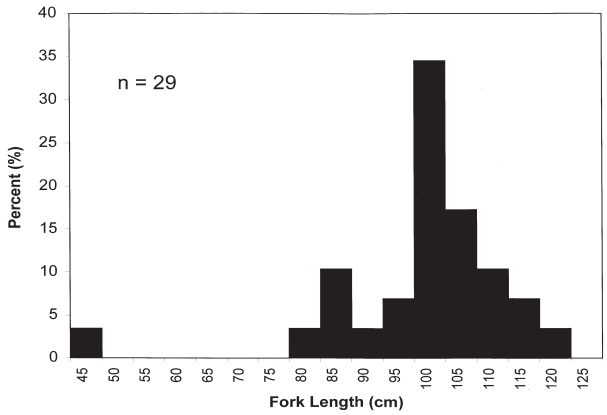

FIG. 7. – Size histogram for *Coryphaena equiselis* in August 1994 and December 1996.

equiselis ranged in size between 45 and 120 cm fl during the study period with a mode around 100 cm (Fig 7).

Biology

Food habits

The quality analysis from 70 *C. hippurus* showed a preference for fishes from the family Exocoetidae, Signathidae and Scombridae. For the mollusks *Loligo* sp. and for the crustaceans *Portunus iridiscens* (Rathbun, 1893) and *Portunus* sp., *C. hyppurus* showed high values of emptiness coefficient, while the coefficient of repletion was low during the whole study period (Fig. 8). The values of prey frequency (F), relative abundance (A) and percent number (CN) showed a dominance of fishes in the diet. During February, the diet showed a high proportion of mollusks (*Loligo* sp.), whereas in April and May, the dominant food was crustaceans (*Portunus* sp.) (Fig. 9 a,b,c). The food coefficient (Q) was calculated to show the significance of each prey item. It demonstrated the importance of the fishes over the mollusks and crustaceans in the food diet of *C. hippurus* (Table 3). Because of the few analyzed stomachs of *Coryphaena equiselis,* the results showed the dominance of fishes from the family Scombridae, and crustaceans such as *Portunus* spp.

Reproduction

Coryphaena hippurus showed a clear sex dimorphism, making it easy to distinguish males from females. The male head exhibited a well-developed crest (vertical slope) while the female head was mostly round. From a total of 3476 individuals of *C. hippurus*, 51% corresponded to males and 49% to

TABLE 3. – The food coefficient (Q) for *Coryphaena hippurus* at different periods.

Month	Fishes	Molluscs	Crustaceans	Others
December 1994	8305.01	1.34	-	-
February 1995	808.58	1654.73	338.18	55.47
April 1995	211.84	-	5769.95	3.31
May 1995	2446.30	-	2521.30	-
June 1995	7671.35	132.11	-	-
August 1995	10000.00	-	-	-
September 1995	10000.00	-	-	-
October 1995	3761.69	11.86	-	333.17
November 1995	4637.37	-	-	985.71
April 1996	244.00	905.63	405.50	479.92
May 1996	6797.00	10.86	-	51.85
August 1996	-	4972.50	-	27.10
September 1996	6255.69	59.17	-	-
December 1996	1761.11	2382.75	0.66	14.97

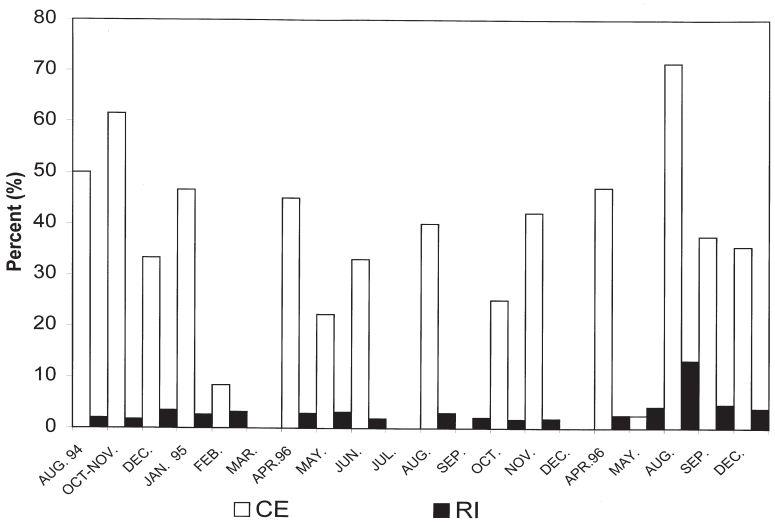

FIG. 8. – Repletion index (RI) and coefficient of emptiness (CE) for *Coryphaena hippurus*.

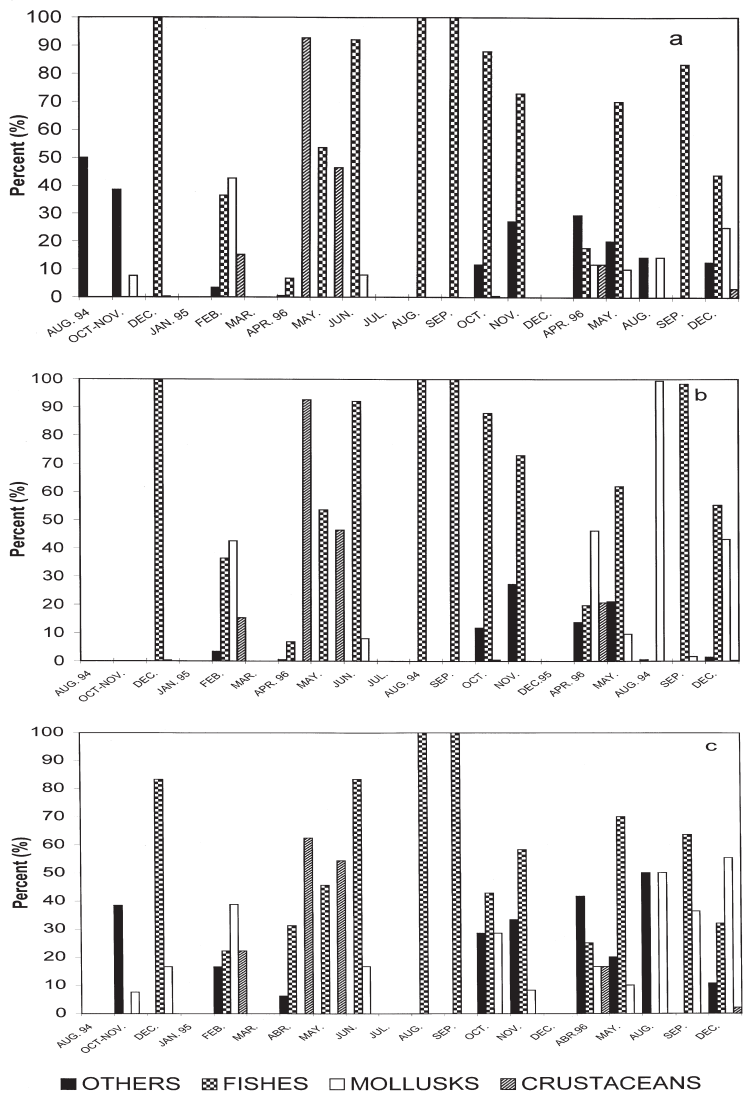

FIG. 9. – Prey frequency indexes PFI (a), index of relative abundance IRA (b), and percent in number PN (c) of the consumed preys of *Coryphaena hippurus*.

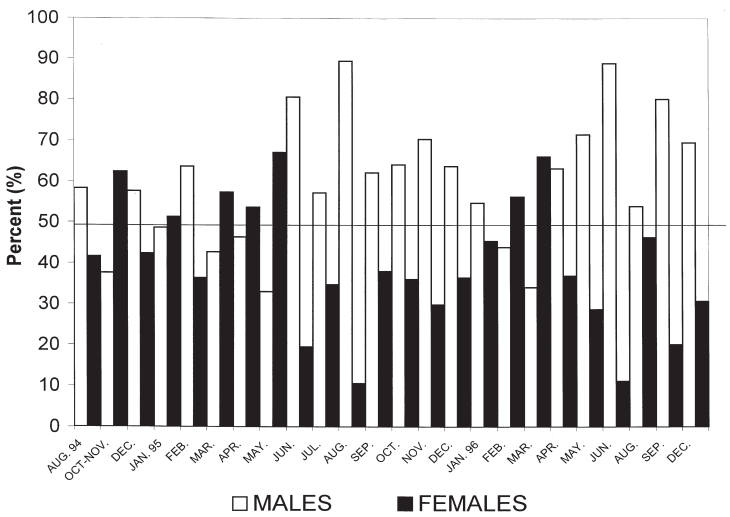

FIG. 10. – Sex proportion for *C. hippurus* during the period December 1994-December 1995.

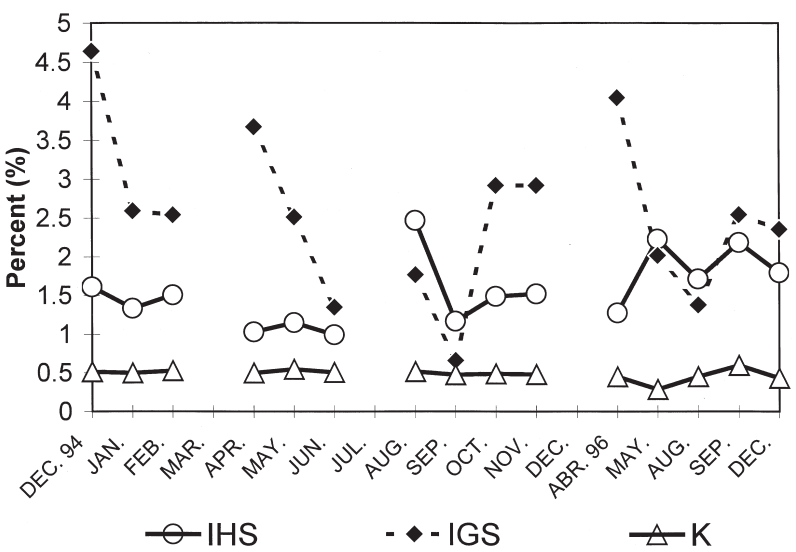

FIG. 11. – Gonads (GI) and Hepatosomatic (HI) indexes for *C. hippurus* in the study area.

females, with a sex proportion of 1 male: 0.96 females. A dominance of male individuals was found in August and December 1994, February and June-December 1995, April-June and September and December 1996. A dominance of females was found in October-November 1994, January-May 1995, and February-March and August 1996. A relatively equal number of males and females was found in January 1995 and January 1996 (Fig. 10).

The gonads index (GI) for *C. hippurus* showed higher values during the months of December 1994, April and October-November 1995 and April 1996. These periods can be related to spawning activity. The hepatosomatic index (HI) showed higher values in August 1995 and May and September 1996, and fell in April 1996. The behavior of these indexes showed an inverse relationship between them. The coefficient K showed no peaks during the study period (Fig 11). On the other hand, *Coryphaena equiselis* consisted of 58 % males.

Growth

In *C. hippurus* the relationship of fork length (FL) and total weight (TW) reflected an allometric growth:

Species: $TW = 0.0224\ (FL)^{2.78}$
$[t_{cal} = 3.388 - t_{2,147} = 1.96; P < 0.05]$
$n = 147 \quad r = 0.9526$

Males: $TW = 0.0406\ (FL)^{2.6588}$
$[t_{cal} = 4.1822 - t_{2,100} = 1.9867; P < 0.05]$
$n = 100\ r = 0.9352$

Females: $TW = 0.042\ (FL)^{2.6328}$
$[t_{cal} = 2.9385 - t_{2,35} = 2.0315; P < 0.05]$
$n = 35 \quad r = 0.9648$

In *C. equiselis* the relationship of fork length (FL) and total weight (TW) also reflected an allometric growth:

Species: $TW = 0.0001\ (FL)^{2.44}$
$[t_{cal} = 4.382 - t_{2,8} = 2.306; P < 0.05]$
$n = 8, r = 0.9920$

The growth parameters for *C. hippurus* were estimated based on 3477 size-frequency measurement and are: $L_\infty = 194$ cm; $K = 0.91$ cm/year and $t_0 = -0.1049$.

Conversion factors

The weight data of *C. hippurus* once they are processed after catch (PW) were used to estimate total weight according to the following equation:

Total Weight (TW) = 0.1065 + 1.093 x gutted weight (PW) $n = 434 \quad r = 0.99$

Likewise, the relationship of total length (TL) and fork length (FL) was represented by the following equations:

C. hippurus: FL = 0.8278 x TL; n = 522, r = 0.9787
Males: FL = 0.8226 x TL; n = 323, r = 0.9824
Females: FL = 0.8386 x TL; n = 199, r = 0.9707

C. equiselis: FL = 0.0788 + (TL*0.836); n = 24
r = 0.9629
Males: FL = 1.5833 + (TL*0.815); n = 16
r = 0.8095
Females: FL = -0.7988 + (TL*0.846); n = 8
r = 0.9822

DISCUSSION

The seasonality of the catches for *Coryphaena hippurus* stock in the Panama Bight showed the highest catches during the first three months of the year (Zapata, 1993). During the occurrence of the Niño event the species migrates south and is more available off north Peru, where its local name is "Perico". Estrella *et al*. (1998) considers it to be an opportunistic species, which appears with warm waters. In the first semester of 1998, the total catch off Peru was 6913 t with significant peaks during the first three months. The migration route of this species could be related to the surface oceanic currents in the Eastern Pacific region. The tropical distribution limits of *C. hippurus* has two mixing zones of tropical and temperate waters. In the north this is with the California Current, and in the south with the Peru Current (an extension of the Humboldt Current). During the first few months of the year (until April), the north-equatorial contracurrent advances south, allowing the intrusion of waters from the California and the Perú currents (Baumgartner and Christensen, 1985). Beardsley (1967) pointed out the possibility of *C. hippurus* performing long latitudinal migrations up to 400 km for its life cycle, although he did not define specific migration routes. Campos *et al*. (1993) stated that the migration patterns of this species are associated with the current circulation system which dominates along the Panama Bight region. Oxenford and Hunt (1986) pointed out the same criteria to establish the migration route of the dolphinfish in the Caribbean, and to relate it to different habitat conditions for the species during its life cycle.

Various authors have reported seasonal patterns in catches. In Costa Rica the peak occurs between September and February (Campos *et al*., 1993), in Colombia between January and April (Zapata, 1993), and in Ecuador between November and May (Patterson and Martinez 1991). This information, together with the sex proportion, the reproductive indexes and the larval surveys in December 1996 (INPA/VECEP DEMER 9611) (Zapata *et al*., 1998) indicated that the migration pattern of *C. hippurus* is mainly related to its spawning activity. Similar results have been observed by Beardsley (1967) in the Caribbean. The reproductive pattern of *C. hippurus* can be characterized as bimodal (Campos *et al*. 1993). The presence of mature males and females in stages III and IV during the first semester of the year is consistent with the reproductive season shown in other areas of the Eastern Pacific. However, a low percentage of mature specimens was observed during the study period, possibly because spawning activity can take place during the whole year. Beardsley (1967) and Chatterji and Ansari (1982) observed that it can last up to nine months. Based on these observations and the reproductive peaks observed in this study, it is expected that spawning takes places from October through December, and in April. Acevedo (1997) concluded that this species has a partial type of reproductive behavior with asynchronic development, which is typical of tropical and subtropical fishes (Oliva *et al*., 1986). They also concluded, that the ovary contains oocytes in different developed stages and that they are normally released in batches within the same reproductive event. Vizziano and Berois (1990) concluded that this mechanism is an adaptation to the environmental variability and minimizes the risk of having one spawning during reproduction.

The food habits of *C. hippurus* reported in this study are consistent with those reported in the literature, which characterize the species as a primary carnivore, mainly consuming fishes and occasionally crustaceans and mollusks, depending on availability (Palko *et al*., 1982, Rubio 1988, Campos *et al*. 1993). Most of the year the data showed the dominance of fishes, especially from the family Exocoetidae. Rossse and Hassler (1974), Morgan *et al*. (1985) and Manooch (1988) indicated the highly predatory conditions of *C. hippurus* and found similar results.

Regarding growth, Patterson and Martinez (1991) obtained a L_{∞} of TL = 195 cm based on FL data collected by Beardsley (1967) in Florida waters. Uchiyama *et al*. (1986) reported an L_{∞} of 189.93 cm of fork length for males and 153.26 cm for females in Hawaii. Palko *et al*. (1982) reported an L_{max} of 153 cm in south Florida. Torres (1991) found an FL of 180 cm for South Africa. Collete (1984) found an FL of 200 cm in the Indian Ocean, and Rubio (1988) an FL of 200 cm on the Pacific coast of Colombia. The FL and L_{∞} reported in this study are above the range of those found in the liter-

ature, but within the range of L_{max} of 197 cm reported for April 1995, which was used to apply Pauly's (1983) formula to get a final value of $L_{max}/0.95$ = 207.37 cm. The higher value of FL and L_{max} can be as a result of the permanent food availability in the study area throughout the year as compared with other areas. Hassler and Hogarth (1977) observed a decrease in the food rate for the species distributed in the western region in the North Atlantic as a result of water temperature below 23°C and rates of zero values below 18°C.

The relatively high values of K obtained in this study (K = 0.91 cm/yr) indicated the high growth rate for the dolphinfish. This value is within the range of those reported in the literature and in agreement with the rapid growth of the species in different world regions. Indeed, Patterson and Martinez (1991) found a K of 0.41 in Ecuador. Uchiyama *et al*. (1986) reported a K value of 1.18 for males and 1.41 for females in Hawaii. And Van der Elst (1981) reported a value of 1.036 in South Africa. Uchiyama *et al*. (1986) observed a growth rate of fishes in captivity of 35 to 125 cm in seven to eight months. Indeed, individuals born in January-February would have sizes around 100 cm in September. Lasso (1996) found an average length of 115.55 cm (95.65 cm of FL), which is close to the value found in this study of 98.21, indicating the steady state of the fish resource as well as the increase of the capture area of this stock. The dominance of adults and the lack of juveniles during the sampling period allowed us to show only a portion of the allometric curve for *Coryphaena hippurus*. Tesch (1970) in (Csirke 1980), concluded that environmental changes or changes in the reproductive stages can be reflected in the slope of the growth curve. For instance, changes in the size-weight ratio can generate an allometric curve.

In recent years there has been an increased interest in the dolphinfish resource, suggesting the importance of implementing a monitoring program and a regional study in the Panama Bight region for its sustainable management.

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