Decadal study of the reproductive stock of *Litopenaeus stylirostris* in the southern gulf of California.

Sepúlveda[1], A. and Soto[2], L. A.

[1] Instituto Nacional de la Pesca. Sagarpa. Mexico. e-mail: adsepulveda@correo.unam.mx
[2] Instituto de Ciencias Del Mar y Limnologia. UNAM. Mexico. e-mail: lasg@mar.icmyl.unam.mx

Abstract

In the southern Gulf of California, the littoral area of Topolobampo represents an overlapping zone in the distributional pattern for three penaeid shrimp species, the blue shrimp (*Litopenaeus stylirostris* (Stimpson 1871), the white shrimp *Litopenaeus vannamei* (Bonne, 1931), and the brown shrimp *Farfantepenaeus californiensis* (Holmes,1900). All these species are commercially harvested since 1954 but due to their depth and spatial excluding patterns, fishing exploitation upon these stocks have required the application of different management regulations. The former species ranks third in terms of volume in the fishery, it is more subtropical in its distribution, estuarine-dependent, and it normally settles along the inner shelf on the continental side of the Gulf (< 40 m). The present contribution addresses the study of its spawning behavior, size structure of the reproductive stock, recruitment, and fishing yield, during a 10-yr sampling survey conducted in the closed fishing season from 1974-1983.

Key Words: penaeid shrimp, spawning, recruitment,

Introduction

In the southeastern coast of the Gulf of California in the region of Topolobampo, Mexico there are highly productive shrimping grounds (annual catch of 700 to 1,000 Tons) in which a fleet of more than 60 vessels operates at least 7 months during a year. Since 1973, a five-month closed fishing season was implemented to protect the reproductive stocks. This fishery is essentially supported by three penaeid shrimps, namely, *Litopenaeus vannamei*, *Farfantepenaeus californiensis*, and the blue shrimp *Litopenaeus stylirostris*. The latter species ranks third in terms of volume in the fishery and, its commercial capture takes place within the boundaries of the inner shelf (7-40 m). In hauls made in this region at depths between 40 to 90 m, there is a predominance of the brown shrimp *Farfantepenaeus californiensis* which contributes nearly 70% of the total catch , whilst that of *L. vannamei* is of 15 %. The Topolobampo fishing fleet operates over and area of approximately 3, 047 Km2 (fig 1), extending from Agiabampo Bay in the north (26° 25´ N and 109° 30´ W) to El Tambor in its southern end (24° 44´ N and 108° 02´ W). This area encompasses several semi-enclosed embayment that receive a significant river discharge, rich in nutrients and organic materials during the rainy season (July - November), presumably the flux of these elements greatly enhance the habitat conditions of the adjacent coastal environment (Figure 1) This favors recruitment of the early life shrimp stages, and the growth of juvenile forms (Edwards, 1978).

Our current knowledge on the general biology of the blue shrimp stock distributed in the Gulf of California has benefited from the prior contributions of Cárdenas (1950), Chapa (1956), and Lluch (1976). Pedraza (1976) described the blue shrimp's postlarval life cycle, and Castro and Sánchez (1976) and later Sepúlveda (1991) have offered further information on population parameters such as growth and mortality rates.

Given the fishing effort supported by the blue shrimp and our limited knowledge on its reproductive behavior, this study is centered on the identification of the main spawning periods, its distribution pattern, size composition, recruitment, and yield per depth stratum during the closed fishing season in the period 1974-1983.

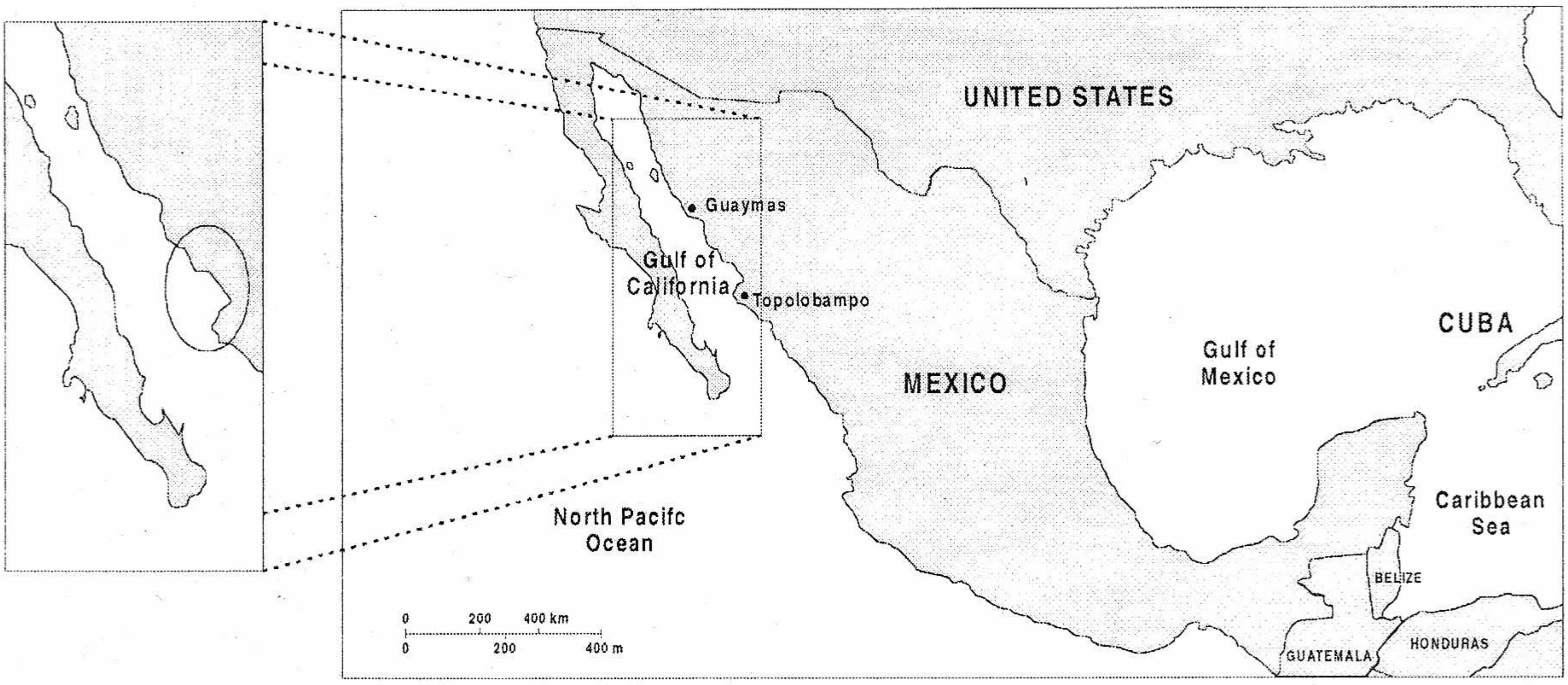

Figure 1: Topolobampo Bay (Southern Gulf of California), Mexico.

Material and Methods

A stratified monthly sampling was conducted at two depth strata, from 4 to 20 m (I), and from 20 to 40 m (II), respectively during the period of 1974-1983. The sampling was on board of a commercial shrimp trawler, during the closed fishing season that was enforced in the months of May to September along the southern Gulf of California. An otter-trawl of 12-m with a mesh-size of 3.5 cm was employed. The results of 440 trawls catches were analyzed; each haul had an average duration of 45-60 minutes. The average shrimp catch per haul was 20 kg/hr. A subsample of 50 shrimp individuals or ca. 5 kg was obtained from each haul as a significant sample size, based on 95 % confidence value and a 5 % marginal error. In cases in which the volume was less than 5 kg, the entire catch was recorded.

Size composition and sex ratio were obtained monthly Yield per depth stratum was estimated as CPUE/hr (catch per unit of effort/hour) these values were later transformed into size-class/weight in kg/hr. Spawning conditions and its frequency were regularly recorded following Cárdenas' (1950) and Chapa's (1954) sexual maturity gonads coloration code for females; special attention was given to the occurrence of spawn females (stage 4) at stratum I (4-20 m) and II (20-40). The spawning cycle was reconstructed using the monthly percentage of spawn females throughout one decade.

Several programming routines were applied in order to process the raw data and obtain the population parameters employed in the present study. Further details on this subject can be found in Sepúlveda (1991).

Results

Seasonal and depth distribution of spawning females.

Gravid females of *L. stylirostris* were firstly recorded in the area of study in early May. Their number tends to increase towards July and September. This species exhibits a protracted reproductive activity over a period of five months. The onset of this process occurs in May attaining maximum strength in July, and declining in September (fig. 2). The analysis of the spawning cycle of the blue shrimp throughout the period 1974-1983 reveals a high inter-annual variability. Its reproductive cycle conforms to a bimodal pattern with significant spawning peaks in the summer and fall. The first one is more stable during a decade, though the precise onset and end of the cycle are more uncertain data.

Spawning females are distributed along the two selected depth strata of the survey area. The number is significantly higher ($p > 0.20$) in the stratum II (20 to 40 m); in contrast with the low percentage recorded in the stratum I (10-20 m). However, the frequency of occurrence of gravid females in shallow depths though significant ($p < 0.20$), does not indicate an aggregate behavior by the species. These depth differences in the distribution of the reproductive stock were not statistically ($p< 0.20$) significant as to infer the existence of two different shrimp stock occupying the same geographical area. A point of major concern for the fishing management of the blue shrimp, should be the diminishing trend observed in the percentage of spawners at the onset phase of the reproductive cycle in the period 1978-1980; such a trend becomes more evident in the depth stratum I, where presumably no recruitment of juvenile stages took place. Shifts in the aggregate behavior of *L. stylirostris* during the process of sexual maturation and spawning along the two depths strata are clearly observed in the period 1981-1983 (fig 2); with the exception of a moderate spawning peak recorded in May of 1981, gravid females were entirely absent in shallow waters (<20 m).

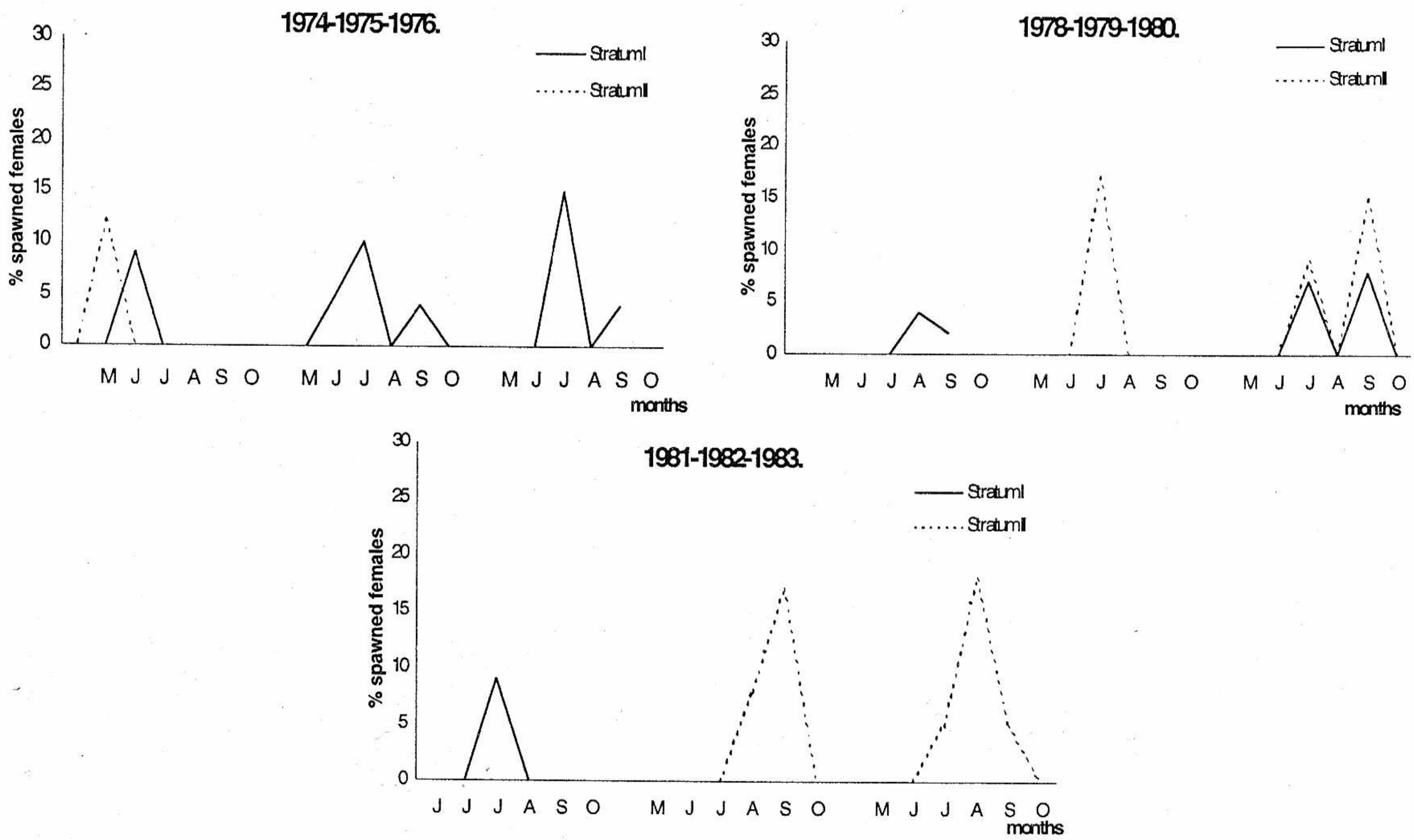

Fig. 2: Profile of spawning per stratum during closing season

Population sizesStructure and yield per recruit

In addition to the percentage estimation of gravid females during the closed fishing season, the sequential analysis of modal peaks here applied contributed to the identification of the cohorts of juvenile individuals that are being recruited into the parental stock. At the onset of the closed season (May-June), two significant modal peaks standout: 180 and 210 mm of Total Lenght (T_L). These values are frequently recorded along the depth stratum I (< 20 m) and correspond to fully matured individuals that have already completed their reproductive cycle in the previous season; as indicated earlier, regardless of their frequency of occurrence the percentage of gravid females at that depth was rather low (< 10 %).(Table I).

The rapid growth of 1.03 mm/day (Sepúlveda, 1999) and the migratory behavior of *L. stylirostris* cause that immature shrimp stages enter the fishing grounds occupied by the parental stock in two recruitment pulses: one in the period May-June, and another in July-September (fig. 3). The first pulse is clearly displayed at the depth stratum I, causing a modal peak displacement from 199 mm to 163 mm of T_L. The second recruitment pulse is better recognized at the depth stratum II; here, a sensible reduction in the modal values occurs from 193 to 177 mm of T_L. Hence, it is plausible to estimate that the size of first entrance to the parental stock varies from 163 to 177 mm of T_L. This size-class corresponds to an approximate age of 4 to 5 months. Similar to the inter-annual variability already described for the reproductive cycle, the recruitment process exhibits seasonal fluctuations than can be attributed to the strength of monthly pulses recorded throughout the summer (July-September) (Table II).

Table I:Total length (TL mm) variability in stratum I (10-20 m) of *L stylirostris* during the closed season of 1974 to 1983.

YEAR	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
1974	194	193	178	138	152	160
1975	206	204	190	170	168	-
1976	200	200	186	169	158	-
1977	-	200	183	185	147	-
1978	-	188	-	174	-	-
1979	-	-	173	165	-	-
1980	-	209	165	169	170	-
1981	208	199	164	162	181	-
1982	170	-	-	181	160	-
1983	-	-	161	177	167	-
T_L (Avg)	196	199	173	169	163	160

Table II: Total length (TL mm) variability in stratum II (21-40 m) of *L stylirostris* during the closed season of 1974 to 1983.

YEAR	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
1974	177	185	181	-	162	-
1975	-	-	-	-	198	-
1978	-	-	-	186	-	-
1979	-	-	195	165	-	-
1980	-	-	201	184	204	-
1981	-	-	-	166	-	-
1982	-	-	-	181	185	-
1983	-	-	184	190	174	-
T_L (Avg)	182	186	193	177	181	

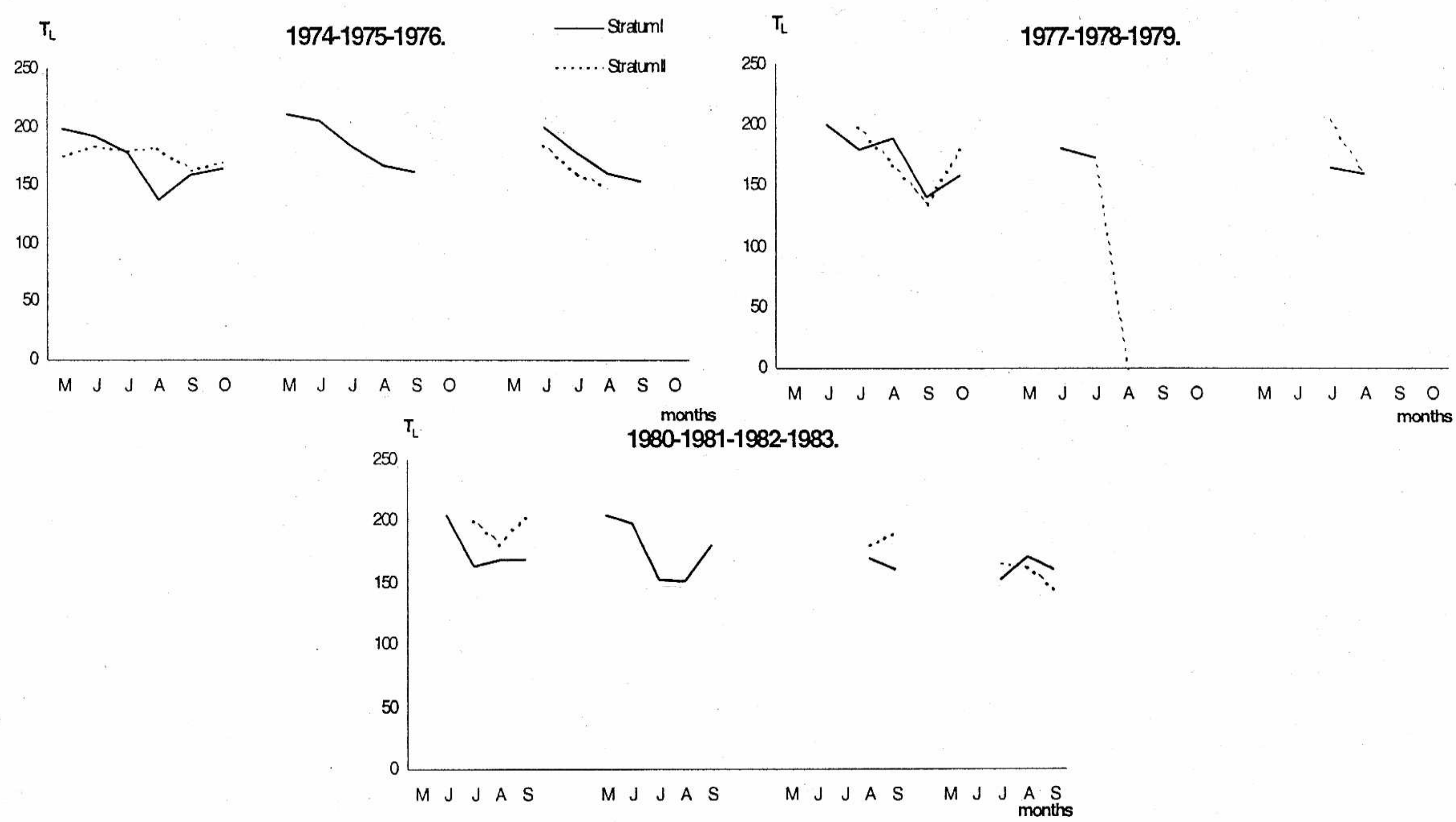

Fig. 3: Profile of variation in modal lengths, closing season

The monthly yield values recorded for the blue shrimps ranged from 10 to 20 Kg/hr (fig. 4). CPUE(Catch per unit of effort), values remained below 10 Kg/hr during the first months of the closed fishing season. Critical years in terms of the size of the reproductive stock of the blue shrimp were from 1975 to 1978; in this period, yield per recruit plummeted down to < 10 Kg/hr. In general, an exponential increase in yield occurs in June, becoming asymptotic towards September, reaching CPUE (Catch per unit of effort), values above 30 to 40 Kg/hr.

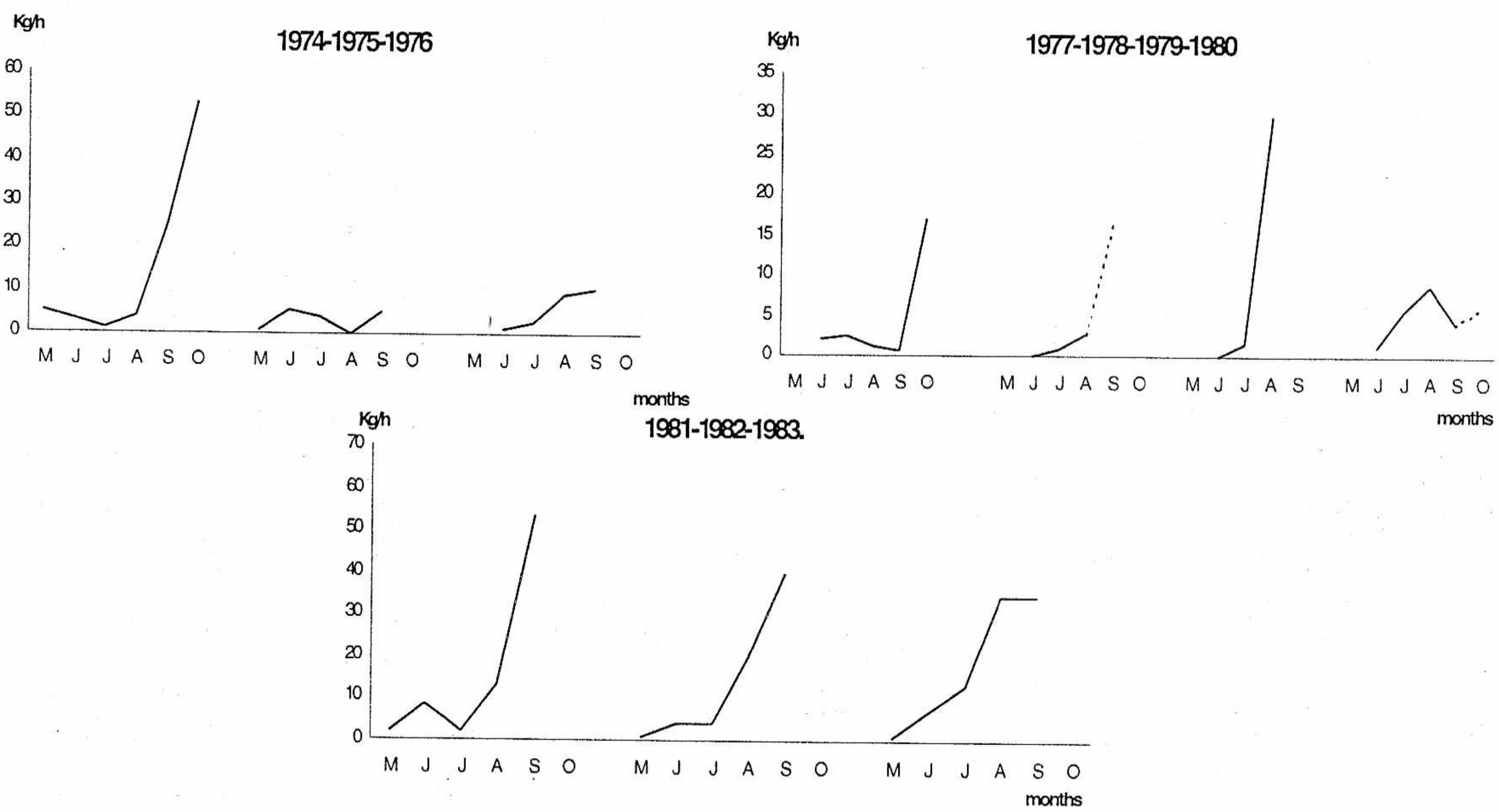

Fig. 4: Profile of yield during closing season 1974-1983.

Population sex ratio

The reproductive population of *L. stylirostris* occurred along both depth strata , with no apparent sex excluding behavior. Nonetheless, there is a significant female predominance over the males throughout the analyzed period. The female: male ratio varied from 1.5: 1 to 2: 1. Thus the ratio is much greater at the onset of the reproductive cycle (May-June), but it tends to reach equilibrium towards the mid-term of the closed season. Interestingly enough, these fluctuations in the sex ratio may indicate that initially, the reproductive stock of the blue shrimp, adopts an aggregate strategy that precedes the months of intense reproduction (August-September), during which the sex ratio is nearly 1:1; afterwards, the population begins to show signs of overdispersion. These conditions may reflect the progression of reproduction phenomena such as reproductive recruitment, coupling, sexual maturity, and subsequent spawning. Presumably, in shrimp species with open-thelycum, like *L. stylirostris and L. vannamei*, coupling and spawning are rather brief events that somewhat explains the dispersion behavior adopted by these the species (fig. 5).

Discussion

The implementation of a closed season in a fishery constitutes one of the key management and conservation measures to promote yield per recruitment, MSY(Maximum Sustainable Yield), and economic efficiency. It is widely applied in tropical and subtropical shrimp fisheries with the purpose of preventing exploitation of undersized shrimp with low commercial value, and to avoid growth overfishing (Ye, 1998). Therefore, this management regulation can be very effective in the decision to select the size of the first shrimp harvest, particularly in situations in which there is strong seasonally changes in the recruitment process, as is the case of the southern Gulf of California. On this subject, recently Rodríguez and Chávez (1996) have stated that the Pacific shrimp stocks would be better protected by reducing fishing effort levels, instead of relying on questionable dates for opening and closing fishing operations.

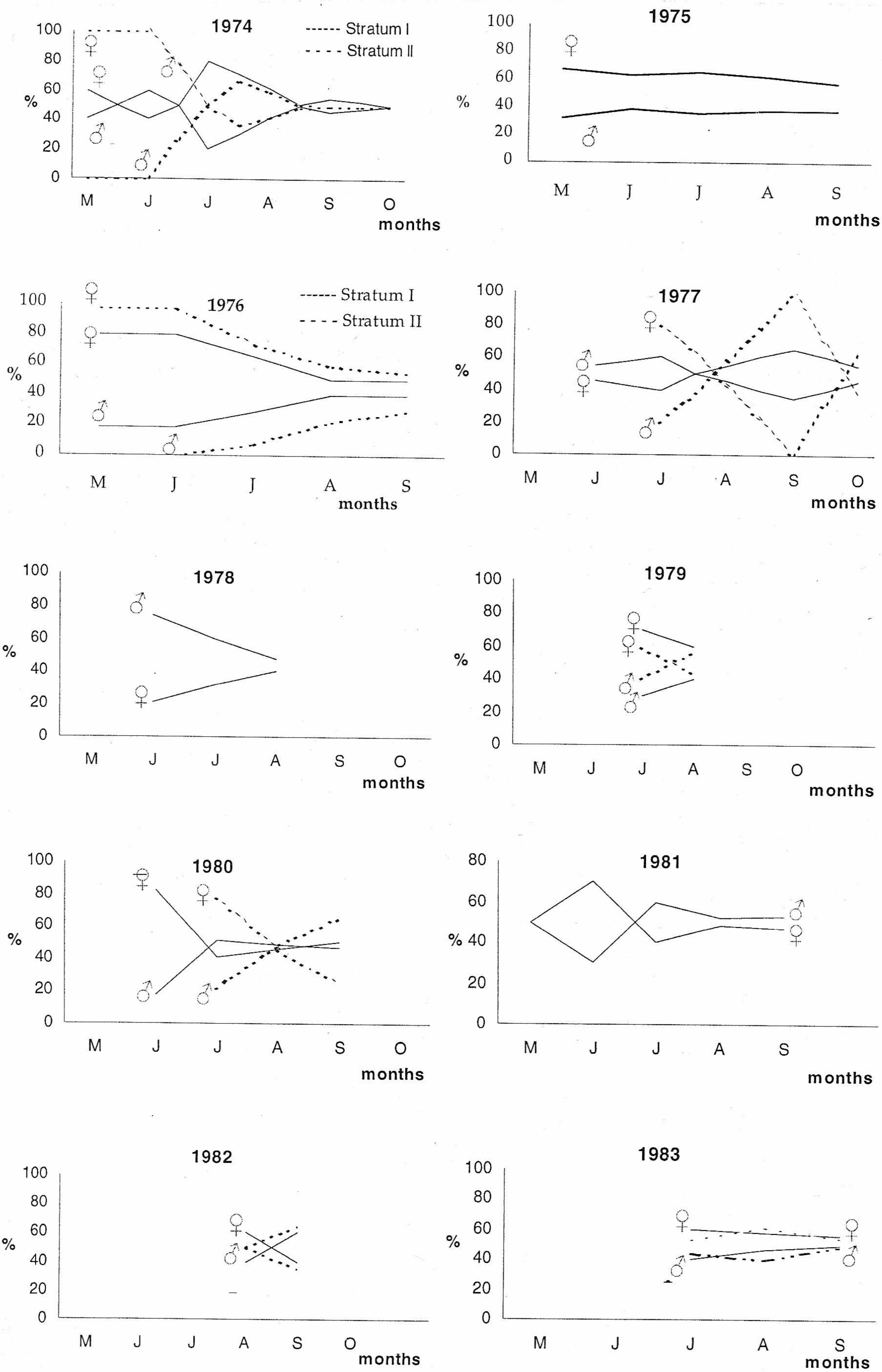

Fig.5: Proportion of sexes, closing season 1974-1983.

This pronouncement was based on a bio-economic simulation model proposed by Willman and García (1986). According to the these authors, by reducing fishing effort there would be an increase in the cost/benefit of the fishery. However, they recommend caution on the possible implementation of such a measure, since there is a need to further validate shrimp data banks, and to evaluate the artisanal fishery in inshore waters of the Pacific coast.

Nonetheless, the application of a closed fishing season and its possible repercussions on a sustainable fishery necessarily requires that a follow up analysis be applied over extended periods, to avoid masking effects of natural population trends. It is of crucial importance then, to refine the growth rate of individuals and the natural and fishing mortality of the stock, prior to the opening of the closure seasons. Similarly, it remains questionable, if by delaying the closure fishing, the shrimp stock would attain a greater growth, and consequently a major market value that might surpass the net loss in biomass caused by natural mortality.

Presently, most world shrimp fisheries have already reached MSY(Maximum Sustainable Yield), levels, though fishing effort continues increasing, giving raise to social and economic concerns. In the case of L. *stylirostris* exploited in the southern Gulf of California, whose reproductive behavior was hitherto unknown, it is here demonstrated that this penaeid shrimp conforms to the spawning pattern described by Garcia (1976), for species with two seasonal reproductive peaks: one in the summer and another of less strength in the fall. This author has emphasized the difficulties in studying the shrimp's reproductive cycle given its inherent variability due to interspecific differences or to abiotic influence. According to Ye (1998) shrimp spawning peaks and its duration are greatly affected by environmental conditions. Therefore, one should bear in mind though, the possible bias involved in calculating gravid female percentages for the recognition of seasonal spawnings. However, the analysis of their abundance, frequency of occurrence, and spatial and temporal variability may shed some light on the evolution of the exploited stock. Thus for instance, *L. stylirostris´* spawning inter-annual variability can be correlated not only to density dependent factors, but also to its response to optimum environmental conditions. Unfortunately, no relationships of this kind have yet being established between shrimp spawning and plankton blooms, or food availability.

On the other hand, aggregate behavior in shrimp populations have been attributed to rainfall and turbidity (Castro Aguirre, 1976; Sepúlveda and Soto, 1987; Rodríguez and Chávez, 1996). However, in the case of the reproduction process, the most cited parameter is temperature. In the case of *L. stylirostris*, its spawning cycle takes place in shallow waters (< 20 m) slightly diluted (< 34 ups) by local river runoff. According to Arozamena (1976), this species possesses osmoregulatory capacity to withstand salinity fluctuations from 20 to 40 ups.

In spite of the high inter-annual variability in the spawning cycle of *L. stylirostris*, which produces an over-masking effect on the modal progression of the offshore shrimp generations, it was possible to identify massive recruitment to the parental stock in July and September. The CPUE values recorded in these months(ca.30Kg/hr) attest to this process.

Conclusions

The reproductive behavior of *L. stylirostris* conforms to a bimodal pattern with two distinguishable seasonal peaks: one in the summer and another of less strength during the fall. Early shrimp spawners appear in the second week of May (5 to 7 % of gravid females) but their frequency of occurrence reach significant numbers (15 to 20 %) in the months of July and September. The decadal analysis of the spawning cycle of the blue shrimp revealed a high interannual variability that may be attributed to both density dependent factors as well as to optimum environmental conditions. Such interannual variability cause a masking-effect on the modal progression of the offshore shrimp cohorts. However, it was possible to follow up the recruitment pattern throughout the months of July and September.

The implementation of the closed season as is currently being applied for the tropical penaeid shrimps of the Mexican Pacific is deemed appropriate. The onset and ending dates of this fishing regulation implies a certain degree of uncertainty. In light of the results here presented, it may be inferred, that a clinal effect on the reproductive behavior of each shrimp stock distributed along the western Mexican coast, would require the application of distinct date for opening and lifting the closed season. There are evidence that indicate a time delay in the spawning cycle along a clinal gradient from the Gulf of California as far south as the Gulf of Tehuantepec. Nonetheless, the authors contend that the current five month closed season provides suffice safe margin to protect early spawners and the cohorts recruited to the parental stock from local bays and estuarine systems.

Acknowledgements

The authors want to thank the National Institute of Fisheries for the access to the shrimp data bank, to the Staff of the Regional Center of Fisheries assigned to the Shrimp Program of the Mexican Pacific for their invaluable assistance in the course of this research, and to Gustavo Sepúlveda Barrera for the computer support.

References

Arozamena, M. 1976. Ritmo alimenticio en los camarones *Penaeus stylirostris* y *Penaeus californiensis*, con relación a la temperatura. Memorias del simposio sobre Biología y Dinámica poblacional de camarones. Guaymas Son. 8-13 agosto 1976. México.(1):24-28

Cárdenas, F. M. 1950. Contribución al conocimiento de la biología de los peneidos, del noroeste de México. Tesis profesional. Escuela Nacional de Ciencias Biológicas. Instituto Politécnico Nacional. México D. F. 76p.

Castro,A. J. L. 1976 Efecto de la temperatura y precipitación pluvial, sobre la producción camaronera. Memorias Del Simposio sobre Biología y Dinámica Poblacional de Camarones Guaymas, Son. 8-13 Agosto1976. México.

Castro, O. J. L. Sánchez R. M. A. (1976) Notas preliminares del comportamiento y dinámica poblacional de *Litopenaeus stylirostris*, en los sistemas lagunarios del centro de Sinaloa. Memorias del Simposio sobre Biología y Dinámica Poblacional de Camarones Guaymas, Son. 8-13 agosto 1976. México(2):213-253.

Chapa, S. H. 1956. La distribución de los camarones del noroeste de México y el problema de las artes fijas. Tesis profesional. Escuela Nacional de Ciencias Biológicas. Instituto Politécnico Nacional. 56p.

Edwards R. C. 1978. The fisheries Biology of Peneid Shrimp on the Pacific coast of Mexico .Oceanography and Marine Biology an Annual Review 16:145-180.

Garcia G. M. 1976. Fecundidad del camarón *P. Californiensis* y camarón azul *P. stylyrostris* de Puerto Peñascoy Guaymas Son. Memorias del simposio Biología y Dinámica Poblacional de camarones Guaymas 8-13 Agosto 1976 México

Lluch. B. D. 1976. La pesquería del camarón en alta mar en el noroeste. Un análisis biológico pesquero. Instituto Nacional de Pesca (S.I.C. Serie Informativa) 73p.

Pedraza M. H. 1976. Estudios de poslarvas de camarón (Penaeus), en el área marítima de Topolobampo, Sinaloa. Memorias del Simposio sobre Biología y Dinamica Poblacional de Camarones. Guaymas, Sonora. México, 8-13 agosto 1976.(2):85-103

Rodríguez de la Cruz. M. C.,Chavez O. E. 1996 .La pesqueria de camarón en alta mar. Pacífico de México. Pesquerias Relevantes de México. xxx Aniversario del INP.(1): 9-27p

Sepúlveda M. A .y Soto G. L. A. 1987. Relación de la Precipitación Pluvial y la Temperatura atmosférica sobre la Producción Camaronera del Golfo de Tehuantepec México.

VII Congreso Nacional de Oceanografía. Ensenada B.C. Julio de 1987 (1): 665-677.

Sepúlveda M. A. 1991. Análisis biológico pesquero de los camarones peneidos comerciales en el Pacífico Mexicano durante el periodo de veda (1974-1983). Tesis de maestría. Universidad Nacional Autónoma de México. 155 p.

Sepulveda M. A. 1999 Dinámica Poblacional de los Peneidos Comerciales en el Alto,Centro Golfo de California, Topolobampo y Costa de la Baja California en el Litoral del Pacífico Mexicano. Tesis Doctoral Instituto de Ciencias del Mar y Limnologia UNAM. 146 P

Willman R. y Garcia S. M. 1986. Modelo Bioeconómico para el Análisis de Pesquerias secuenciales , Artesanales e Industriales de camarón Tropical (con un estudio de la pesqueria de camarón de Surinam). FAO Doc. Tec. Pesca. 270: 47.

Ye, Y. 1998. Assessing effects of closed seasons in tropical and subtropical penaeid shrimp fisheries using a length-based yield-per recruit model. ICES Journal of Marine Science, 55:1112-1124.

Received: 19th Jul 2001
Accepted: 25th Jun 2002