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Population dynamics of the king mackerel (*Scomberomorus cavalla*) of the Campeche Bank, Mexico*

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SUMMARY: The king mackerel (*Scomberomorus cavalla*) is a migratory pelagic resource which is caught along the coasts of the Gulf of Mexico, where some hypothesis suggest the existence of at least two stocks. In this contribution, the population dynamics of the Campeche Bank stock is analyzed. It is a small scale fishery with limited access to the whole population. Several locations along the coast were sampled around the Peninsula of Yucatan. Size structure of catches indicates a spatial gradient with large fishes found on the northeastern coast of the Yucatan Peninsula, and smaller ones on the southern Gulf of Mexico. This behavior is associated with environmental factors; the southern region, with fluvial influence, probably acting as a nursery area; while in the northeastern region the population dynamics is in syncrony with a seasonal upwelling. The average population parameters estimated were as follows: growth parameters of the von Bertalanffy equation: L_∞=140 cm; K=0.19 (1/year), and tz=0.54 years. Total mortality was estimated as Z=2.16, and natural mortality was estimated to be M=0.4. Length-structured-VPA was applied in order to estimate fishing mortality by size, which was more intensive on fishes ranging 60 cm to 80 cm; however, for Campeche, the small length at first catch (Lc) imposes large fishing mortalities on small sizes, and an increment to the Lc was recommended. The Thompson and Bell method suggests the stock is being exploited at the maximum biological production level. Results are discussed within the framework of ecological behavior, stock identity and fish accessibility. The emerging hypothesis is that a well defined stock occurs in the Campeche Bank, with a certain degree of mixing with other stocks from the Northern Gulf of Mexico.

Key words: Scomberomorus cavalla, Gulf of Mexico, population dynamics, stock identity.

RESUMEN: DINÁMICA DE POBLACIONES DEL CARITO (*SCOMBEROMORUS CAVALLA*) DEL BANCO DE CAMPECHE, MÉJICO. – El carito (*Scomberomorus cavalla*) es un recurso pelágico migratorio que es capturado a lo largo de las costas del Golfo de México, donde algunas hipótesis sugieren la existencia de al menos dos stocks. En esta contribución la dinámica de la población del Banco de Campeche es analizada. Se trata de una pesquería en pequeña escala con limitado acceso a todo el stock. Se tomaron muestras de las capturas comerciales de varias localidades a lo largo de la costa de la Península de Yucatán. La estructura por tamaños de las capturas indican un gradiente espacial con los peces más grandes hacia el Noreste de la península de Yucatán, y los más pequeños hacia el Sur del Golfo de México. Ese comportamiento está asociado con factores ambientales; En la región Sur, con influencia fluvial, probablemente actuando como zona de crianza; mientras que en la región Noreste la dinámica de la población está sincronizada con la surgencia estacional. Los parámetros promedio de la población estimados fueron: parámetros de la ecuación de crecimiento de von Bertalanffy: L_∞ = 140 cm; K=0.19 (anual); tz=0.54 años. La tasa instantánea de mortalidad total fué estimada como Z=2.16 y la de mortalidad natural M=0.4. El análisis de población virtual basado en la estructura por longitudes fué aplicado para obtener estimadores de mortalidad por pesca por clase de longitud, el cual fué más intenso en peces cuya talla varió entre 60 cm y 80 cm; no obstante, que en el puerto de Campeche la talla de primera captura impone altos niveles de mortalidad por pesca a tallas pequeñas, sugiriéndose incrementar la tallas de primera captura. El análisis con el modelo de Thompson y Bell sugiere que el stock se está explotando en niveles cercanos al de máxima producción biológica. Estos resultados son discutidos dentro del marco de referencia del comportamiento ecológico, identidad de stock y accesibilidad. la hipótesis que emerge indica la probable existencia de un stock independiente en el Banco de Campeche que tiene un cierto grado de mezcla con otros stocks de la región Norte del Golfo de México.

Palabras clave: Scomberomorus cavalla, Golfo de México, dinámica de poblaciones, identidad de stock.

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INTRODUCTION

The king mackerel, *Scomberomorus cavalla*, is an important migratory fish resource exploited along the coast of the Gulf of Mexico. In Mexican waters, annual yields averaged 3203.7 mt, but decreased from 5893.6 mt in 1982 to 2130.5 mt in 1990. The Campeche Bank, on the Southern Gulf, contributes an average 35.8% of this producton.

The Campeche Bank region comprises the north and western continental shelf of the Peninsula of Yucatan.The fishery occurs in shallow waters using mainly gillnets with a mesh of 3.25 inches in Campeche (pers. comm. Ramos-Miranda, J., Programa EPOMEX, México), and 4.0 inches in Yucatan and Quintana Roo states. In general, highest yields were obtained during 1982-1983 (1500 mt) showing an apparent stable tendency around 1000 mt (Fig. 1) in the recent years. Almost 90% of the annual king mackerel yields in the Campeche Bank are caught from October to March, when a south - north migration occurs close to the coast.

Some authors, based on tagging experiments, suggest the existence of only one stock in the whole Gulf of Mexico (NAKAMURA, 1987), while others suggest the existence of at least two stocks, the northern stock, from Texas to Florida, and the southern stock, from Yucatan to Tamaulipas; Texas waters being a transition area where both stocks could have a certain degree of mixing (VASCONCELOS, 1987; SÁNCHEZ-GONZÁLEZ and SCHULTZ-RUÍZ, in press).

In order to contribute to the knowledge of this resource, we have developed a population dynamics study for *S. cavalla* inhabiting the Campeche Bank.

MATERIALS AND METHODS

Information consists of length-frequency data collected from commercial landings of the artisanal fleets. Three sample sites were selected along the coast of the Peninsula of Yucatan, the Campeche City, on the southern Gulf, Progreso Port, on the northwestern coast and Holbox Island, on the northeastern coast (Fig. 1). These locations are also the most important ports where regional commercial catches are landed.

Length frequency data, as fork length, were taken from different fishing seasons and months; in Campeche, during 1988-89; from Progreso, during

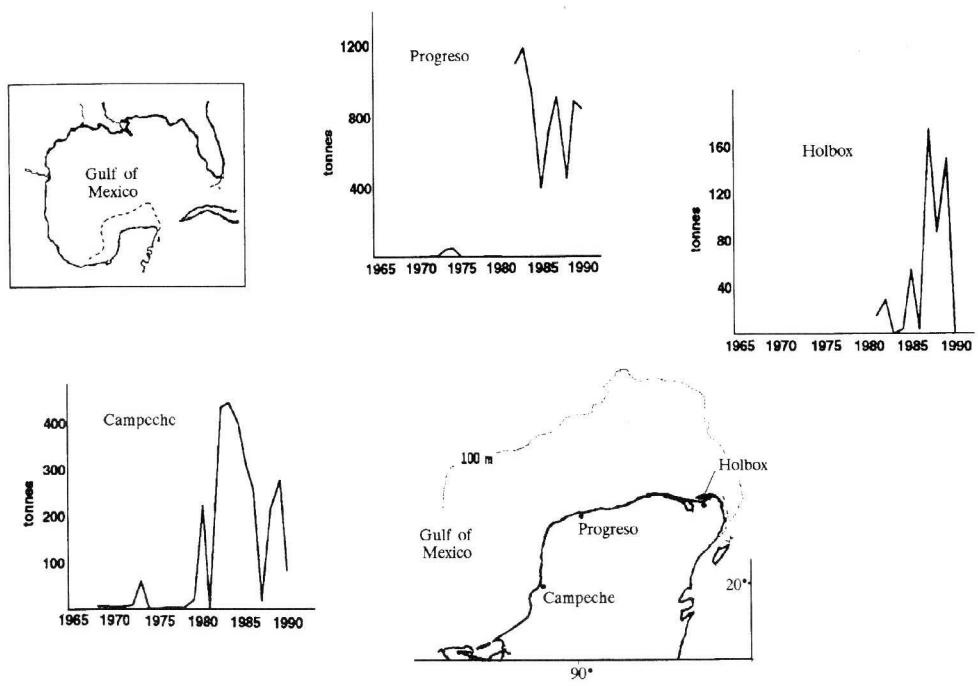

FIG. – 1. Catch tendencies of the king mackerel (*Scomberomorus cavalla*), from the three main landing sites of the Campeche Bank, Southern Gulf of Mexico.

TABLE 1. – Available samples of the length-frequency distributions per year, month, and location. C=Campeche, P=Progreso and H=Holbox.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983											H	P,H
1984	H	P,H	P,H	P,H				P		P,H		
1985	P	P,H	P,H	P						P		
1986	P		P	P					P			
1988								C			C	
1989	C	C	C									

the period of 1983 to 1986, and for Holbox, during 1983-84. The number of months sampled each year varied depending on the activity of the artisanal fleet and the seasonality of the resource (Table 1). Catch records were taken from SÁNCHEZ-GONZÁLEZ and SCHULTZ-RUÍZ (in press).

Analysis of length frequency distributions were carried out using the FiSAT package (GAYANILO et al., 1993). Growth parameters of the von Bertalanffy equation were computed from both ELEFAN I (Pauly, 1987) and SLCA (SHEPHERD, 1987), assuming one stock of *S. cavalla* for the Campeche Bank.

Because regional fleets could present different behavior due to resource seasonality and other local target species, mortality studies were developed assuming information comes from different fleets. Some initial estimates of total mortality (Z) were obtained weighting each sample by the amount of catch. Natural mortality was estimated using Pauly's equation (PAULY, 1980) and the estimated growth parameters as above, with a mean annual temperature of 24(C, which was assumed as constant. Fishing mortality with length was estimated for each fleet through the length-structured VPA as suggested by PAULY (1984). Catch probabilities by size were estimated from gillnet selection according HOLT (1963) and PAULY (1984).

In order to obtain a diagnosis of the state of exploitation for *S. cavalla* per each region of the Campeche Bank, the THOMPSON and BELL (1934) method was used to define the fishing mortality required for the maximum yield level and its comparison with yields for the years analyzed.

TABLE 2. – Parameters of the von Bertalanffy growth equation for the king mackerel mackerel *Scomberomorus cavalla*. L_∞ in cm fork length; y=year; ϕ' growth index of performance from PAULY and MUNRO (1984); M=males; F=females; B=both sexes combined.

L_∞	K y^{-1}	t_0 y	ϕ'	sex	site	Reference
84	0.350	2.5	3.39	M	Florida	BEAUMARIAGE (1973)
114	0.210	2.4	3.44	F		
124	0.210	2.40	3.51	F		
90	0.350	2.50	3.46	M		
148	0.115	2.36	3.40	B	Florida and Texas	MANOOCH *et al.* (1987)
142	0.136	1.98	3.44	F		
111	0.208	1.48	3.41	M		
130	0.172	1.55	3.46	F		
104	0.258	1.12	3.45	M		
107	0.290	0.97	3.52	F	Florida	JOHNSON *et al.* (1983)
97	0.280	1.17	3.42	M		
123	0.230	0.26	3.54	B	NW Yucatan	AGUILAR *et al.* (1981)
138	0.240	0.24	3.66	B		
117	0.230	0.27	3.50	B	N Yucatan	
123	0.230	0.26	3.54	B		
134	0.240	0.25	3.63	B		
140	0.190	0.54	3.57	B	Campeche Bank	this contribution
132	0.164	2.00	3.45	F	Brazil	XIMENES *et al.* (1978)
113	0.229	1.50	3.47	M		
137	0.150	0.13	3.45	F		NOMURA and RODRIGUES 1967)
116	0.180	0.22	3.38	M		

RESULTS

Growth

In order to facilitate the growth analysis based on length frequency distributions it was decided to compute L_∞ as a first step, to fix this value, and then to estimate the growth coefficient K. For this, the length distributions from Campeche were excluded because the largest fish in the sample was 76 cm, while in the others it was 118 cm. From this analysis L∞ was estimated at 140 cm using the Powell-Wetherall plot (POWELL, 1979; WETHERALL, 1984). The K parameter was obtained using this L∞ value and the length frequency samples from the three ports. The SLCA method did not show a clear convergence for K, but considering its order of magnitude from other authors (Table 2) it was estimated as K=0.2 year^{-1}. The ELEFAN I method was also applied considering seasonal oscillations of growth according to HOENIG and CHOUDARY-HANUMARA (1982). The value for the intensity of the oscillation was fixed at C=0.3 (see LONGHURST and PAULY, 1987) because it was considered an average difference in temperature along the year of 3°C (YÁÑEZ-ARANCIBIA and SÁNCHEZ-GIL, 1988). The "Winter Point" parameter used to estimate the fraction of the year where growth is slowest, was initially fixed at WP=0.2 because this value corresponds to the coldest time of the year in the Campeche Bank. With L∞, C and WP fixed, the growth coefficient was computed as K=0.21 year-1. A more accurate estimation of WP and K parameters was obtained using the automatic search routine in FiSAT. Final estimates were as follows: L∞=140 cm, K=0.19 year-1, C=0.3 and WP=0.24 (Rn=0.388). The tz value, corresponding to the time of the year on which growth curve starts, was estimated as tz=0.54 year.

Mortality

Natural mortality M was estimated with the above growth parameters computed and Pauly's equation (PAULY, 1980) as M=0.4. Total mortality Z was estimated through the catch curve was Z=2.16, but partial computations for each fleet suggest differences in fishing mortality between them (Campeche, ZC=1.78; Progreso, ZP=2.31; and Holbox, ZH=1.67).

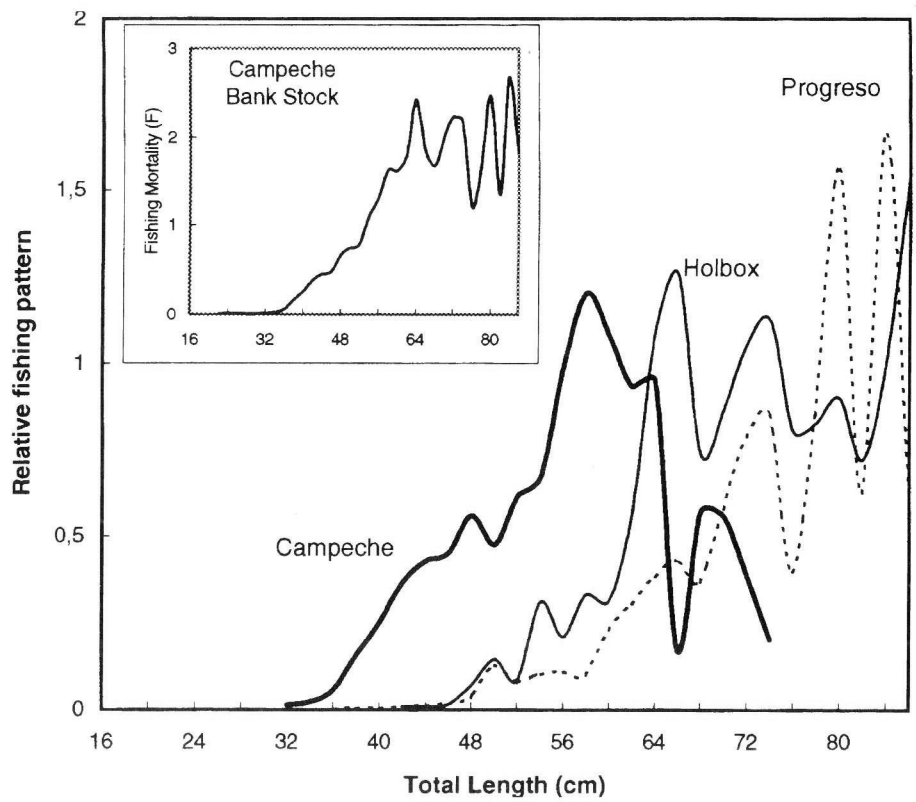

FIG. 2. – Fishing mortality at length for the king mackerel, *Scomberomorus cavalla*, stock; and relative fishing patterns for three main landing sites of the Campeche Bank, Southern Gulf of Mexico.

The length-structured VPA was applied for the whole stock using catch structured data from the three ports. As a general pattern, length dependent fishing mortality shows increments with fish size (Fig. 2), ranging between F=0.158 for fishes of 38 cm, to F=1.8 (as an average) for fishes up to 60 cm. For each individual port, the exploitation pattern was obtained in terms of their particular contribution to the total fishing mortality applied to the whole stock. For Campeche, higher F values were present in the range of 56 cm to 70 cm; while for Progreso and Holbox, higher values ocurred between 68 cm and 86 cm. Values of fishing mortality-at-length for the king mackerel stock, as well as the relative contribution per fleet/port, are given in Table 3.

Diagnosis

The THOMPSON and BELL (1934) method was applied by using selection probabilities for both sides of the distribution, as well as the fishing mortality at length estimated per fleet. For Campeche, the analysis suggests higher yields could be obtained with 60% of the current fishing mortality, while for Progreso and Holbox, the analysis indicates fleets are operating under the maximum yield level. Obviously, the current state corresponds to the period of time studied.

TABLE 3. – Fishing mortality-at-length and steady state population estimated through the length structured VPA as implemented in FiSAT (GAYANILO *et al.*, 1992). Length means mid length class. Maximum observed length, Lmax=116 cm. F for group 86+ was F=1.832 (=FT, fishing mortality of the largest length class). Relative fishing pattern means the relative contribution of each fleet - location, to the stock fishing mortality, F.

Length (cm)	Fishing mortality	Relative fishing pattern			Catch	Population (numbers)	Steady-State Biomass
		Campeche	Progreso	Holbox	(tonnes)	(000's)	(tonnes)
16					0.01	2135	7.44
18	0.0014			0.00	2063	10.09	
20					0.06	1992	13.25
22	0.0045	0.0045		0.21	1992	16.93	
24	0.0122			0.30	1852	21.14	
26	0.0141			0.21	1783	25.92	
28	0.0080			0.15	1717	31.27	
30	0.0049	0.0049		0.49	1652	37.18	
32	0.0133	0.0133		0.96	1588	43.62	
34	0.0221	0.0221		2.91	1523	50.50	
36	0.0574	0.0567	0.0007		9.11	1455	57.49
38	0.1582	0.1554	0.0028		16.41	1374	64.19
40	0.2552	0.2526	0.0026		26.80	1283	70.24
42	0.3809	0.3671	0.0050	0.0088	33.83	1181	75.45
44	0.4476	0.4287	0.0101	0.0088	38.44	1077	79.99
46	0.4796	0.4503	0.0146	0.0146	55.06	977	83.19
48	0.6604	0.5601	0.0326	0.0677	62.87	866	84.62
50	0.7411	0.4748	0.1227	0.1436	66.15	759	84.87
52	0.7774	0.6159	0.0777	0.0839	90.21	660	82.82
54	1.0862	0.6745	0.0997	0.3120	101.80	551	77.65
56	1.3066	0.9907	0.1061	0.2098	114.42	446	69.81
58	1.6325	1.2036	0.0959	0.3329	99.11	344	60.93
60	1.6187	1.0779	0.2261	0.3147	94.12	265	52.13
62	1.7942	0.9332	0.3026	0.5584	102.42	197	41.87
64	2.4257	0.9505	0.3816	1.0937	61.96	134	32.97
66	1.8589	0.1711	0.4268	1.2610	46.09	97	27.08
68	1.6781	0.5703	0.3657	0.7421	44.50	72	21.78
70	2.0046	0.5590	0.5775	0.8681	38.00	50	16.58
72	2.2332	0.3894	0.7886	1.0552	27.71	33	12.23
74	2.1844	0.2020	0.8570	1.1255	12.16	22	9.63
76	1.2033		0.3950	0.8083	14.00	17	7.83
78	1.6819		0.8518	0.8301	15.08	12	5.59
80	2.4695		1.5671	0.9024	6.08	7	3.98
82	1.3494		0.6252	0.7242	8.71	5	2.70
84	2.6736		1.6694	1.0042	4.67	2	1.54
86+	1.8320		0.6556	1.5494	4.99	1	2.77

DISCUSSION

Growth estimates appear to be adequate. Figure 3 shows the distribution of the ϕ' value (PAULY and MUNRO, 1984) which represents a growth pattern index which is independent of the individual variations of L_∞ and K. The ϕ' value corresponding to growth parameters estimated in this contribution are just at the middle of the distribution, of K.

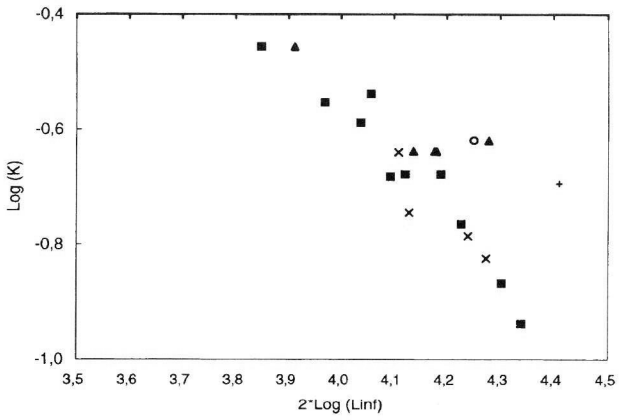

FIG. 3. – .Distribution of ϕ' values for the king mackerel, *Scomberomorus cavalla*. ■ = Northern Gulf of Mexico; ▲ = Northern coast of the Yucatan Peninsula; ✖ = Brazil. ✚ = Western Gulf of Mexico; and ○= estimated value from this contribution.

Fishing intensity for the time period analyzed suggests exploitation is carried around the maximum biological production level (MBPL), except for Campeche, where a decrement in fishing intensity on small fish could be recommended, if the objective of the exploitation is to maintain the fishery on its MBPL. A yield-per-recruit (Y/R) analysis (BEVERTON and HOLT, 1957) indicates that the length at first catch (Lc) from Campeche is around 50% of that which could be recommended to produce the maximum Y/R, while for other ports the current Lc is close to this level (Table 4). This result suggests that an increase of the length-at-first catch in Campeche could be useful to reduce the fishing mortality on small fish. Despite these results it must be considered that this is an artisanal fishery where fishermen operate in shallow waters, close to the coast, and have incomplete access to the whole area where fish are distributed.

Concerning stock identification it is possible to formulate an hypothesis on the existence of one well defined stock inhabiting the Campeche Bank, which has some degree of exchange with other stocks.

GRIMES and FINUCANE (1991) studied the influence of the Mississippi River discharge plume and its relationship with recruitment. They mentioned that this phenomenon promotes hydrodynamics convergence where the ichtyoplankton and small fishes (i.e. engraulids) are concentrated. This concentration of anchovies represent an important source of food for young piscivores like king mackerel *S. cavalla*.

TABLE 4. – Main estimators obtained from the yield per recruit analysis using the BEVERTON and HOLT (1957) model. E* = exploitation rate at maximum of biological production; Y/R=yield per recruit; B/R = biomass per recruit; $E_{0.1}$ = exploitation rate at the marginal yield level (from GULLAND, 1968; and GULLAND and BOEREMA, 1971); L_{50} = length-at-first catch

Parameters	Stock	Campeche	Yucatan	Holbox
E* at maximum Y/R	0.550	0.600	0.650	0.600
E* at 0.50 of B/R	0.391	0.364	0.361	0.375
$E_{0.1}$	0.483	0.513	0.598	0.534
current E max	0.604	0.557	0.684	0.675
current $E_{0.1}$	0.603	0.553	0.651	0.666
current L_{50} / L_∞	0.430	0.450	0.430	0.450
maximum L_{50} / L_∞	0.370	0.260	0.480	0.450

On the other hand, FABLE *et al.* (1987), based on tagging experiments in the same region (Grand Isle), suggest that the northwest Gulf region maintains a resident population of larger king mackerels year round, which may move into Mexico to some extent, and that this group mixes to some degree in the warmer months with smaller migrants from south Florida and Mexico.

GRIMES *et al.* (1990) show that the highest abundances of larval ((10 mm) king mackerel are on the north and northwest Gulf of Mexico, while large juveniles (> 50 mm SL) are abundant on the north and southwest Gulf of Mexico. These observations suggest at least three reproductive areas.

On the southern Gulf of Mexico similar mechanisms could be occurring. The delta conformed by the Usumacinta and Grijalva Rivers, including the Lagoon of Terminos system produce an analogous ecosystem than in the delta of the Mississippi River.

From tagging experiments (VASCONCELOS, 1987) it is clear that from this region fishes move towards the Peninsula of Yucatan, or to the northwest coast; and such as it was mentioned above, the biological and hydrodynamics characteristics of the discharge plume has a potentially important effect as a source of food of predatory species like the king mackerel. The most abundant sizes in this region were small fishes, as was shown by the catch structure of Campeche. Dominant large fishes on the north and

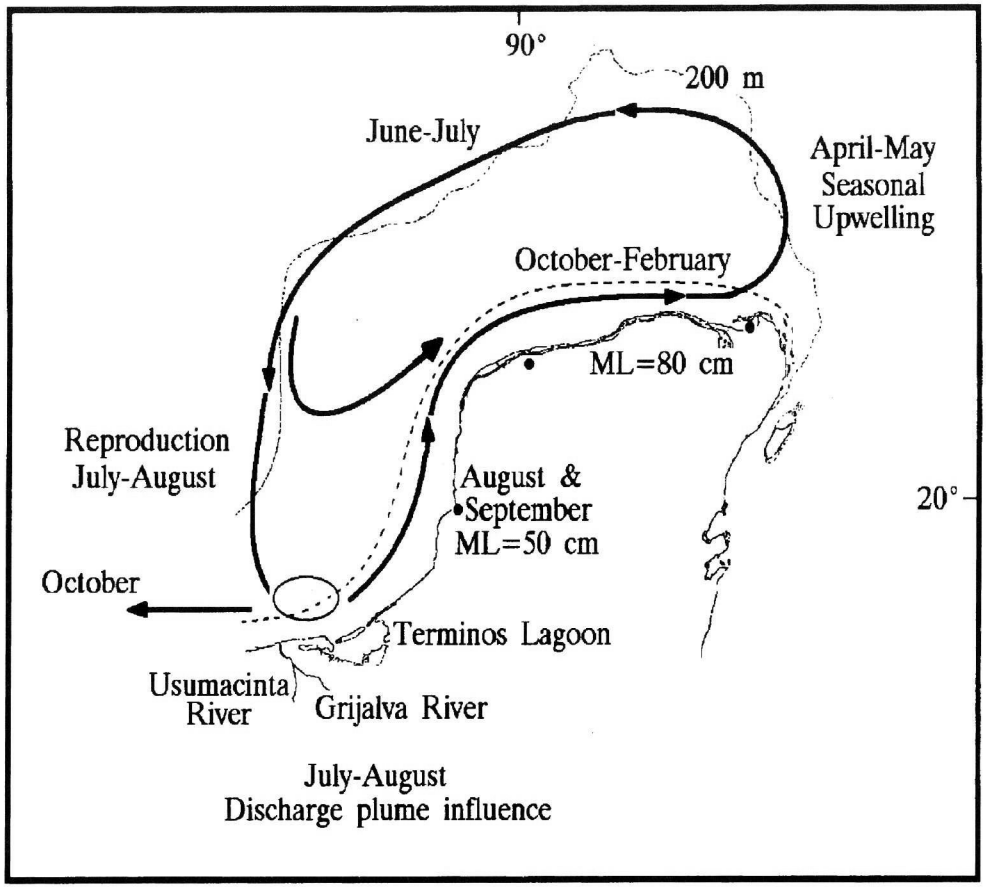

FIG. 4. – Hypothesis proposed for the dynamics of the southern king mackerel (*Scomberomorus cavalla*) stock on the Campeche Bank. Circle represents the area of influence of the discharge plume. For full explanation see text.

northeastern coast of the Peninsula of Yucatan could also be interpreted as similar to the resident large fish population on the northwestern Gulf of Mexico mentioned above. Moreover, OLVERA *et al.* (1991) high abundances of larvae of *S. cavalla* on the shelf, just in front of the Lagoon of Terminos, which coincides with observations of GRIMES *et al.* (1990) for the same region.

The role of the Lagoon of Terminos on the productivity and production of the adjacent continental shelf is well known (YÁÑEZ-ARANCIBIA and DAY, 1988), however from a macro scale point of view, it could be formulated an hypothesis involving large scale movements of *S. cavalla*. The king mackerel is abundant during August - September on the adjacent shelf to the Lagoon of Terminos, just after the rainy season, where discharges are higher. This could be associated with a higher availability of food. During October and November the "nortes" season (cold winds from the north) probably induce fishes to move in both northeast and northwest directions (Fig. 4). Large fishes are concentrated in shallow waters on the north and northeast coast of the Peninsula of Yucatan. During this time until March, higher yields are obtained by fishermen. In April-May a seasonal upwelling occurs on the eastern border of the continental shelf of the Peninsula of Yucatan (MERINO, 1992). This has the same effect concerning an increasing availability of food for piscivores fishes on the shelf deep waters. However, it also produces fish movements because of changes in temperature. This probably promotes fish to move westward to the coast (at the end of the fishing season) and some probably go back to the southern Gulf, or remain in deeper waters until environmental conditions change. During this time reproduction takes place; according to OLVERA *et al.* (1991) the highest intensity of reproduction occurs during July and August, on the border of the continental shelf in front on the Lagoon of Terminos region.

CONCLUSIONS

The population dynamics of *S. cavalla* on the Campeche Bank was studied. This stock supports an artisanal fishery whose fleets operate on different schemes in different locations. Three areas/fleets were considered. Campeche, on the Southern Gulf of Mexico, and Progreso and Holbox, on the Northern and Northeastern coasts of the Peninsula of Yucatan, respectively. In Campeche small fish dominate ound hthe catch, the largest fish being 76 cm. In other localities large fishes were well represented in catches, the largest fish were close to 120 cm. Length dependent fishing mortality patterns show higher values for larger fishes, however, it appears that, while in Campeche the Maximum Biological Production Level was slightly over-passed, other areas are being exploited under this level. It was also considered in this diagnosis that the artisanal fleet probably have incomplete access to the resource because of both limited autonomy and fish behavior.

On the other hand, from the management point of view, it is important to be aware of the stock identification problem. It is proposed that the Campeche Bank contains one regional stock whose dynamics is governed by the physical and biological processes associated with the freshwaters occurring in front of the Lagoon of Terminos and adjacent deltas, as well as by the seasonal upwelling on the northeastern border of the continental shelf, on the north of the Peninsula of Yucatan.

The proposed hypothesis is analogous to that mentioned by some authors for the Mississippi delta and adjacent region, which could lead a third stock on the western Central Gulf of Mexico. These stocks, even if they have a degree of exchange, could probably be managed separately.

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