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Decadal variability in growth of the Caribbean spiny lobster *Panulirus argus* (Decapoda: Paniluridae) in Cuban waters

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Abstract: Annual von Bertalanffy growth parameters of the Caribbean spiny lobster (*Panulirus argus*) in Cuban waters were estimated from a long term study (40 years) by length-based methods ELEFAN and the new version of SLCA. Data of around 800 000 lobsters (with carapace length ranging 14 to 199mm) were randomly sampled in artificial shelters (a non selective fishing gear very common in the lobster fishery), through the field monitoring program established for this species since 1963 in 14 localities of southwestern Cuban shelf. The software ELEFAN showed problems to converge in an optimal combination of the instantaneous growth coefficient (K) and the asymptotic length (L_{∞}) of the von Bertalanffy equation, whereas the new SLCA software produced value estimates of K between 0.20 and 0.27 year⁻¹ and values of L_{∞} between 177 and 190 mm carapace length, all within the range reported in the literature. The standardized anomalies of both parameters showed the presence of cycles along the analyzed time series. Decadal variability in growth parameters was revealed through the spectral analysis indicating cycles of 16 and 20 years for K and of 16 years for L_{∞} . The incidence of some factors such as biomass and temperature that modulate growth in this crustacean was explored, using a nonlinear multiple regression model. These combined factors explained 33% and 69% of the variability of K and L_{∞} respectively. The growth coefficient appeared to be maximum with annual mean sea surface temperature of 28.1°C and the largest L_{∞} is reached at a annual men biomass level of 23 000 t. These results should be the basis to understand the Cuban lobster population dynamics. Rev. Biol. Trop. 53(3-4): 475-486. Epub 2005 Oct 3.

Key words: Growth parameters, decadal variability, *Panulirus argus*, Cuba.

The Caribbean spiny lobster, *Panulirus argus* (Latreille, 1804), is widely distributed throughout the tropical and subtropical waters of the Western Central Atlantic Ocean, ranging from North Carolina, U.S.A., to Sao Paulo in Brazil, and extending through the Bahamas, Bermudas and the Greater and Lesser Antilles. It is usually recorded from shallow waters, but may occur down to about 90 m (Tavares 2002). The fishery of this crustacean has significant importance for the countries of the region. The attractiveness of this low cost and high revenue activity has lead the resource to be in a fully to

over-exploited conditions along its entire distribution range (Puga and de León 2003).

Cuba, one of the largest producers of *P. argus*, carry out their fisheries all around the country, but this activity is particularly important in the Southwest shelf, commonly named Gulf of Batabano. This area produce 60% of the total national catch and is characterized by shallow-water rocky habitats, mangroves and seagrass beds (Páez and Revilla 1991), where the Caribbean spiny lobster found the adequate habitat to develop the benthic stages of its life history. The most important features on the biology, fisheries and management

of the species in Cuban waters are examined by Baisre and Cruz (1994).

Since 1963, a biological sampling program in Cuban fishing grounds provides monthly information on size, sex-ratios, reproductive activity and molting frequency of *P. argus* stock. Fishery information is also available through a detailed data-collection system. Both sources are systematically analyzed at the Fisheries Research Centre, which gives off the recommendations to be annually included in the management plan for the sustainable use of the stock (Puga and de León 2003).

Age of crustaceans cannot be directly determined due to the lack of permanent hard body parts, so most growth studies on Caribbean spiny lobster have relied on length-frequency analysis. More than 20 estimates of *P. argus* growth parameters, adjusting the von Bertalanffy growth function (VBGF), have been obtained in different areas of the Western Central Atlantic in several times. The obtained parameters are listed in Arce and de León (2001), including those from Cuba during the 60's (Buesa 1972), the 70's (Cruz *et al.* 1981), the 80's (Baez *et al.* 1991, de León *et al.* 1993) and the 90's (de León *et al.* 1995). Only a few studies have explored other functions to describe growth in Caribbean spiny lobster (Arce *et al.* 1991, Zetina and Rios 1999).

Taking into account the long-term series available of biological information (1963-2002), this study was conducted to obtain annual growth parameter of *P. argus* in Cuban waters using a single methodology to adjust VBGF, to determinate periods of particularly fast or slow growth and the existence of some kind of inter-annual to decadal patterns in their behavior. The incidence of some factors that modulate growth in this valuable crustacean is explored.

MATERIALS AND METHODS

Data sources: The biological data collection system on *P. argus* was designed to obtain random samples of lobsters from artificial shelters, a non-selective fishing gear very

common in the Cuban lobster fishery. Details of the sampling methodology are described by Cruz (2002). Monthly field samples in the Gulf of Batabano from 1963-2002 were carried out in 14 localities. The information of about 800 000 lobsters has been processed at the Centro de Investigaciones Pesqueras (C.I.P.) between 1963-2002 to generate monthly frequency distributions of carapace length (*CL*), considering 5 mm class intervals. The Table 1 shows the number of lobsters and the length range sampled by year.

While local conditions (temperature, food, etc) may affect the precise course of the growth, data of monthly mean sea surface temperature (*SST*) in the Gulf of Batabanó (22.5° N and 82.5° W) was average over the year for the period 1963 – 2002 (Table 2) to test the relevance of temperature over growth parameters. The *SST* data series were kindly provided by the Centro de Investigaciones Biológicas del Noroeste, México, originally obtained from <ftp://ftp.cdc.noaa.gov> and based on optimal interpolation sea surface temperature according to Reynolds *et al.* (2002).

To explore the relationship between *K* and L_{∞} with lobster biomass, annual mean lobster biomass (*B*) for the analyzed period (Table 2) was gently contributed by Puga as an extension of his previous paper (Puga *et al.* 2005) based on a sequential population analysis (SPA) with the ADAPT framework.

Growth parameters estimation: Despite of being criticized (Knight 1968, Roff 1980), the simple VBGF continues being the most commonly used growth model in fishery science, because of its easy way to be incorporated in many stock assessment techniques:

$$L_t = L_{\infty} \{1 - \exp[-K(t - t_0)]\}$$

Where:

L_{∞} is the asymptotic average maximum body size.
K is the growth coefficient which determines how quickly L_{∞} is attained.

t_0 is the hypothetical age when L_t is zero.

TABLE 1
Number of lobsters and the carapace length range
sampled by year (1963-2002)

Year	N	CL min. (mm)	CL max. (mm)
1963	13919	31	142
1964	20220	27	147
1965	35543	26	149
1966	10223	45	153
1967	14468	31	137
1968	9999	46	142
1969	10701	35	152
1970	11040	45	160
1971	16357	37	154
1972	16778	37	159
1973	19675	41	148
1974	21589	35	158
1975	31405	41	173
1976	37271	46	162
1977	30559	45	150
1978	28874	47	158
1979	12457	35	149
1980	13376	50	153
1981	6408	46	158
1982	8078	45	150
1983	17974	28	157
1984	10734	27	160
1985	11484	30	163
1986	16814	26	181
1987	21574	25	173
1988	19122	25	186
1989	26814	23	192
1990	26436	29	167
1991	62984	16	198
1992	48992	30	199
1993	53439	14	199
1994	11188	26	179
1995	14628	24	192
1996	14086	47	167
1997	12420	44	169
1998	13340	40	168
1999	15597	41	165
2000	10553	45	166
2001	8576	43	159
2002	12089	45	163

TABLE 2
Annual sea surface temperature (SST) and annual
mean lobster biomass (B) data for the Gulf of Batabanó
(1963-2002)

Year	Annual mean SST (° C)	Annual mean B (t)
1963	28.17	15180
1964	28.10	15633
1965	28.03	16956
1966	28.12	16207
1967	28.06	15880
1968	28.09	16323
1969	28.02	16822
1970	27.86	16002
1971	27.90	16829
1972	27.91	17387
1973	27.97	18647
1974	27.81	21137
1975	27.84	20649
1976	27.70	20070
1977	27.92	18389
1978	28.05	20949
1979	27.93	20579
1980	28.06	20287
1981	27.98	20801
1982	28.15	21224
1983	27.86	21415
1984	27.78	23517
1985	28.01	24482
1986	28.05	23909
1987	28.01	24866
1988	27.88	24893
1989	27.83	24410
1990	28.02	23238
1991	28.03	25240
1992	27.88	24624
1993	27.93	23770
1994	28.06	23452
1995	28.15	21788
1996	27.94	20083
1997	28.01	18892
1998	28.06	19097
1999	27.96	18663
2000	27.98	17369
2001	28.07	18520
2002	28.02	19918

Other models concerning growth have been developed; this is the case of molt-based model which has apparently a more realistic fit to represent growth in lobster (Caddy 1977), however, it is more rigorous regarding

data-requirements such as high expensive tagging programs and/or lab studies.

Taking into account the nature of the information available, the three-parameter VBGF was fitted to length-frequency data by two

indirect methods to estimate growth parameters: Electronic Length Frequency Analysis, ELEFAN 1 (Pauly and David 1981) and New Shepherd's Length Composition Analysis, NSLCA (Shepherd 1987, Pauly and Arreguin-Sánchez 1995). Both routines are available in FAO ICLARM stock assessment tools, FISAT, in its Windows version (Gayaniño *et al.* 1996).

The ELEFAN routine in FISAT suit of programs fits VBGF by a non-parametric method where an optimum curve, which cross through the most number of modes, is selected based on a goodness of fit value.

The NSLCA method is similar to ELEFAN, maximizing a non-parametric scoring function. It fits a circular function to the overall length-frequency distribution of each sample, and in the process, computes a total score function for a set of samples. At the maximum score function, the growth curve with the testing L_∞ and K values predicts the modal lengths closer to the observed values.

Annual values of t_0 were obtained by the inverse VBGF: $t_0 = t + 1/K * \ln[(1 - L_t)/L_\infty]$, considering the analysis proposed by Cruz *et al.* (1991) in puerulus collectors in Cuban waters, where puerulus stage of *P. argus* returns to the SW Cuban shelf seven months after larval release, attaining a length of 5.78 mm of carapace length (CL).

The values of L_∞ expressed in CL were transformed into total lengths (TL) according the relationship published by Cruz (2002) ($TL = 2.5402 * CL + 36.3535$) to calculate the overall growth performance index Φ' (Pauly and Munro 1984): $\Phi' = \log_{10} K + 2 \log_{10} L_\infty$.

The overall growth performance indexes Φ' were also calculated with L_∞ and K values listed in Arce and de Leon (2001) concerning growth studies of Caribbean spiny lobster in Western Central Atlantic. The index Φ' were used as a tool to examine differences among the present annual estimates as well as with others *P. argus* growth parameters in other areas and/or periods.

Time series analysis of growth parameters: The presence of fluctuations and patterns in the annual growth parameters were examined along the 40 year series. A preliminary searching was done through the standard anomalies (SA) behavior around the mean values of K , L_∞ and Φ' for the analyzed period: $SA = (X_i - X_m)/S$, where X_i is the value of the parameter in the year i , X_m is the mean value of the parameter for the considered period and S is the standard deviation. Notwithstanding the close statistical relation between K and L_∞ as a result of metabolism and growth across species (Jensen 1997), the average maximum size always will be strongly sensitive on the nature of the length range sampled available (Gulland and Rosenberg 1992), then the decision was focused to investigate the temporal patterns on the time series of K and L_∞ instead off explore Φ' patterns directly.

Rhythmic cycles in the annual data of both time series were explored using autocorrelation function. Dominant periodicities were inspected by single spectrum (Fourier) analysis to decompose each series into the energy spectra that shows the concentration of energy or variance under the curve, using a Hamming filter to smooth the periodogram value. All time-series analyses were performed using the computer program Statistica 6.0 (StatSoft 2001).

Relation with temperature and biomass: Present knowledge of the relationship between *P. argus* growth parameters (K and L_∞) and environmental variables is not sufficient to know a priori their correct form. For that reason, it was applied a nonlinear multiple regression model (or generalized additive model) using Alternating Conditional Expectations algorithm, ACE (Briedman and Friedman 1985) to explore the relationships between the response (K and L_∞) and the predictor variables (SST and B). This methodology was successfully applied to analyze the relation between recruitment and climatic factors in pelagic stocks of Californian

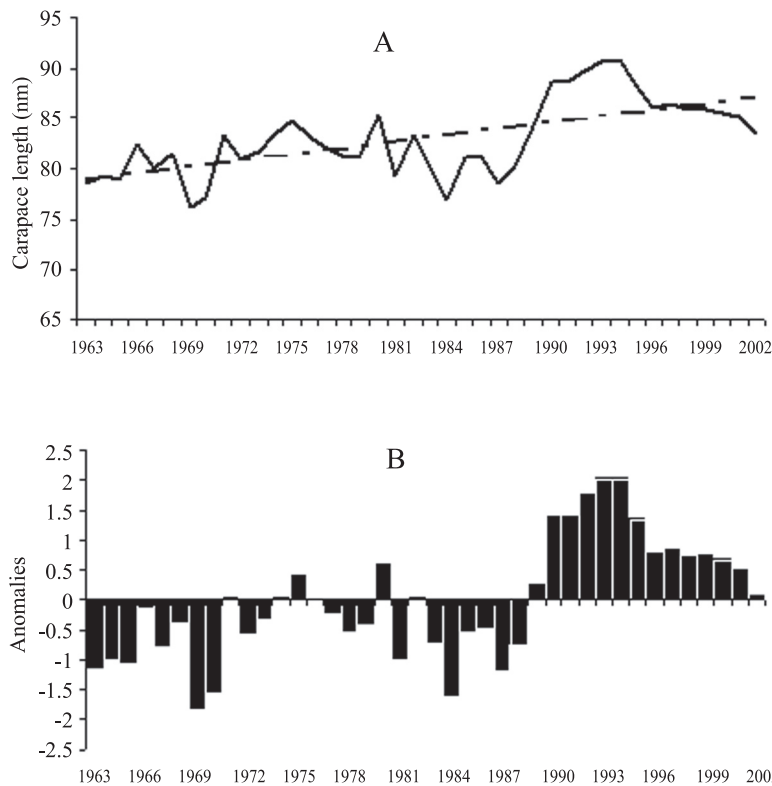


Fig. 1. (A) Annual mean carapace length (CL) and its tendency along the time series. (B) Standardize anomalies of CL.

anchovy (Cury *et al.* 1995) to obtain an “optimal environmental window”.

RESULTS

Lobster sizes sampled through the four decades has a mean *CL* of 83.02 mm and a minimum and maximum *CL* of 14 and 199 mm respectively. An evidence of a positive tendency of mean *CL* is observed along the time series ($y = 0.22092 + 78.737$, Fig. 1a), reaching the highest values during the 1990's. Obvious differences are observed between the average lengths of each year. Moreover, at first glance the standardize anomalies of average *CL* series (Fig. 1b) reveals the possible presence of periods: two with values generally below the mean (1963-1970 and 1980-1988), one around the mean (1971-1979)

and the last (1990-2002), with values greater than the general average *CL*.

Annual growth parameters by ELEFAN routine does not converge in an optimal estimation in the 25% of the years analyzed. The rest of the years show a tendency to overestimate L_{∞} , in the 50% of the cases, with values very far from maximum *CL* reported for the species, 225 mm *CL* in SE Cuba (de León *et al.* 1995) and in the Mujeres Island, Mexico (González-Cano 1991).

The results obtained with NSLCA routine are better, due to a good convergence of growth parameter in all cases. The L_{∞} values obtained by NSLCA vary between 170 and 199.1 mm *CL* and parameter *K* fluctuates from 0.20 to 0.27 year⁻¹. Average values for L_{∞} and *K* were 183.6 mm *CL* and 0.2405 year⁻¹ respectively.

The combination of annual growth parameters provided indexes Φ' oscillating from

2.71 and 2.87 with an average of 2.78. In other localities and/or periods, index Φ' ranged from 2.54 and 3.18 and the average value is 2.79 (papers cited by Arce and de León 2001). A summary of present results of annual estimates for L_∞ and K as well as t_0 and Φ' parameters calculated are presented in Table 3.

Since there is much interannual variability in K and L_∞ time series, there are significant features exposed in the plots of standardized anomalies of K (Fig. 2a) and L_∞ (Fig. 2b) along the 40 years analyzed. Both parameters denote cyclic patterns, although it is more evident in the case of K , presenting well defined periods of low and high values, whereas L_∞ also seems to have incorporated some positive trend.

The autocorrelation function indicated cycling around 15 years for L_∞ and 18 years for K .

To carry out time series analysis, previously both series were transformed by tapering at 10% to reduce linkage in the periodogram and also the respectively mean and tendency (K : mean = 0.2405, tendency = 0; L_∞ : mean = 183.6,

tendency = $x[-9.074 + 0.4426*t]$) were removed. Spectrum (Fourier) analysis of parameter K series indicated the presence of low-frequency patterns, with significant cycles of 16 and 20 years ($\alpha= 0.05$) (Fig. 3a). Similar results were observed in the spectrum of L_∞ series, but the variance was only significantly concentrated in the cycle of 16 years (Fig. 3b).

The relationships between K and L_∞ as response factors, with annual means SST and B as predictors, were explored by plotting the raw data (Fig. 4). No significant relationships between K with annual mean SST (Fig. 4a) and with B (Fig. 4b) were observed, but a positive trend is observed in the first case and a negative in the second one. Asymptotic length and annual mean SST (Fig. 4c) also show no significant relation, however, it seems to have a positive correlation between L_∞ with annual mean B (Fig. 4d).

Using the ACE algorithm, the shape of the optimal empirical transformation of the predictor variables from this model are presented in Fig. 5, corresponding 5a and 5b to response

TABLE 3
Annual growth parameters estimated by new SLCA and the growth performance indexes (1963-2002)

Year	L_∞ mm CL	K year ⁻¹	t_0 year	Φ'	Year	L_∞ mm CL	K year ⁻¹	t_0 year	Φ'
1963	177.5	0.24	0.44	2.76	1983	176.0	0.26	0.45	2.78
1964	175.0	0.22	0.43	2.71	1984	184.0	0.25	0.45	2.80
1965	177.4	0.27	0.46	2.81	1985	183.0	0.25	0.45	2.80
1966	170.0	0.27	0.45	2.77	1986	190.4	0.25	0.46	2.83
1967	170.2	0.27	0.45	2.77	1987	186.0	0.23	0.44	2.77
1968	170.5	0.27	0.45	2.77	1988	189.7	0.23	0.45	2.79
1969	171.0	0.26	0.45	2.76	1989	194.4	0.22	0.44	2.79
1970	170.6	0.24	0.44	2.72	1990	196.8	0.22	0.44	2.80
1971	182.5	0.21	0.43	2.72	1991	185.5	0.22	0.44	2.75
1972	181.4	0.21	0.43	2.72	1992	195.5	0.2	0.43	2.75
1973	181.6	0.21	0.43	2.72	1993	196.1	0.22	0.44	2.80
1974	182.5	0.21	0.43	2.72	1994	194.6	0.23	0.45	2.81
1975	189.0	0.22	0.44	2.77	1995	192.6	0.25	0.46	2.84
1976	180.0	0.23	0.44	2.75	1996	180.0	0.24	0.44	2.77
1977	188.0	0.25	0.46	2.82	1997	180.1	0.24	0.44	2.77
1978	180.3	0.24	0.44	2.77	1998	179.6	0.24	0.44	2.77
1979	187.0	0.25	0.45	2.82	1999	199.1	0.25	0.46	2.87
1980	182.2	0.25	0.45	2.79	2000	190.1	0.27	0.47	2.86
1981	183.5	0.25	0.45	2.80	2001	180.0	0.26	0.45	2.80
1982	179.0	0.25	0.45	2.78	2002	189.4	0.27	0.47	2.86

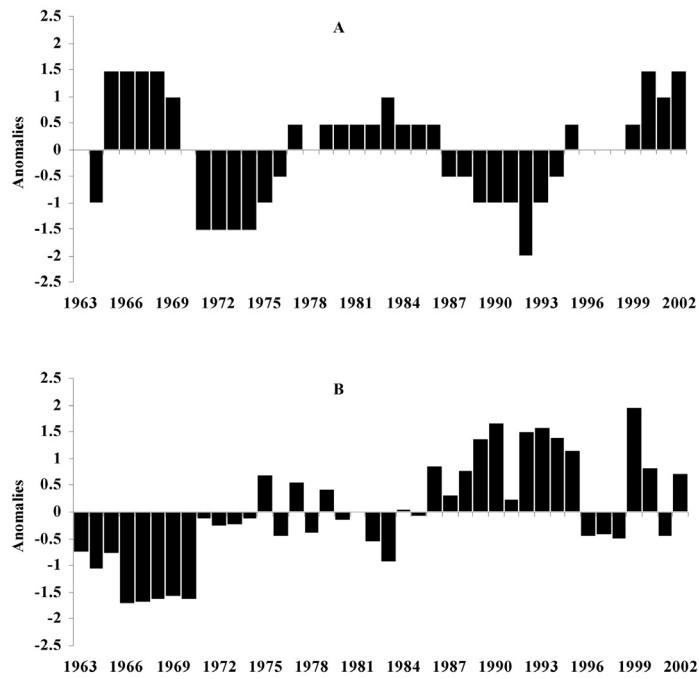


Fig. 2. Standardize anomalies of (A) the instantaneous growth parameter and (B) the asymptotic length along the 40 years studied.

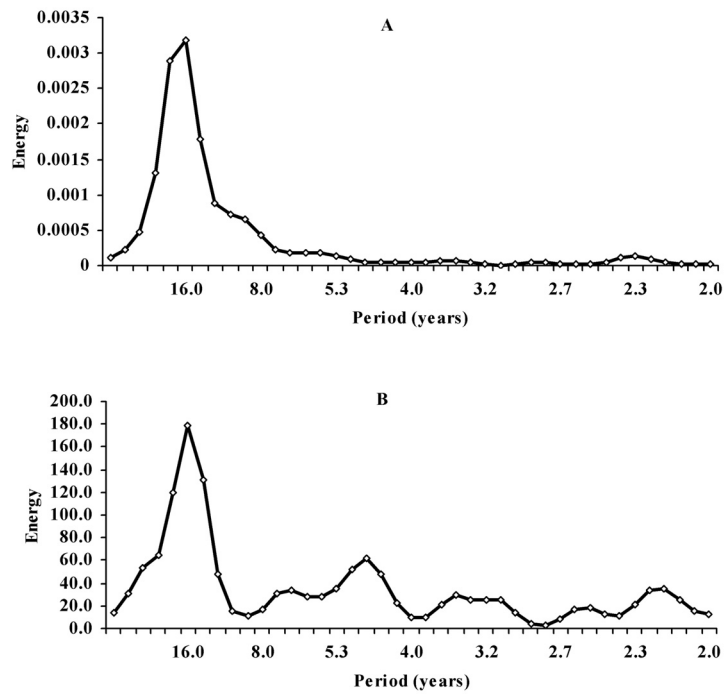


Fig. 3. Spectral analysis of (A) the instantaneous growth parameter with significant cycles of 16 and 20 years and (B) the asymptotic length denoting the variance concentrated in the cycle of years.

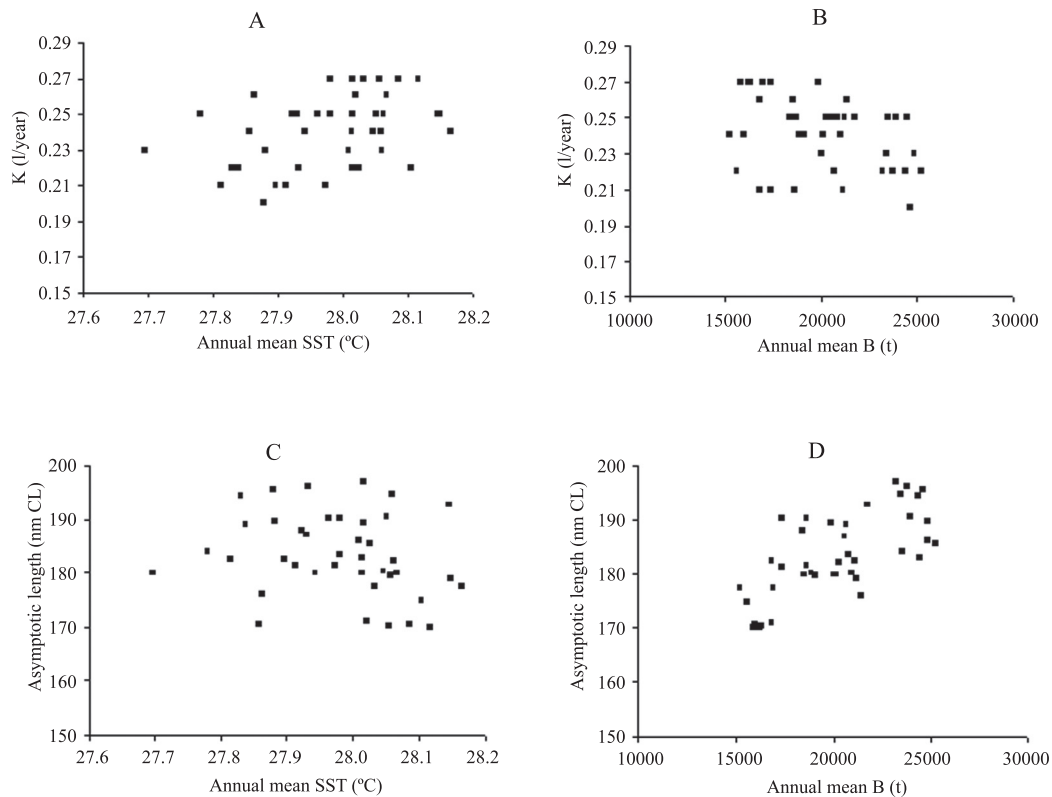


Fig. 4. Plotting raw data of the (A) Annual mean SST (°C) and (B) annual mean biomass (t) versus annual instantaneous growth parameter- K . (year^{-1}) as dependant variable, and the corresponding transformation of (C) annual mean SST and (D) annual mean biomass with the asymptotic length parameter- L_{∞} (mm CL) as response variable.

variable K and 5c and 5b with response variable L_{∞} . Predictor variables explain the 33% of the variability of K and the 69% of L_{∞} . However, when both predictors are considered separately in the analysis for each response, the temperature is responsible of the 22% of the variability of K and annual mean B explain the 61% of variance of L_{∞} . Growth coefficient looks like to be maximum with annual mean SST of 28.1°C, and the largest L_{∞} are reached with levels of annual mean B of 23 000 t.

DISCUSSION

Many studies focus on growth estimates have been made for *P. argus* in the Western Central Atlantic, but growth patterns seem to vary markedly between localities probably due to differences in environmental conditions,

length composition of the lobsters examined and the method used to estimate growth parameters. It is important to highlight the differences between present results and those obtained by Ivo and Pereira (1996) through ELEFAN routine in Brazilian waters ($L_{\infty} = 257$ mm CL; $K=0.32$ year^{-1} ; $\Phi' = 3.18$), by Arce (1990) with SLCA and data of Yucatan Bank in Mexico ($L_{\infty} = 142$ mm CL; $K=0.22$ year^{-1} ; $\Phi' = 2.54$), by Buesa (1972) with data from the 60's of SW Cuban shelf using Bhattacharya ($L_{\infty} = 174$ mm CL; $K=0.16$ year^{-1} ; $\Phi' = 2.56$) and those from Baez *et al.* (1991) through ELEFAN routine based on data from the 80's in the last mentioned area ($L_{\infty} = 228$ mm CL; $K=0.30$ year^{-1} ; $\Phi' = 3.06$).

The results provide evidence of a decadal pattern in the growth of spiny lobster. Decadal cycles in the growth and recruitment have been

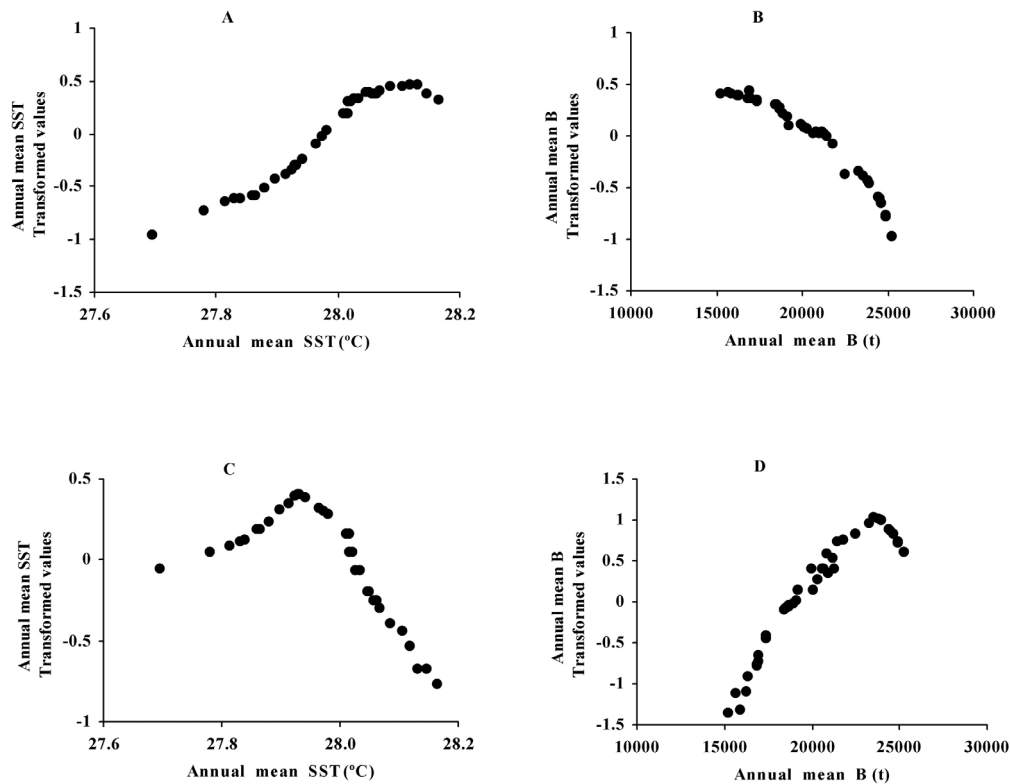


Fig. 5. Optimal empirical transformations from the ACE algorithm, period 1963-2002, of (A) annual mean SST and (B) annual mean biomass using the instantaneous growth parameter- K . (year^{-1}) as dependant variable, and the corresponding transformation of (C) annual mean SST and (D) annual mean biomass with the asymptotic length parameter- L_{∞} (mm CL) as response variable.

documented for halibut in the Pacific (Clark *et al.* 1999), but no details of this kind of cycles has been found in literature for a tropical organism such as the Caribbean spiny lobster, perhaps due to a lack of long-term biological studies. Acosta *et al.* (1997) determined temporal patterns in *P. argus* puerulus recruitment in Florida Keys identifying weekly annual patterns in the supply of postlarvae. They also observed an interannual variability in the magnitude of the puerulus recruitment, but the time series of 8 years data used was not suitable for determining low frequency cycles.

Many are the reasons that could cause this growth pattern in the spiny lobster. As growth also depends on biomass via food competition (Pitcher and Hart 1982), an apparent dependence of growth on population density is common in studies of population dynamics.

However, the results here presented, based on the physiological concept underlying the von Bertalanffy growth function (Beverton and Holt 1957), density-dependence growth is revealed on the asymptotic length (or asymptotic weight) behavior, but not on the growth rate at which this size is approached. Although spiny lobsters are communal in nature, at very high densities, their growth can be depressed (Pollock 1991, Briones-Fourzan and Lozano-Alvarez 2003), suggesting a density-dependent regulation of growth rate.

The evidence of decadal cycles in the growth coefficient of Caribbean spiny lobster perhaps has their origins in decadal environment variations. If we review the environmental conditions in Cuban waters, located in the North Atlantic sector, they must have an influence of three interconnected phenomena (Hurrell *et al.*

2001, Marshall *et al.* 2001). The interannual climatic variability is determined by the easterly trade winds and has the influence of the prevailing ocean-atmosphere interaction in the northern sector of tropical Atlantic, where long-term time *SST* series contains low-frequency cycles in the scale of 10 to 20 years (Carton *et al.* 1996, Xie and Carton 2004).

Temperature is a decisive factor for growth (Fry 1971), because it controls the rate of metabolism. Caribbean spiny lobster, as a tropical crustacean, do not have a specific molting season, even though it has been proved that the process goes on faster in summer than in winter (Munro 1974, Davis 1981, Hunt and Lyons 1986, Forcucci *et al.* 1994).

Present results agree with the range reported for the optimum temperature for growth and survival in palinurids (Chittleborough 1977) in the range of 25°- 28°C, but temperatures higher than this maximum are detrimental for lobster growth.

It seems that the optimal “window” for a successful growth rate in *P. argus* in Cuban waters according to temperature is around the 28°C, but it will be necessary to explore other abiotic (like photoperiod, oxygen and salinity) and biotic (food availability and food quality) factors that limit the growth of organism (Fry 1971, Pitcher and Hart 1982). An additional motive of further investigation will be long-term field studies of these factors and their relation with juvenile stage abundance in nursery areas, where the changes could be more dramatic.

The traditional practice of predictive models used for fish resources is to consider population parameters such as growth, natural mortality, and recruitment as averages (stationary models). To take in consideration these results should be the basis for further advances in the understanding and prediction of Cuban lobster fishery dynamics and the role that could be played from now on in suitable management policies depending on the kind of variation observed.

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RESUMEN

Los parámetros de crecimiento anuales para la langosta espinosa del Caribe (*Panulirus argus*) en aguas cubanas se estimaron para una serie de 40 años de datos de composición por longitud, a través de los métodos indirectos basados en la talla ELEFAN y el nuevo SLCA. Las composiciones por talla de alrededor de 800 000 langostas (con un ámbito de longitud de cefalotórax entre 14 y 199 mm) fueron obtenidas en muestreos aleatorios, realizados en arrecifes artificiales (arte de pesca muy común en esta pesquería cubana), a través del programa de monitoreo de campo establecido para esta especie desde 1963 en 14 localidades del Golfo de Batabanó, plataforma suroccidental de Cuba. El método ELEFAN mostró problemas para convergir en una combinación óptima del coeficiente de crecimiento (K) y el largo asintótico (L_{∞}) de la ecuación de von Bertalanffy, mientras que el método nuevo SLCA proporcionó valores de K entre 0.20 y 0.27 año⁻¹ y de L_{∞} entre 177 y 190 mm de longitud de cefalotórax, todos dentro del ámbito reportado en la literatura. Las anomalías estandarizadas de ambos parámetros mostraron la existencia de ciclos a lo largo de la serie de tiempo analizada. El análisis espectral demostró una variabilidad decadal en los parámetros de crecimiento, con ciclos significativos de 16 y 20 años para K y de 16 años para L_{∞} . La incidencia de algunos factores, que modulan el crecimiento en este valioso crustáceo, como la biomasa y la temperatura fue explorada usando un modelo no-lineal de regresión múltiple. Los resultados indicaron que ambos factores combinados explican el 33% y el 69% de la variabilidad de la K y del L_{∞} respectivamente. El coeficiente de crecimiento alcanzó

su máximo con temperaturas medias anuales de superficie del mar de 28.1° C y el mayor valor de L_{∞} se alcanza con niveles en la biomasa media anual de 23 000 t. La consideración de estos resultados debe ser la base para estudios posteriores en el conocimiento y predicción de la dinámica de la población de langosta en Cuba.

Palabras clave: Parámetros de crecimiento, variabilidad por década, *Panulirus argus*, Cuba.

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