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An assessment of pink shrimp *(Penaeus brasiliensis)* populations, in three areas of the Caribbean coast of Costa Rica

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Abstract: Pink shrimp, Penaeus brasiliensis, were caught from May 1990 to February 1991 in three sites of the Caribbean coast of Costa Rica: Limón, Parismina and Barra del Colorado. Length frequency data were used to estimate, with the Compleat Elefan computer program, growth, mortality, optimum exploitation rate, probability of capture, recruitment, relative yield and biomass per recruit for each sex and study area. Using modal progression analysis, three age groups were determined in each zone. There was significant seasonal growth. Fishing mortality and the exploitation rate in these areas were low, indicating that these stocks are probably underexploited.

Key words: Length frequency distribution, *Penaeus brasiliensis,* growth, mortality, recruitment, population dynamics, Costa Rica.

Exploitation occurs twice in the life cycle of penaeid shrimp populations. The appropiate description of spawning areas and spawning seasons has been very important component in population dynamics studies of shrimp fisheries (Cummings 1961, Rao 1968, Thomas 1974, O'Connor 1979, Penn 1980, Kennedy and Barber 1981, Mathews 1981, Motoh 1981, Crocos and Penn 1983, Choy 1988, Caddy 1989, Herke and Rogers 1989, and Shepherd and Nicholson 1991).

Due to variations in the molt process and shrimp frequency in each sampling, it is difficult to distinguish successive age classes (Bowler and Brown 1977, Hazlett and Rittschoff 1985). In species with long life cycles this does not occur because the size overlap between the successive age classes generates higher growth rates (Flint 1975).

Ease of analysis depends on seasonal spawning patterns and sampling quality. In areas of strongly seasonal reproductive patterns, the principal cohort can often be followed. In estuaries where growth is very rapid, frequent and careful sampling should often make it possible to follow micro-cohorts generated by recruitment periods (Garcia and Le Reste 1981). Seasonal growth oscillations in Penaeus shrimps were reported by Mathews (1974) in *P. semisulcatus,* Rodríguez (1977) in *P. kerathurus* and Mathews *et al.* (1987) in *P. setifera.*

Male shrimp usually grow less than female shrimp. As a consequence, male length frequency distributions contain smaller size ranges and are therefore more difficult to analyze than those of females (Hartnoll 1982).

The consideration in each fishery assessment study of growth, mortality, spawning seasons, probability of capture and recruitment, reveals the fishery potential of the species (Stanley and Caddy 1989).

The aim of this study is to assess the population of *P. brasiliensis* sampled in three study areas in the Caribbean coast of Costa Rica, using length frequency distribution analysis.

MATERIAL AND METHODS

Data on *P. brasiliensis* were obtained from a trawl survey designed to monitor the shrimp fishery from May 1990 to February 1991 at three study locations: The Colorado river outlet, the Parismina river outlet, and and the Moín river outlet .(Fig. 1)

These areas were selected because they are relatively well developed in terms of commercial fishing, they are outside national marine park borders, and are mostly frequented by small-scale commercial fishermen.

Trawling samples were obtained with a trawl net 16 m in length, with 7.6 m of headrope, and a 1.0 cm mesh size. Trawling time was 30 min and the trawled area extended from the nearest point of the river outlet at a right angle to the 100 m isobath. After some preliminary samples and an acoustic survey of the area, the trawling frequency was set at one trawl/area/month.

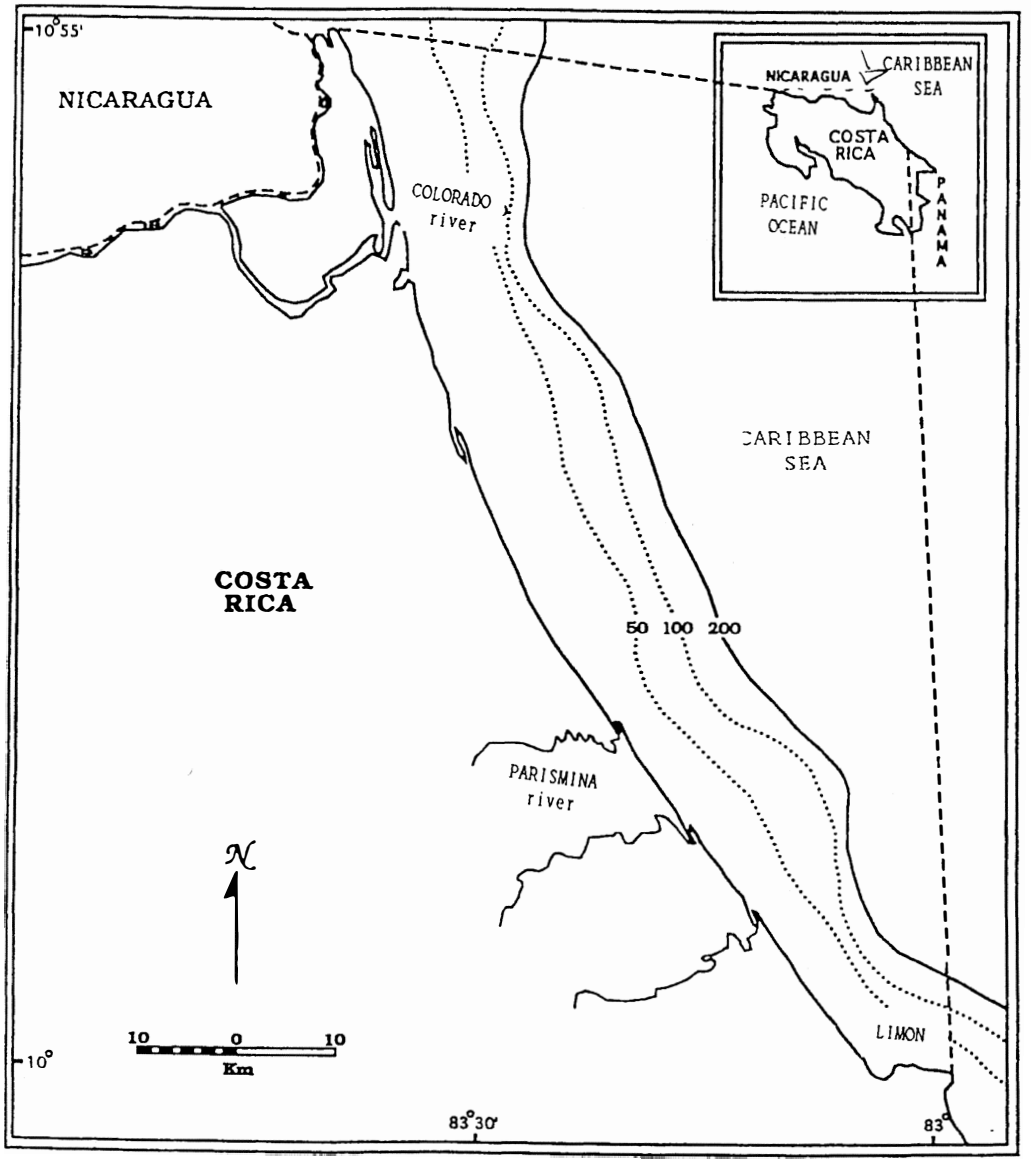


Fig. 1. Sampling areas of the north Caribbean coast of Costa Rica.

The shrimp were separated from the by-catch and shipped on ice to the Fishery Sciences Laboratory at the School of Biological Sciences at the Universidad Nacional (UNA).

A total of 5736 individuals of *P. brasiliensis* were caughted in Limón, 6363 in Parismina, and 4329 in Barra del Colorado, their total length (mm) and total weight (g) was measured and grouped in 5 mm length classes.

The length-frequency analysis was carried out with the Compleat ELEFAN software package (Gayanillo *et al.* 1988) in order to obtain the modal distribution of the population and the growth parameters (L_∞, K) of von Bertalanffy's (1934) growth curve as used by Pauly (1978). The original growth parameters were re-estimated with the addition of a seasonal growth oscillation, using the modifications of the von Bertalanffy growth function (VBGF) proposed by Pauly and Gaschultz (1978) and Sommers (1988).

The jacknife method was used to estimate the 95% confidence limits for L_∞ and K values (Pauly 1984). Assuming that the samples are representative of P.brasiliensis population, an empirical relationship (ø') was obtained, as proposed by Pauly and Munro (1984) and modified by Appeldoorn (unpublished) from intraspecific comparisons based on the relation between Loo and K values.

Using the length frequency distribution obtained in this study, a modal progression analysis was performed with the Battacharya method permit to identify all the age groups , by area and by sex.

A length-converted catch curve, pooling the percent samples, was used to estimate total mortality (Z) by area and sex, and to derive approximate probabilities of the first capture by length (Pauly 1984). This probability of capture assumed use of a trawl net. The capture of all smaller shrimps by trawl net, and the generation of the natural mortality (M) obtained under minimum length as well as the estimated Z by interpolation between M and Z.

Natural mortality was estimated using Pauly's empirical relationship (Pauly 1980). Fishing mortality (F) was computed by subtraction and the optimum exploitation rate (E) by calculating the ratio of F over Z.

This method assumes that Z was the same in all age groups used in the plot. All the age groups recruited had the same abundance, all were equally vulnerable to the gear used and the sample was large enough to effectively represent the average population structure over the time period considered.

Recruitment patterns were obtained by projecting length-frequency data backward along the time axis, using the growth equation to recover the pulsing of annual recruitment (Pauly 1986). This allowed quantification of recruitment seasonality.

Estimations of Relative Yield per Recruitment and Relative Biomass per Recruitment were plotted for *P. brasiliensis* populations in Barra del Colorado, Parismina and Limón.

RESULTS

The length-frequency distribution obtained from *P. brasiliensis* and the growth curves by sex and total population are presented in Fig. 2. Table 1 presents the growth parameters estimated in the three sampling areas for individuals larger than 40 mm Lt as well as the ø' values obtained. The C and WP parameters suggest a strong seasonal oscillation in growth. The growth parameters (Loo and K) do not present variations in the C value. The WP parameter indicates a minimum growth between June and August.

The modal progression analysis applied using the Battacharya method is presented in Figure 3. A maximum of four age groups were detected monthly in Limón, Parismina and Barra del Colorado, but taken over the whole year, this method defines 3 age groups. Possibly, age groups 3 and 4 overlap. This result corresponds to the number of modes obtained in the length frequency distribution.

The length converted catch curves for *P. brasiliensis* in Limon, Parismina and Barra del Colorado for the total population and separated by sex are presented in the Fig. 4. Estimates of Z, F, M , E and probabilities of capture are presented in Table 2. Total mortality obtained in the three areas refers only to shrimp fully recruited by the trawl net. In all areas total mortality did not differ between sexes. In Barra del Colorado, a higher fishing mortality ($F=0.54$ year^{-1}) with a natural mortality of 1.95 year^{-1} for total population was obtained, assuming that intraspecific distribution by sex did not exist. Apparently the sex ratio in catch-

TABLE 1

Growth parameters (Loo, K), seasonal oscillation (C,WP) and ø' value obtained for P. brasiliensis *population sampled in Limón, Parismina and Barra del Colorado, Costa Rica*

Parameter	Sampling areas.								
	Limón			Parismina			Barra del Colorado		
	P.t	M	F	P.t	M	F	P.t	M	F
Loo (mm)	186.4	189.0	186.4	181.0	185.0	184.6	183.8	182.0	186.0
K (year^{-1})	0.748	0.810	0.820	0.580	0.600	0.600	0.990	1.240	0.800
C	0.80	0.90	0.80	0.90	0.90	0.80	0.90	1.00	0.90
WP	0.70	0.80	0.70	0.80	0.70	0.70	0.80	0.70	0.93
ø'	4.414	4.460	4.455	4.278	4.312	4.311	4.524	4.613	4.442

P.t = Total population
M = Males
F = Females.

TABLE 2

Total mortality (Z), fishing mortality (F), natural mortality (M), mean length of probability of capture (Lc-50) and exploitation rate (E) estimated for P. brasiliensis *populations sampled in Limón, Parismina and Barra del Colorado*

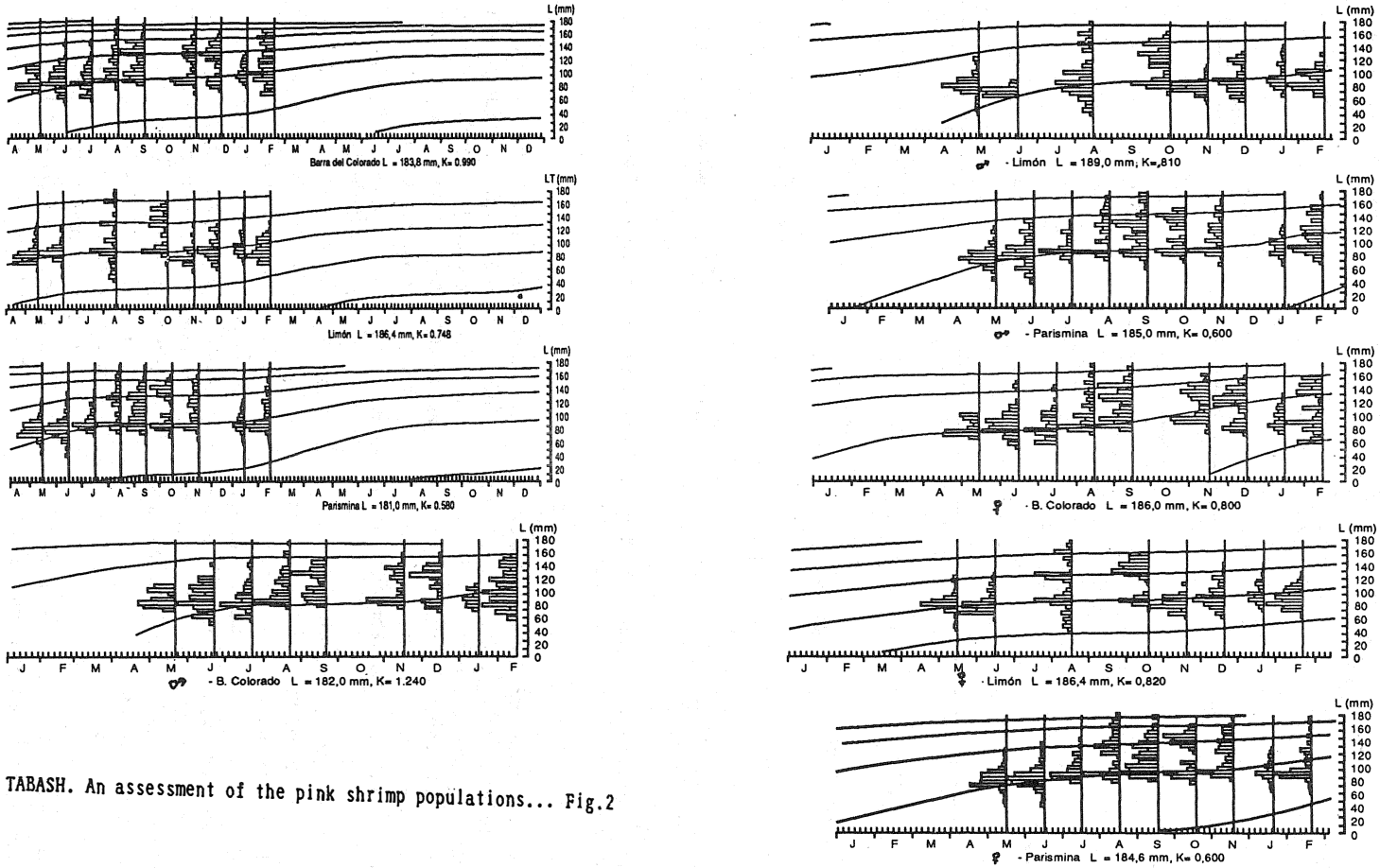
Parameter/Area	Limón			Parismina			Barra del Colorado		
	P.t	M	F	P.t	M	F	P.t	M	F
Z (year^{-1})	1.78	1.81	1.67	1.55	1.55	1.51	2.49	2.44	2.39
F (year^{-1})	0.49	0.48	0.46	0.19	0.18	0.13	0.54	0.48	0.44
M (year^{-1})	1.29	1.33	1.21	1.36	1.37	1.38	1.95	1.96	1.95
E	0.27	0.26	0.27	0.14	0.14	0.11	0.22	0.18	0.16
Lc-50 (mm)	68.5	67.0	69.5	68.0	69.5	69.0	71.0	70.5	67.0

P.t = Total population.
M = Males
F = Females

es was 1:1, in general agreement with the biology of this species. The value of M, which varies from 1.21-1.95 year $^{-1}$ for the total population, could be due to this sex ratio and to the lower optimum exploitation rate obtained in Limon, Parismina and Barra del Colorado.

Gear efficiency was related to the behavior of the shrimp and could modify the sex ratio. However Lc_{50} lengths can help illustrate the effect of similarity in natural mortality between sexes and its effect on fishing mortality. Probability of capture patterns are presented in Table 2 in Limon, Parismina and Barra del Colorado, those patterns enable estimation of the mean lengths of the first capture, mainly owing to the selectivity effect of the trawl net.

In the recruitment patterns obtained (Fig. 5), *P. brasiliensis* populations caught in Limon presented high similarity between sexes. For males the second pulse represents 74% of the recruitment population and for females, 85%.



TABASH. An assessment of the pink shrimp populations... Fig.2

Fig.2. Reestructured length-frequency data of total population, females and males of *Penaeus brasiliensis* in Limón, Parismina, and Barra del Colorado, and estimate of growth curves and seasonality.

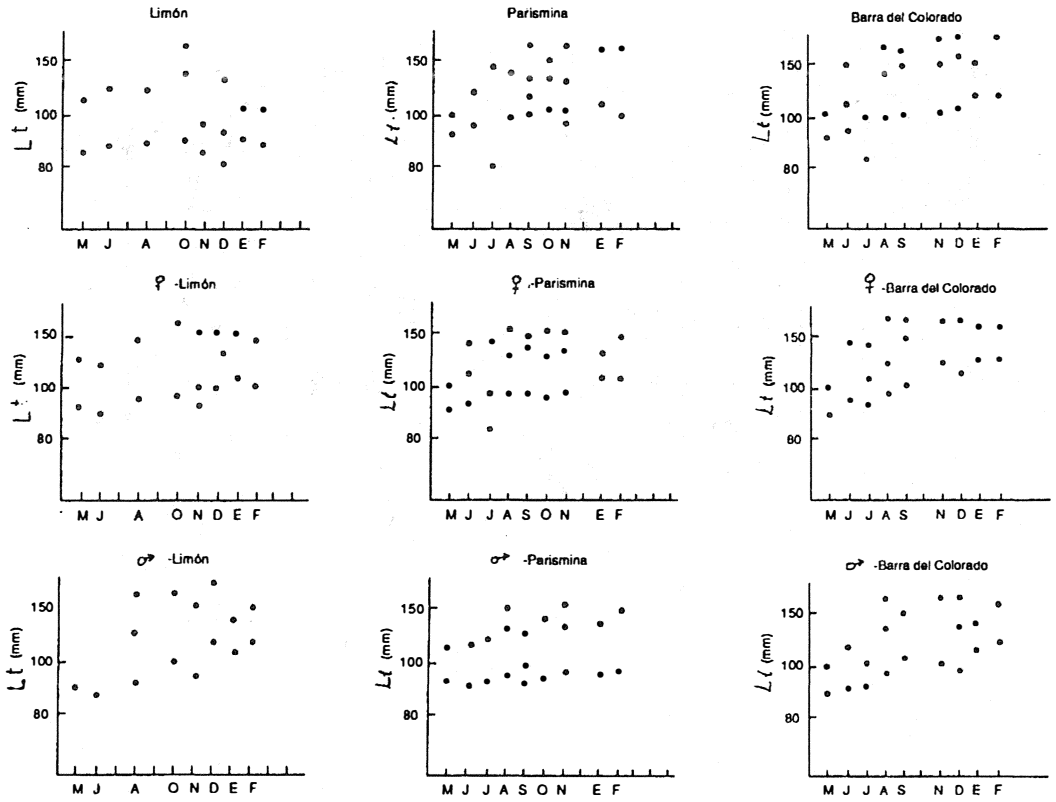


Fig. 3. Results of modal progression analysis by Battacharya's method on pooled samples of total population, males and females of *Penaeus brasiliensis* in the three areas studied.

In Parismina, the main recruitment pulse represents 79% with a secondary pulse that includes 21%, without sex-related differences. In Barra del Colorado, the recruitment patterns are similar to those of Limon and Parismina. In all three areas, the difference between recruitment pulses was 3 months.

The relative yield per recruitment (Y'/R) and Biomass per Recruitment (B'/R) were calculated (Fig. 6). The population of *P. brasiliensis* in Limon, Parismina and Barra del Colorado, shows M values of 1.29, 1.36, and 1.95 year^{-1}, respectively, and M/K ratios of 0.0172 in Limón, O.023 in Parismina, and 0.019 in Barra del Colorado.

DISCUSSION

By means of the length-frequency distribution obtained in this study for *P. brasiliensis* populations, according to the number of shrimp caught and the length interval obtained, we may establish that the sample size obtained is adequate. The minimum length caught was lower than those reported by Garcia and Le Reste (1981) and Kawahara (1983) for the same species. A decrease in the number of modes for greater lengths indicates that data collection was carried out under a precise sample design (France *et al.* 1991).

This population presents 3 clearly distinguishable age groups, suggesting consecutive spawning periods. This result coincides with the number of modes obtained in the length frequency distribution. The sample size reported by month, in the three sampling areas, is greater than those reported by Jones (1981), France (1985) and Davies (1989), which were adequate for several crustacean species.

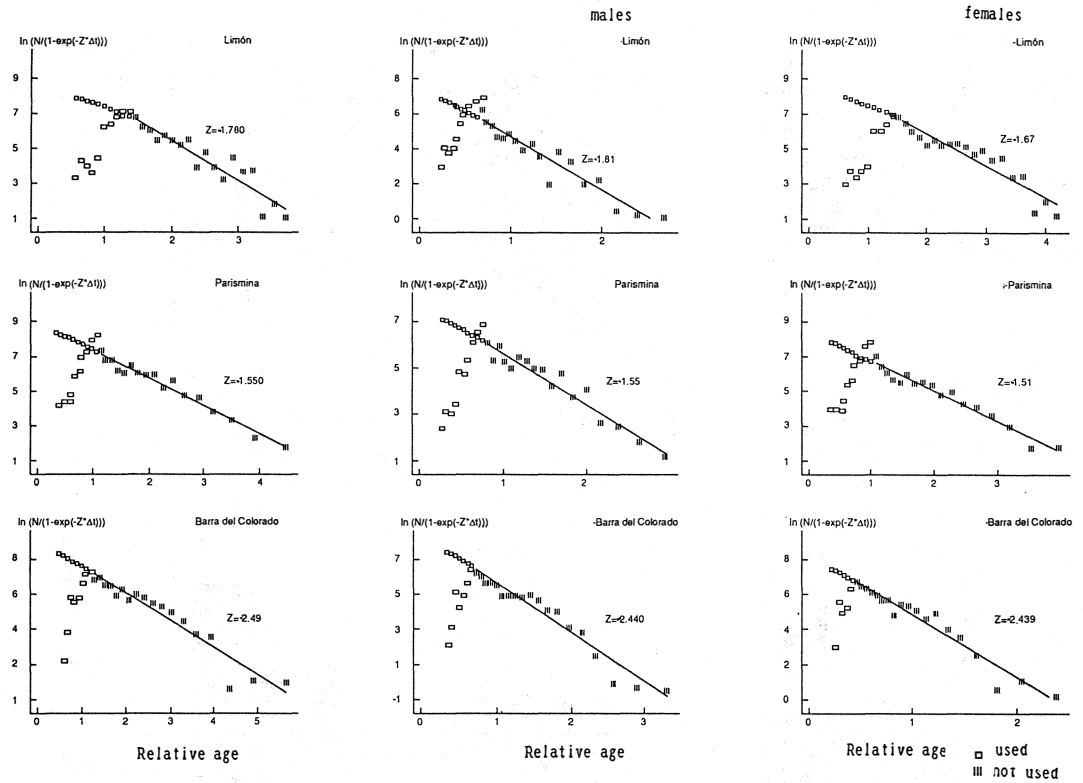


Fig. 4. Length-converted catch curves by sex and total population of *Penaeus brasiliensis* in Limón, Parismina and Barra del Colorado.

The estimates of L_{00} and K are homogeneous between sexes. Similar results were reported by Sumiomo (1988). Therefore, the *P. brasiliensis* growth level in Limón, Parismina, and Barra del Colorado did not present a higher sex variability.

In general terms, the L_{00} and K estimates are consistent with the assumption that penaeids are small sized, fast-growing, and short-living animals. The parameter ø', as originally described by Pauly and Munro (1984), used for intraspecific comparisons (Appeldoorn, unpublished) indicates similar growth performance, and these values are the same as those obtained for other related species. Garcia (1977) reported analogous ø' values in *P. notialis* (ø'=4.46) and Kawahara (1983) in *P. subtilis* (ø'=4.39), both of these in French Guiana. Willmann and Garcia (1986) reported that P. notialis, P. subtilis, and *P. brasiliensis* correlate with respect to their maximum length, maturation and life cycle.

Growth coefficients (K) vary greatly from one area to another, between ranges of 0.58 and 1.24 $year^{-1}$ for males and intervals of 0.6 and 0.82 $year^{-1}$ for females. With regards to this variance, the estimated growth seasonality (C and WP) of *P. brasiliensis* in the three study zones, and the relative difference of ø' values calculated by zone, according to reported by Oliver *et al.*(1971) and Defeo *et al.*(1988), suggest that probably the seasonality of penaeid growth, underestimates or overestimates the K value obtained.

Assuming that the age composition is in equilibrium, just as a previous condition for the estimation of Z, required establishing that the mortality is constant in time by cohort, it is

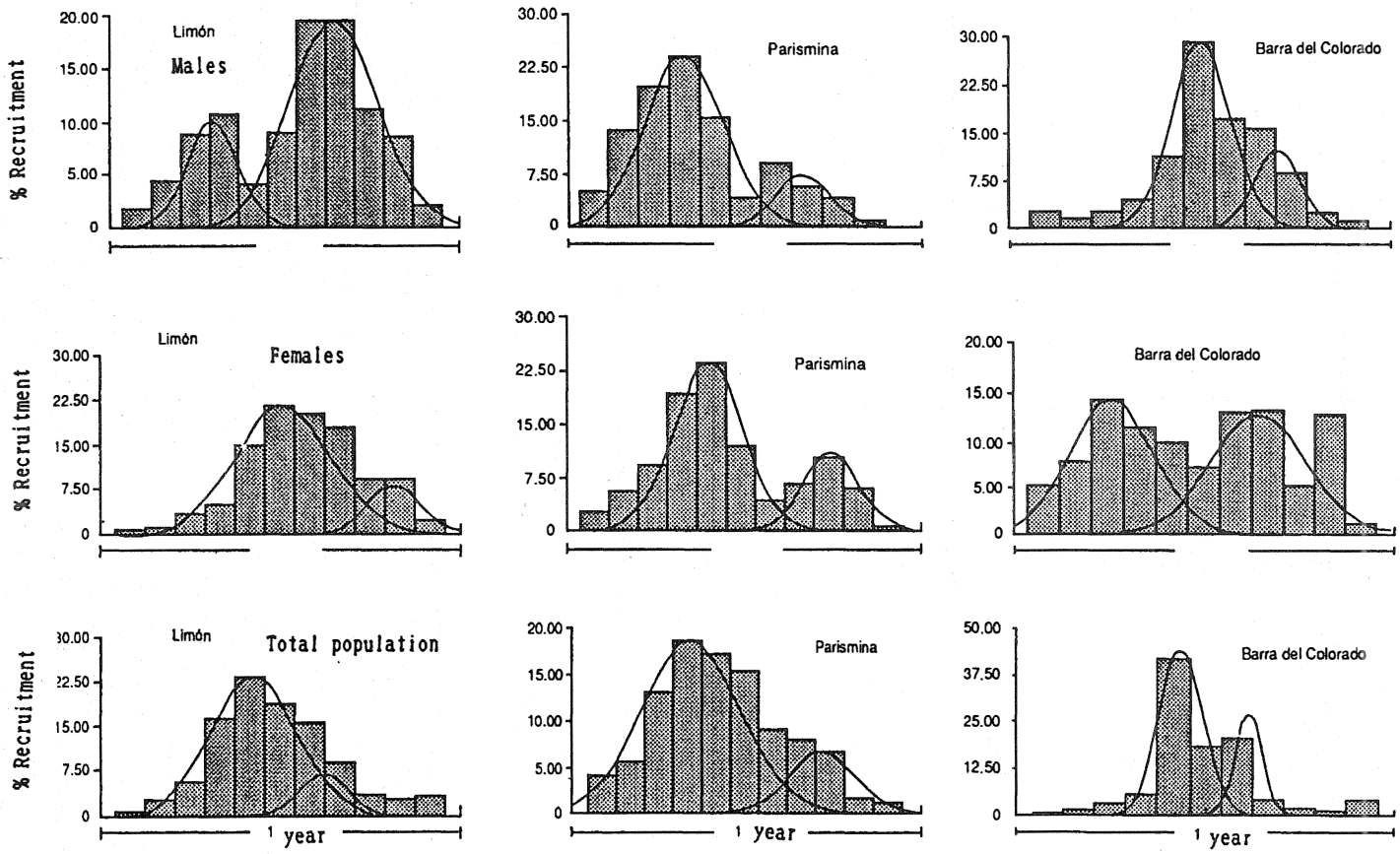


Fig.5. Recruitment patterns by sex and total population in *Penaeus brasiliensis* in Limón, Parismina and Barra del Colorado.

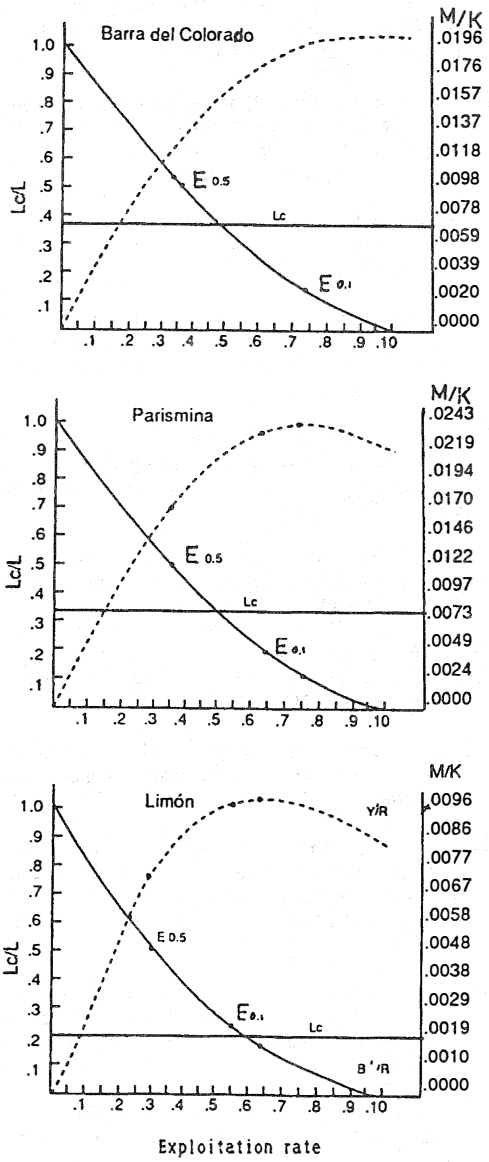


Fig. 6. Relative yield per recruitment (Y'/R) and biomass per recruitment (B'/R) calculated from the total population of *Penaeus brasiliensis*.

likewise important to consider this limitation in order to analize the total mortality values in the three areas.

Total mortality is lower than that reported for other species with similar small-scale commercial fishing pressure (Manisseri 1981, Demm 1986 and Choy 1988). Estimations of natural and fishing mortality show the area as underexploited because the probability of death by natural causes is higher than the fishing mortality. Probably the Z value was overestimated, because when total mortality decreases, the exploitation rate obviously decreases accordingly. Since the fishing mortality in Limón, Parismina, and Barra del Colorado is lower than the natural mortality, the effect of F on E was very small.

The length of probability of capture ($Lc_{50\%}$) was 69 mm Lt in all three areas. Comparing this result with the minimum length of maturation reported by Ligthburn and Orellana (1983) in the Nicaraguan Caribbean by Willmann and Garcia (1986) in Suriname for *P. brasiliensis*, both of 75 mm Lt, it was determined that over 50% of the sampled shrimps are immature. Thus, an increase in the mesh size was recommended, starting with lengths greater than 70 mm Lt.

The average of the first recruitment pulse incorporated 78.6% ± 6.2% in Limón, Parismina, and Barra del Colorado, the second recruitment pulse was presented 2 or 3 months after; result that is in correspondence with the modal progression analysis applied. These types of successive recruitment patterns are typical of shrimp of *Penaeus* genera and correspond to migration cycles, spawning and rain patterns (Gwyther 1980, Tenakanai 1980, Waffy 1980, Garcia 1984, Robertson *et al.* 1984, and Agasen and Del Mundo 1988).

The actual exploitation rate is considerably low, despite its being a very commercially important species along the entire Caribbean coast. The relative yield per recruitment (Y'/R) reveals that these populations can withstand an increase of 55% in current fishery production in Barra del Colorado, 38% in Parismina, and 73% in Limón, without affecting the population renewal rate (B'/R). During this sampling period the B'/R was estimated at 0.65 in Limón and 0.75 in Barra del Colorado and Parismina.

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RESUMEN

Datos de frecuencia de longitud del camarón rosado, Penaeus brasiliensis Latreille, se obtuvieron en tres áreas de estudio en la costa Caribe de Costa Rica: Limón, Parismina y Barra del Colorado, se utilizaron para estimar parámetros de evaluación pesquera. Por sexo y área de muestreo, se obtuvieron el crecimiento, mortalidad, probabilidad de captura, patrones de reclutamiento y los estimados de producción y biomasa relativa por recluta. Además, se realizó un análisis de progresión modal con el objeto de determinar exactamente el número de grupos de edad presentes en la población analizada. Ello por medio de la programación de evaluación pesquera ELEFAN. Los parámetros de crecimiento son consistentes con las características de los camarones peneidos, referidas a su rápido crecimiento, tamaño y corto ciclo de vida. Se estimó una significativa variación estacional en el crecimiento y el punto de mínimo crecimiento se ubicó entre julio y agosto. Se obtuvieron bajos valores de mortalidad por pesca y tasa de explotación en las tres áreas de estudio, lo que indica que se encuentran subexplotadas, no obstante que los estimados de producción y biomasa relativa por recluta indican que en las tres zonas poseen poblaciones que soportan un incremento en la producción pesquera sin afectar su tasa de renovación.

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