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Stock assessment of two penaeid prawn species, *Penaeus occidentalis* and *Penaeus stylirostris* (Decapoda: Penaeidae), in Golfo de Nicoya, Costa Rica

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Abstract: Analysis on the maturation rate, growth, mortality, selection patterns, recruitment and yield (Y/R) and biomass (B/R) per recruitment of *P. occidentalis* and *P. stylirostris* in the lower Golfo de Nicoya (Puntarenas, Costa Rica) was undertaken using a length frequency analysis. Results showed that this stock is similar to the one studied in the inner part, as for their maturation and growth parameters. High values of total mortality and exploitation rate were obtained, which indicate that these stocks are overexploited. The analysis of Y/R and B/R showed an overexploited penaeid stock with a very low renewal rate.

Key words: Shrimp, assessment, growth, mortality, recruitment, maturation, fishery dynamics, *Penaeus*.

Coastal penaeid shrimp stocks have become more intensively studied in the tropics. Scientific work on population dynamics and stock assessment has greatly developed in Latin America, West Africa, South East Asia, Persian Gulf and eastern Indian Ocean (Garcia 1985). The limiting factor in shrimp stock assessment and management, at present, does not appear to be a shortage of methodologies, at least for single species, but rather the scarce knowledge of the mechanisms of shrimp production and fleet dynamics (Garcia 1985).

In Costa Rica populations of two species of shrimp, *P. occidentalis* and *P. stylirostris* support valuable fisheries in the Golfo de Nicoya. The Gulf is divided in two areas, the inner part where a fishery close season is applied and the lower part where do not exist management restraints. An intensive fisheries exist in the two areas, but few biological data are available for these two species (Carranza 1985, Vítola 1985, and Palacios *et al.* 1993).

In the study of these stocks, the patterns of seasonal recruitment, growth, behavior and catchability, fishing mortality, age structure of the exploited population, reproductive potential, biomass, etc. had important consequences to the outcome of specific management measures (Garcia 1977a, Garcia & Le Reste 1981).

Considering the spawning as the base of the resource renewal mechanism and stock conservation, in the lower Golfo de Nicoya, spawners of *P. occidentalis* appears to be more or less continuously present (Alfaro *et al.* 1993), showing at least two peaks, probably three per year (Angulo 1993).

At present, the main problems in the Golfo de Nicoya fishery are heavy fishing effort, poor economic benefit, few biological and fishery information and extravagant power consumption, which will eventually produce the fluctuations in the population. The aim of this paper is to contribute to the biological and fishery information pool, estimating maturation patterns of the two species, growth parameters, mortality, probability of capture, recruitment and yield and biomass per recruitment in the lower part of the Golfo de Nicoya.

MATERIAL AND METHODS

Monthly length composition data from samples of shrimps were caught on board of commercial trawler vessel during the period 1990-1991, in the lower part of the Golfo de Nicoya (Fig. 1). The mesh size at the cod end was 37.5 mm. For practical reasons, the analysis considered all the outward zones integrally, mainly because this zone is open to the fishing activity during year-round.

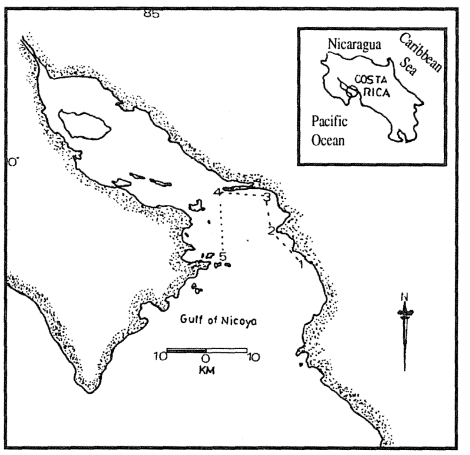


Fig.1. Study areas sampled during the period 1990-1991 in the lower part of Golfo de Nicoya, Puntarenas, Costa Rica.

A total of 2178 individuals of *P. occidentalis* and 2474 of *P. stylirostris* was sampled, their total length (mm) and total weight (g) was measured and grouped in 5 mm length classes. Samples were brought to the laboratory and their sex and maturation state was also recorded, according to Yano *et al.* (1988).

The length-frequency analysis was applied to estimate growth parameters using ELEFAN I subpackage as incorporated in the FiSAT software (Gayanillo *et al.* 1994). It was assumed that the length-frequency data are representative of the population, that the growth parameters are repeated from year to year, that the von Bertalanffy formula describes the mean growth in the population and that all the shrimps in the samples have the same growth parameters. The seasonal oscillation (C) and the point of minimum growth (WP) was also calculated. Using Length Frequency Distribution Analysis (LFDA) package

TABLE 1

Growth parameters (L_{oo}, K) and seasonal oscillation level (C, WP), growth performance (ø') and "t_0" value estimated for P. stylirostris *and* P. occidentalis *sampled in the lower part of the Gulf of Nicoya*

Parameters	*P.stylirostris*	*P.occidentalis*
L_{oo}(mm)	250.0	252.0
K(year^{-1})	1.29	1.10
C0.80	0.70	
WP	0.70(Aug.)	0.80(Sept.)
t_0(year^{-1})	-0.01	-0.01
ø'	4.91	4.84

(Holden & Bravington 1992), the "t_0" value were estimated and the relationship between L_{oo} and K value was found out.

According to Udupa (1986), based on acumulative percentage frequency curve of maturation stages of *P. occidentalis* and *P. stylirostris*, the mean size at first maturity (M_L) was determined at 95 % confidence limits.

Total mortality (Z) was found from length-converted catch curve analysis (Pauly *et al.* 1984). Natural mortality (M) was estimated from the empirical equation obtained by Pauly (1980 a). Anyhow, this relationship can be used to predict reasonable values of M in any species of fish, can be expected to generate equally reasonable estimates of M in shrimps, because the shrimps and fish generally share the same habits, resources and predators, and that therefore, they are not likely to differ widely in their vital parameters (Pauly *et al.* 1984). Fishing mortality (F) was estimated by subtraction of Z and M. The optimum exploitation rate E = F/Z has been computed for a preliminary assessment of whether a stock is lightly (E < 0.5) or strongly exploited (E > 0.5), based in the assumption that a shrimp stock is optimally exploited when F = M or E = 0.5 (Gulland 1971).

Identification of selection patterns was estimated by backward projection of straight portion of catch curves obtained in *P. stylirostris* and *P. occidentalis.*

Recruitment patterns, allowing for the inference of this method, were obtained. ELEFAN II incorporated in FiSAT implemented this routine, projecting the length frequency data avilable

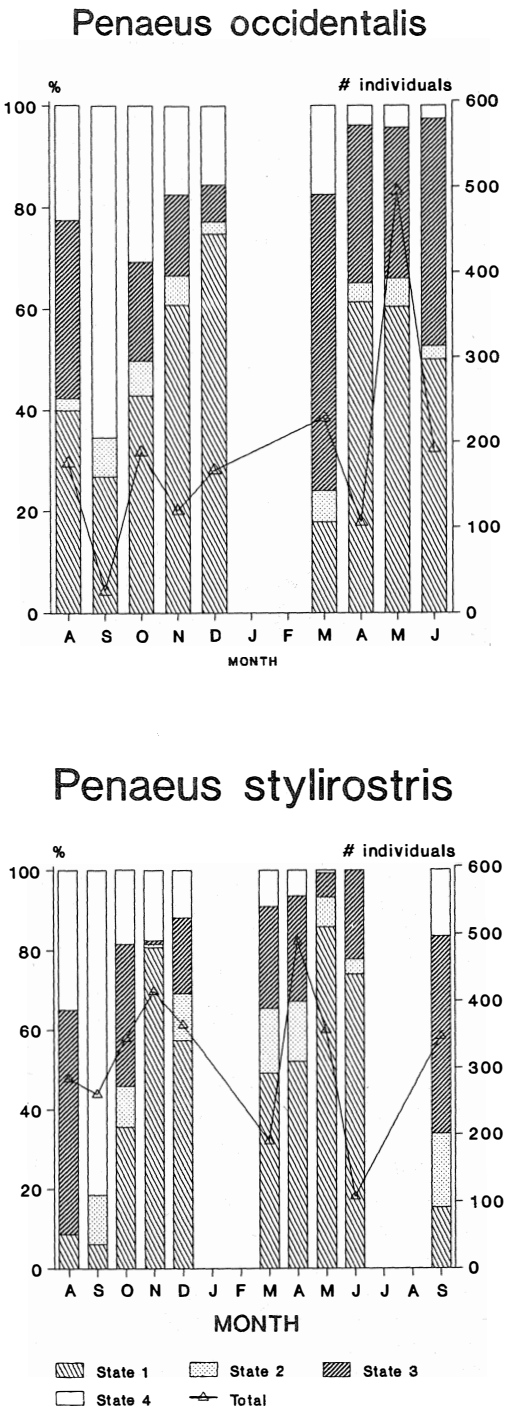


Fig.2. Variations in the maturation stages obtained during the sampled period in *P. occidentalis* and *P. stylirostris* populations in the lower part of the Golfo de Nicoya.

backward into the time axis (by means of a set of growth parameters) generates "recruitment patterns" which can be used to obtain the information pertaining to the recruitment processes (Pauly *et al.* 1984). Estimations of yield and biomass per recruitment were plotted for *P. occidentalis* and *P. stylirostris.*

RESULTS

The first maturation peak of *P. occidentalis* and *P. stylirostris* females takes place between August and October and the second, five months latter, between March and June (Fig.2). Throughout the sampling period, the number of mature males represented 28.0% ± 2.7% for the two species.

An "auximetric grid" obtained with LFDA, is presented which allows comparison of the growth patterns (L_{OO}, K) of the shrimps stocks (Fig. 3). A given K and L_{OO} value, corresponds to the growth curves obtained with FiSAT in the two species (Fig.4). Seasonally oscillating curves fluctuated strongly. The "Winter Point" indeed correspond in full to the maturation peaks obtained for the two species (*P. stylirostris* in August and *P. occidentalis* in September).

The total mortality (Z) obtained from the length converted catch curves, calculated for both species (Table 2) assumes that Z is constant from some lengths upwards. This assumption could be violated by migration out of the fishing area of the mature shrimps, or by avoidance of the trawl by the larger individuals.

Natural mortality rates (M) are smaller than fishing mortalities (F), these values are complemented with the exploitation rates reported, which show an overfishing state in the two stocks. The mean size at first maturity (M_L) in the two species, indicates that when females of *P. stylirostris* and *P. occidentalis* reach an average size of 115.50 and 122.70 mm respectively, 50% of the population are at middle of stage III.

There are, two selection patterns, one for each species (Fig.5). The length at 50% retention for *P. stylirostris* was larger than the obtained for *P.occidentalis.*

Recruitment patterns in *P. stylirostris* stock, suggest two recruitment events per year, but it is possible that more occur (not presented in

TABLE 2

Mortality estimates, length of probability of capture (Lc-50%) and first maturation length (M_L) for P. stylirostris *and* P. occidentalis *sampled in the lower part o the Gulf of Nicoya*

Parameter	*P.stylirostris*	*P.occidentalis*
Z(year^{-1})	4.925	5.274
M(year^{-1})	1.870	1.996
F(year^{-1})	3.055	3.278
E	0.62	0.62
$Lc_{50\%}$(mm)	171.54	164.26
M_L(mm)	115.50	122.70

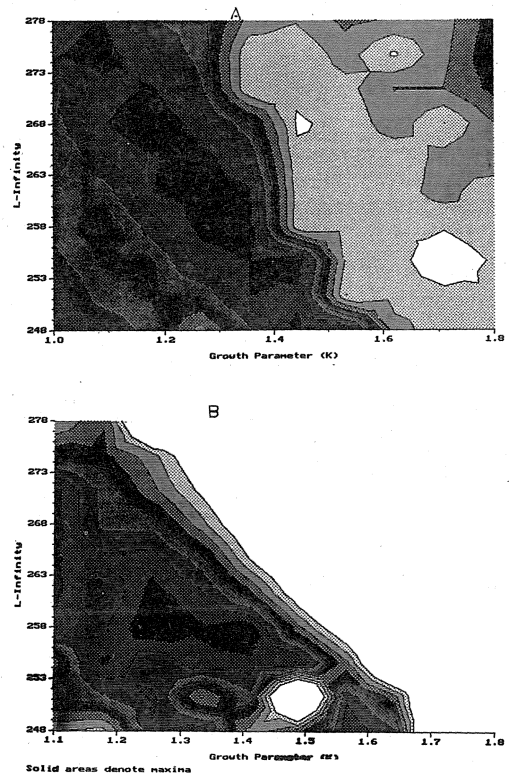
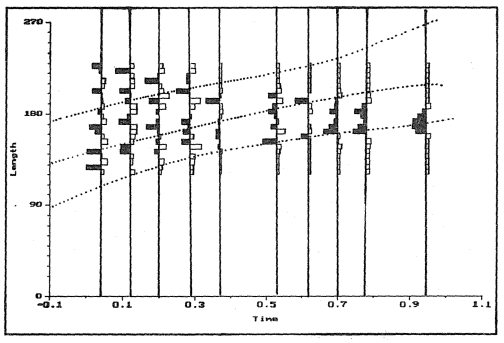


Fig.3. Relationship L_{oo} and K value obtained, during the sampled period in *P. occidentalis* (A) and *P. stylirostris* (B) **populations in the lower part of the Golfo de Nicoya.**

Penaeus occidentalis



Penaeus stylirostris

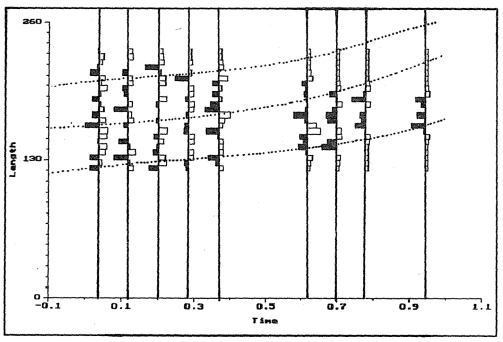
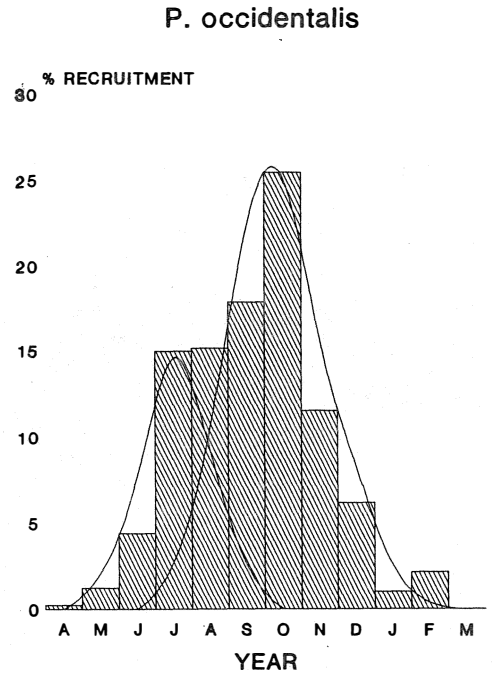
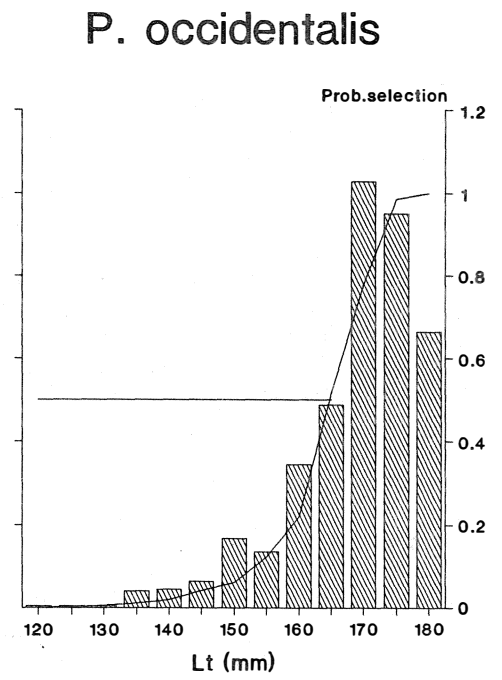


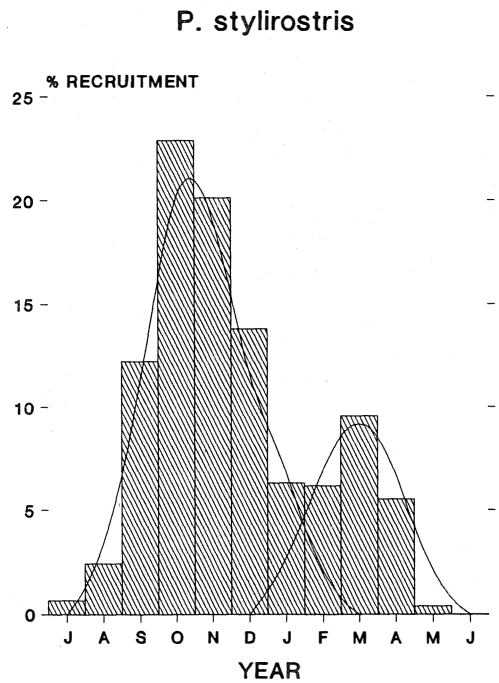
Fig. 4. Length frequency distribution and growth curves obtained for *P.occidentalis* and *P. stylirostris* populations in the lower part of the Golfo de Nicoya.

the Fig.6 due to limitations in the FiSAT program). The estimate of "t_0" allows to predict the months for these peaks. The first pulse incorporate 72.5% ± 1.27% of the total recruitment that occurred between September and November, and the second pulse incorporates 25.46% ± 1.06% and appeared four months later, between March and April. In *P. occidentalis* population, the first recruitment peak was present between July and August, incorporating 30.16% ± 0.82% of the population and the second pulse appeared three months latter, between October and November and incorporated 68.82% ± 1.11% .

Using the values of L_{oo} and M/K ratio, together with the probabilities of capture obtained from the selection curve, yield and biomass per recruitment (Y/R, B/R) for the two species were computed (Fig. 7). Yield per recruitment reached a maximum at the







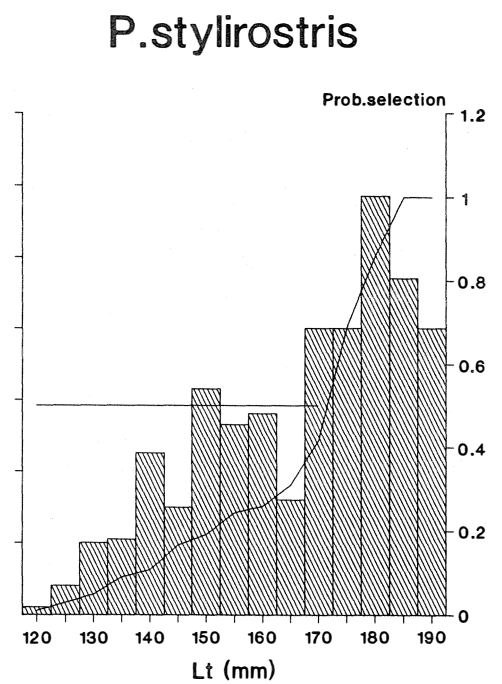


Fig. 5. Selection curves for *P. occidentalis* and *P. stylirostris* populations, caught with trawl net in the lower part of the Golfo de Nicoya.

Fig. 6. Recruitment patterns for *P. occidentalis* and *P. stylirostris* populations,obtained during the sampling period in the lower part of the Golfo de Nicoya.

exploitation rate of 0.60 with a renewal rate of 0.30 in the *P. occidentalis* stock. With *P. stylirostris*, Y'/R were estimated in 0.62 and B'/R in 0.20 product of the actual exploitation rate applied at the area.

DISCUSSION

Short term variation in the proportion of active spawners was evident for both species, however, no discernible pattern of variation may be suggesting a regular cycle. Throughout the sampling period more than 40% of female *P. stylirostris* and *P. occidentalis* had mature, during August to October and then between March to June, result very similar to reported by Angulo (1993) in the same species studied in the inner part of the Gulf of Nicoya.

Females of *P. stylirostris* and *P. occidentalis* were mature when reached 115-123 mm Lt. Palacios *et al.*(1993) report in the inner part that females of *P. stylirostris* reaches the length at first maturity between 124 and 139 mm Lt, using gill net. The high incidence of mature females in the study area throughout, the sampling period, raises the possibility that two penaeid stocks have the potential for successive spawning during the entire year. It is expected that a spawning season could be determined from the abundance of females in a spent condition.

The spawning seasons of some penaeids are closely associated to an increase in water temperature (Penn 1980 a). As spawning of the two penaeid species occurred in months that represent transition from dry to rainy season, it could involve changes in water temperature.

Estimated growth parameters obtained in this study, are in agreement with Angulo (1993) in the same species studied in the inner part of the Gulf of Nicoya. However, Palacios *et al.* (1993) working in the inner part of the Gulf, reported lower values than the ones obtained in this study. The parameters C and WP, for the two species, suggest a strong seasonal oscillation of the growth, where the minimal growth of *P. stylirostris* and *P. occidentalis* ooccurred during the females maximum maturation period.

The index of growth performance(ø') (Pauly y Munro 1984) is quite close to that found in the inner part of the Gulf of Nicoya (Angulo 1993, Palacios *et al.* 1993), and

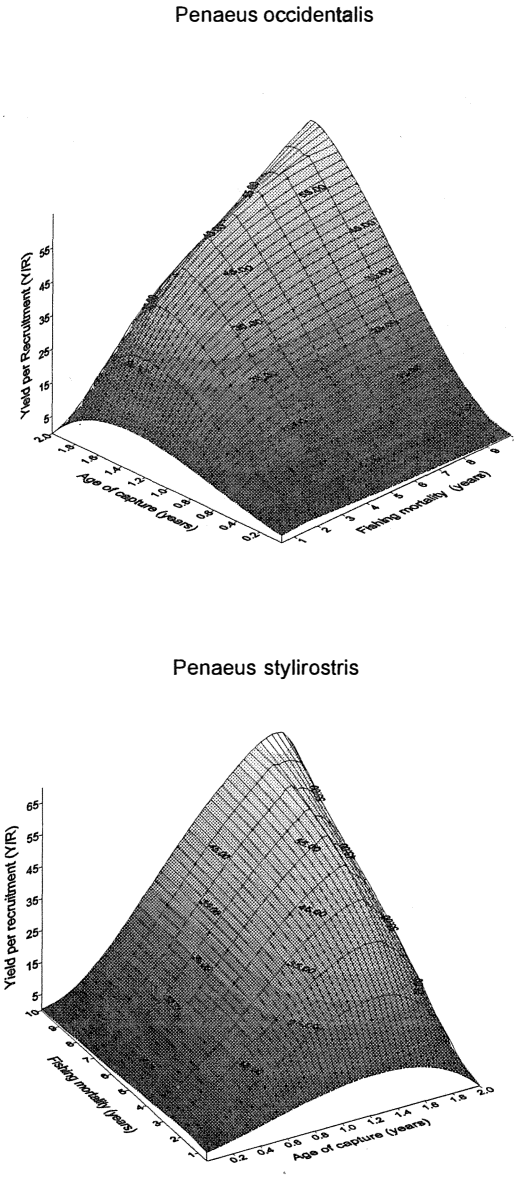


Fig. 7. Relative yield (Y'/R) and biomass (B'/R) per recruitment estimated for *P.occidentalis* and *P. stylirostris* populations in the lower part of the Golfo de Nicoya.

express a relationship between the growth parameters estimated (Pauly 1991).

High values of mortality and exploitation rate indicate that all the areas sampled are overexploited. However, mortality estimates in both species suggest a very low natural mortality, due to intensive fishery activity (F). Fluctuations in monthly biomass caught, probably do not reflect

changes in the two species stock biomass, but rather a change in vulnerability to the gear (Vibhasiri 1988). Angulo (1993) and Palacios *et al.* (1993) reported overexploitation in the inner part of the Gulf too. Length of probability of capture (Lc_{50}) was 171.54 mm for *P. stylirostris* and 164.26 mm by *P. occidentalis.*

In *P. stylirostris* females Palacios *et al.* (1993) caught with gill net, report a length of the first capture of 141 mm in the inner part, stablishing that in this area Lc_{50} was very close to the length of first maturation, recommending to increase the actual mesh size. On the contrary in the lower part, the length of the first maturation was smaller than Lc_{50} calculated, stablishing that with the actual mesh size used, the shrimps can reproduce at least once before 50% of total population can be caught.

The recruitment patterns calculated for the two species are similar, and the age at recruitment is about 7.5 months, corresponding to total length of 130 mm. According to our results, the most important spawning season for both species is between March and April, and the recruits are presented four months later (August/October). It is very important to consider, that this is the same reproductive behavior followed by these two shrimp species in the inner part of the Gulf, according to Palacios *et al.* (1993).

On the basis of yield per recruitment (Y/R) applied at *P. stylirostris* and *P. occidentalis* stocks, the actual fisheries are exploiting the species above the optimum level of fishing mortality. The actual Y/R avoids the renewal rate (B'R) to keep the stock in equilibrium with the actual level of fishing effort.

The consequences of such reduction and subsequent recruitment of the shrimp fishery is not known, mainly because the similarity between the shrimp population dynamics in the inner and outer areas of the Gulf of Nicoya are very close, and the possibility of mutual exchange between these areas is high. As a result, the maturation and spawning seasons can affect the biomass of both zones, considering that probably exist some degree of immigration.

An increase in Y/R may also be achieved by increasing the size of probability of capture (Lc_{50}), a direct consequence of the new recommendations of management policies. For example, an increase to 180 mm Lt (about 1.2 years old) in Lc_{50}, result in a 22% increase in Y/R and a B/R increased in a 18% over the actual renewal rate, at the present exploitation level. An increase in the size of probability of capture, would also have the advantage of reducing the impact on spawning stock abundance, since most immature shrimps would be subject to exploitation.

The fishery of white shrimps in the Gulf of Nicoya (inner and outward) is therefore, probably incapable of a expansion of the actual fishery effort and for future management proposes is necessary to consider both zones.

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RESUMEN

Un análisis de la proporción de individuos maduros, crecimiento, mortalidad, patrones de selección, reclutamiento y de producción y biomasa por recluta se llevó a cabo en las poblaciones de *P. occidentalis* y *P. stylirostris*, ubicadas en la parte externa del Golfo de Nicoya, Puntarenas, Costa Rica. De acuerdo con los resultados se presentan en ambas poblaciones patrones de maduración, de reclutamiento y de crecimiento muy similares a los obtenidos en la parte interna del Golfo de Nicoya. Altos valores de mortalidad y de sus tasas de explotación fueron obtenidos en ambas poblaciones, lo que indica que ambas se encuentran sobreexplotadas. Se presenta el análisis de producción y biomasa por recluta para ambas poblaciones de camarones blancos.

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