Evaluation and management of blue crab *Callinectes sapidus* (Rathbun, 1896) (Decapoda - Portunidae) fishery in the Estuary of Cananéia, Iguape and Ilha Comprida, São Paulo, Brazil

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(With 6 figures)

Abstract

The Estuary of Cananéia, Iguape and Ilha Comprida is a part of the Estuarine Lagoon System of Cananéia, Iguape and Paranaguá , on the south coast of São Paulo State, Brazil. It has been recognised for its high standards of environmental conservation. The objective of this paper was to assess the blue crab (*Callinectes sapidus*) fishing in the region, from January 1998 to December 2006, and obtain supportive data to implement technical rules for the rational exploitation and resulting conservation of this resource. The results show a remarkable decrease in the fisheries' abundance index (CPUE) up to 2005, from 9.4 to 4.0 kg/hour, mainly caused by an increase in fishing effort, from 1,960 to 13,776 hours on a yearly basis. With the decrease in the fishing effort in 2005 and 2006, the abundance index reacted positively, indicating a recovery of the exploited population. Due to the lack of appropriate regulation limiting the fishing effort and organising the fluctuating admission rates of new fishermen, there is a noticeable increase of the effort, above the sustainable level. Therefore, there is a need for measures to limit and control the admission of fishermen in this activity. One of the measures to be considered is the establishment of regular periods where fishing the species is prohibited (called "defeso"), each year, especially from September to January. Another measure is to create a fishermen registry and special licenses, to limit the number of new entrants. Such actions require, for their implementation, a co-managed initiative, involving the blue crab fishermen themselves, governmental agencies and resource management researchers, and the integration of ecological, socioeconomic and cultural dimensions.

Keywords: Callinectes sapidus, artisanal fishing, CPUE, management.

Avaliação e gestão da pesca de siri-azul *Callinectes sapidus* (Rathbun, 1896) (Decapoda - Portunidae) no Estuário de Cananéia, Iguape e Ilha Comprida (São Paulo, Brasil)

Resumo

No litoral sul do Estado de São Paulo (Brasil), encontra-se o estuário de Cananéia, Iguape e Ilha Comprida que está inserido no Complexo Estuarino-lagunar de Cananéia, Iguape e Paranaguá, reconhecido pelo elevado grau de conservação ambiental. O presente documento visou avaliar a pesca do siri-azul (*Callinectes sapidus*) nesta região, no período de janeiro de 1998 a dezembro de 2006 no intuito de fornecer subsídios para a implementação de normas técnicas para a exploração racional e a conseqüente conservação do recurso. Os resultados mostraram que a pesca do siri-azul sofreu quedas significativas no índice de abundância (CPUE) até 2005, declinando de 9,4 a 4,0 kg/hora, tendo como principal causa o aumento do esforço pesqueiro, de 1.960 para 13.776 horas de pesca anuais. Com a diminuição do esforço pesqueiro em 2005 e 2006, o índice de abundância aumentou, respondendo positivamente a recuperação da população explorada. Devido à falta de regulamentação que limite o esforço pesqueiro e organize a variação de entrada de pescadores na atividade de pesca do siri-azul, observa-se um aumento do esforço de pesca acima do sustentável, havendo necessidade de medidas que limitem e controlem a entrada de pescadores na atividade. Um dos instrumentos que podem ser adotados é a implementação de períodos de defeso da espécie, principalmente no período de setembro a janeiro. Outra forma é o cadastramento e licenças especiais, limitando a entrada de pescadores na atividade. Tais ações devem ser concretizadas por meio do co-manejo que pressupõe a participação dos pescadores de siri, de órgãos de governo e de acadêmicos na gestão dos recursos, tomando-se como base a integração das dimensões ecológica, sócio-econômica e cultural.

Palavras-chaves: Callinectes sapidus, pesca artesanal, CPUE, gestão pesqueira.

1. Introduction

Crustacean fisheries account for 30% of all fish and shellfish landings by value worldwide (Smith and Addison, 2003), considered to be an important activity in several countries and one of the most valuable on the planet, especially regarding the commercialisation of animal parts (e.g. appendices) (Tully, 2003). The large production and consumption of crabs and blue crabs in North-American and European countries as well as in Japan is supplied by important commercial fisheries (Branco and Fracasso, 2004).

The literature on the activities of blue crab fisheries in Brazil is scarce, but this resource is known to be the bycatch of several fisheries. There is great fishing potential for the species of the genus *Callinectes*, since blue crab fisheries are still mostly artisanal, located in small fishing communities scattered along the Brazilian coast (Severino-Rodrigues et al., 2001).

There has been an ongoing interest in blue crab fisheries in the northeast of Brazil since the 1960's, when the state of Alagoas recorded an average annual yield of 57 tons. In southern Brazil, more precisely in the State of Santa Catarina, 1,545 tons were landed in 1970; these two data sets were the first on blue crab fishing to be collected in Brazil (Pereira-Barros and Travassos, 1972). Nowadays due to the scattered fishing effort, very little data is available on blue crab catches along the Brazilian coast, and the lack of a well-defined system for collecting data on the fisheries yield hinders the consolidation of reliable statistics that would allow estimating the real landing volume (Severino-Rodrigues et al., 2001). Mendonça and Barbieri (2001) presented more recent statistical data on blue crab commercial fisheries, including aspects such as socioeconomic conditions on the Brazilian coast, description of the activity and the gear employed. Other articles cited have described the species biology of the genus *Callinectes* and their presence not as the target species, but as bycatch of fisheries (Branco and Lunardon-Branco, 1993a b; Mantelatto and Fransozo, 1999).

The Cananéia, Iguape and Ilha Comprida estuary, on the southeastern coast of the State of São Paulo, Brazil, is

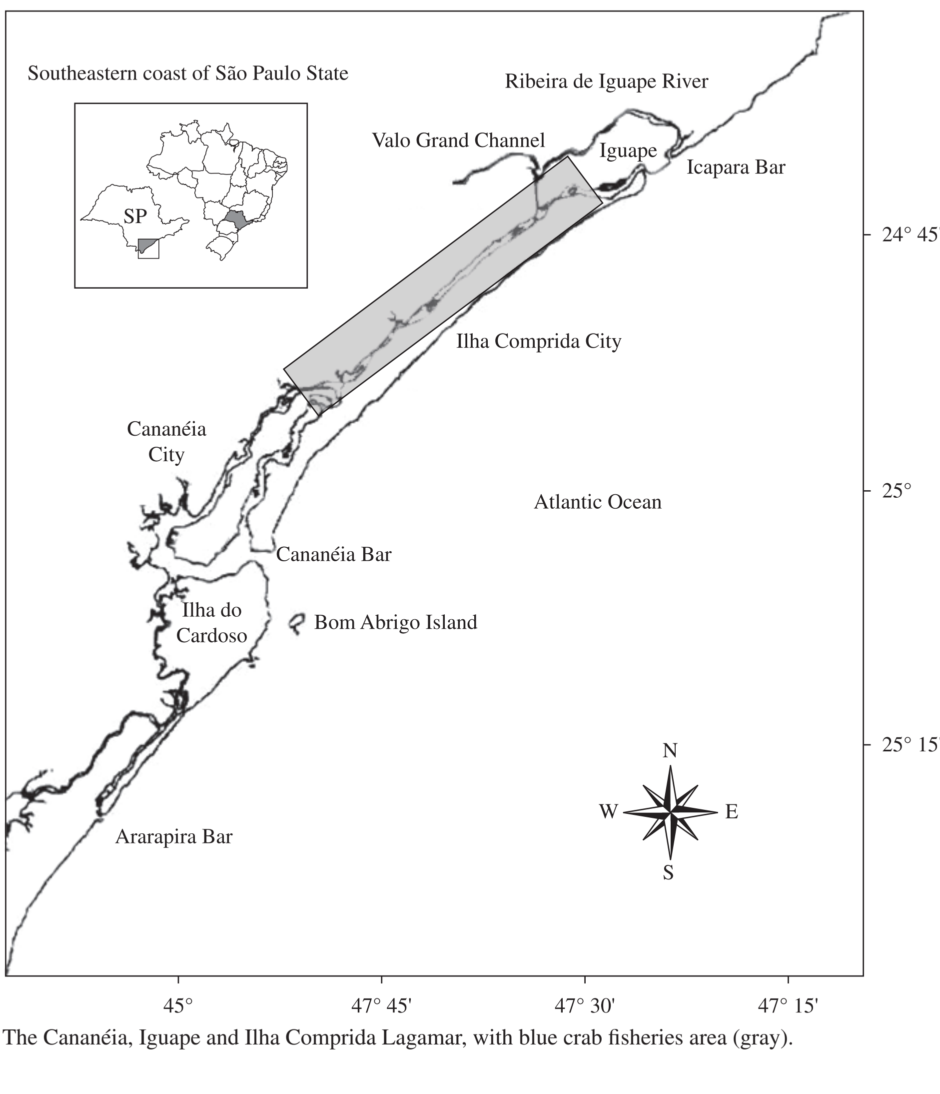

Figure 1. The Cananéia, Iguape and Ilha Comprida Lagamar, with blue crab fisheries area (gray).

inserted into the Cananéia, Iguape and Paranaguá Lagoon Estuarine System. The area is recognised both locally and internationally as the third most productive ecosystem of the South Atlantic, due to its well-conserved environmental features. In 1993, according to a later report, it was considered as an Atlantic Forest Biosphere Reserve (UNESCO, 2005); in 1999, it was nominated a World Natural Heritage Site for its importance for scientific research and the preservation of human values and traditional knowledge based on sustainable development patterns (UNESCO, 1999).

There is an intense fishing activity in that system, especially artisanal, comprising more than 3,000 fishermen, the lagoon area of the system and the adjacent coastal area being the main fishing grounds (Barreto et al., 2000; Machado et al., 2000; Mendonça and Barbieri, 2001; Mendonça and Katsuragawa, 2001).

Blue crab fishing, with *Callinectes sapidus* as the main species, is one of the local fishing activities that requires regulation. Blue crab fishing started in the 1990's and reaches more than 100 t per year, employing lift-nets, in professional and organised catches in the estuary (Mendonça and Barbieri, 2001). Due to its productivity and socioeconomic importance, it is constantly monitored and evaluated, with the purpose of maintaining its sustainability, i.e. keeping it at a level that does not affect the blue crab population, thus ensuring the continuing existence of the fisheries. The objective of this paper is the assessment of the blue crab (*Callinectes sapidus*) fisheries in the Cananéia, Iguape and Ilha Comprida estuary, and the obtaining of supportive data to implement technical rules for the rational exploitation and resulting conservation of this resource.

2. Material and Methods

This study was carried out in the Estuarine Lagoon System of Iguape-Cananéia-Paranaguá, on the southeastern coast of São Paulo, Brazil (25° 51' S and 47° 50' W), in the blue crab (*Callinectes sapidus*) fishing area called Cananéia, Iguape and Ilha Comprida estuary (Figure 1). The period of analysis ranged from January 1998 to December 2006, with data collection on the blue crab commercial fisheries landing.

In the period from January 1998 to December 2006, the produce was calculated from data collected at landing points, including fish markets and/or landing harbours, interviews with fishermen or stubs of fishermen payment coupons (Mendonça et al., 2000). The catch per unit of effort (CPUE) is widely used as a relative abundance index in several fisheries all over the world (Fréon and Misund, 1999; Gatica and Hernandez, 2003). Therefore, the CPUE was chosen as an indicator of the status of blue crab fisheries at the estuary. The CPUE in kilograms per fishing hours was estimated from the total monthly or annual production divided by the total effort in fishing hours of all the fishermen active during the index month or year. The annual CPUE was estimated from the total annual production divided by the total annual effort, and the average annual CPUE was calculated as the average of the monthly CPUEs. The analysis of variance (ANOVA) was used to check for significant differences in average annual CPUEs, and complemented with the Tukey test to indicate in which years these differences were more significant, considering an α of 5% (Callegari-Jacques, 2004). Due to the large range of the data, a log scale was used for the averages, reducing the amplitude of the curve.

To increase the ANOVA reliability, the analyses were complemented with the application of the F-test, to check for significant differences between annual CPUEs, comparing the annual CPUE trend line and zero line , and considering a significance level (α) of 5% (Zar, 1999).

From 1998 to 2005, samples were taken on a weekly basis and total size (crab carapace width, taken between the basis of the lateral spines) and sex data were recorded, to characterise the specimens caught. The ANOVA was used to check for significant differences between average monthly widths of unloaded specimens, with an α of 5%.

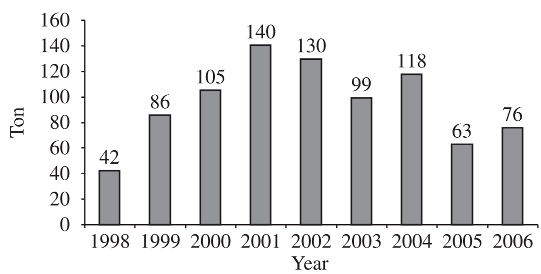

Figure 2. Yield total land of blue crab *Callinectes sapidus* from January 1998 to December 2006.

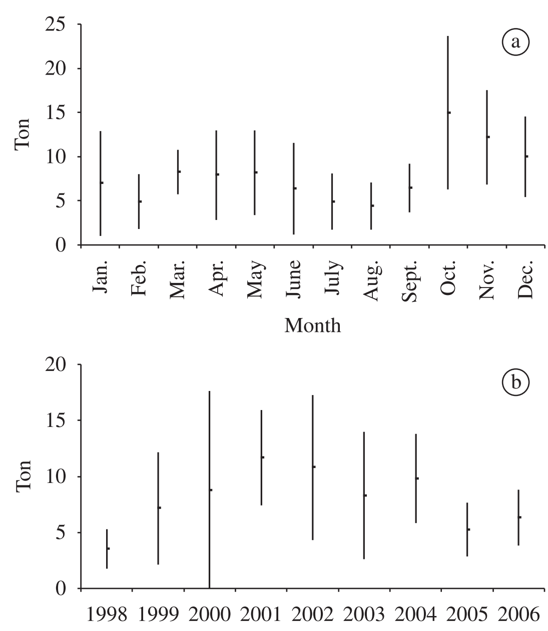

Figure 3. Yield average month (a) and annual (b) of blue crab *Callinectes sapidus* from January 1998 to December 2006.

The *chi*-square test (χ^2), with a confidence limit of 95% (Vazzoler, 1996) was applied to verify if the differences between sexual proportions were significant. The Propesq® (Ávila-Da-Silva et al., 1999) data bank was used to consolidate the production data.

3. Results

From January 1998 to December 2006, the annual yield ranged from 42 to 140 t, with an annual average of 95 t (±32 t). Increasing landing volumes were observed up to 2001, when the production reached 140 tons. From 2001 on, the production stabilised at 100 annual tons, decreasing to nearly 70 tons in the past two years (Figure 2). The highest landings always occurred in the second half of the year, mainly from October to December. Over the study period, the year 2000 showed the broadest range of variation in monthly landings, with peaks and valleys occurring

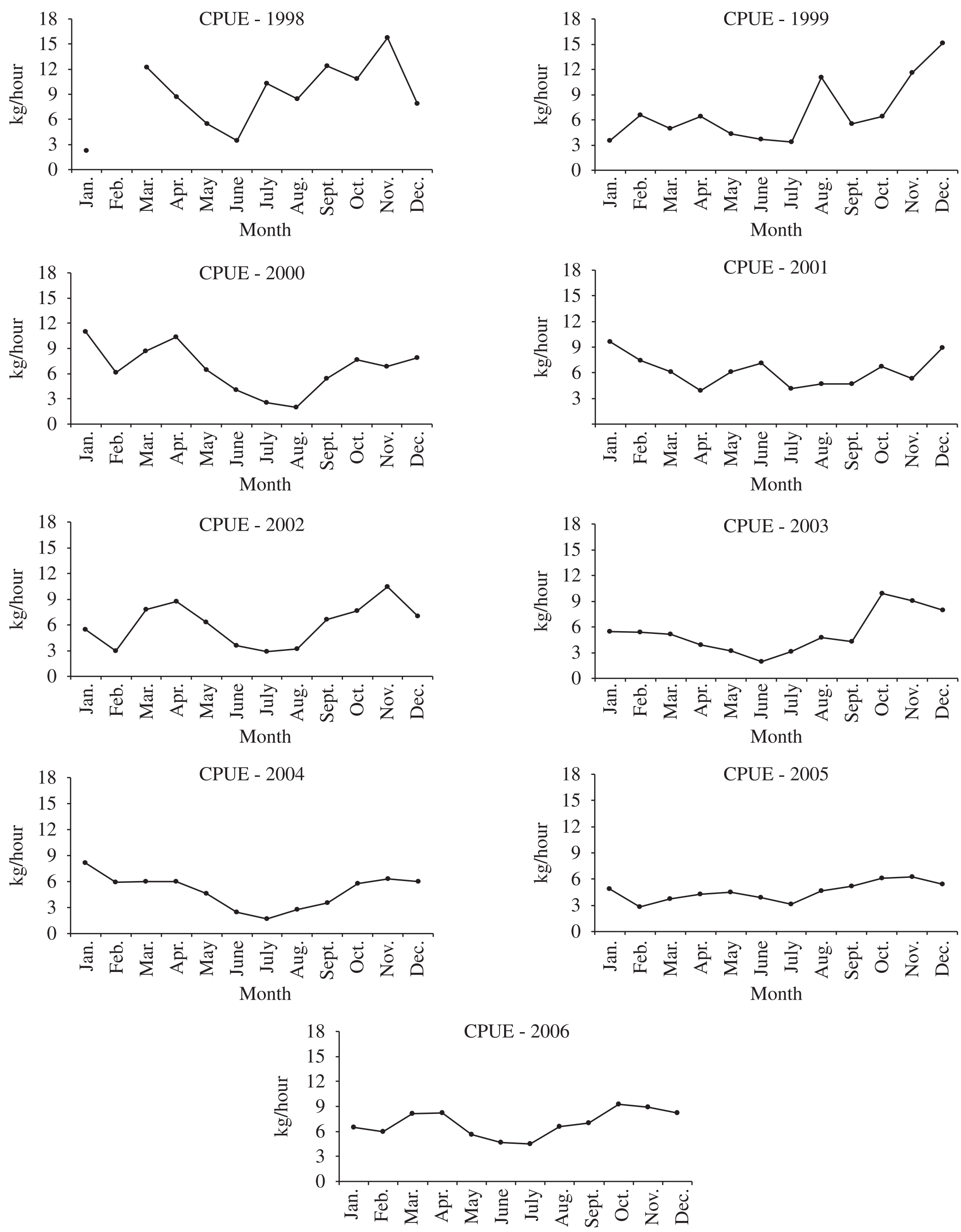

Figure 4. Capture for unit of effort (kg/hour) month between January 1998 and December 2006.

from one month to the other, throughout the whole year (Figure 3).

The catch per unit of effort (CPUE), considering all the years under study, ranged between 1.7 and 15.8 kg/hour. The lowest CPUE values were always registered in winter (Figure 4). As for monthly averages, the lowest values were registered in June, 3.9 kg/hour (± 1.5 kg/hour); the highest values of CPUE were registered in spring and summer, with monthly averages from 6.1 to 9.0 kg/hour. The annual CPUE ranged from 4.0 to 9.4 kg/hour, with the peak in 1998, gradually decreasing from then to 2005 (Figure 5).

The analysis of the average annual CPUE showed significant differences ($p = 0.05$) over the nine-year study period, even though these were not observed between consecutive years. The CPUE regression curve showed a slope significantly different from zero ($p < 0.05$), confirming the decline of the catches over the studied period (1998 to 2006) (Figure 5).

In the present study, the highest yields occurred during the second half of the year, in spring, when the highest number of active workers was recorded (42 fishermen in October, peaks average).

From January 1998 to July 2005 the fishermen worked an average of seven fishing hours per day. From August 2005 on, this average dropped to approximately

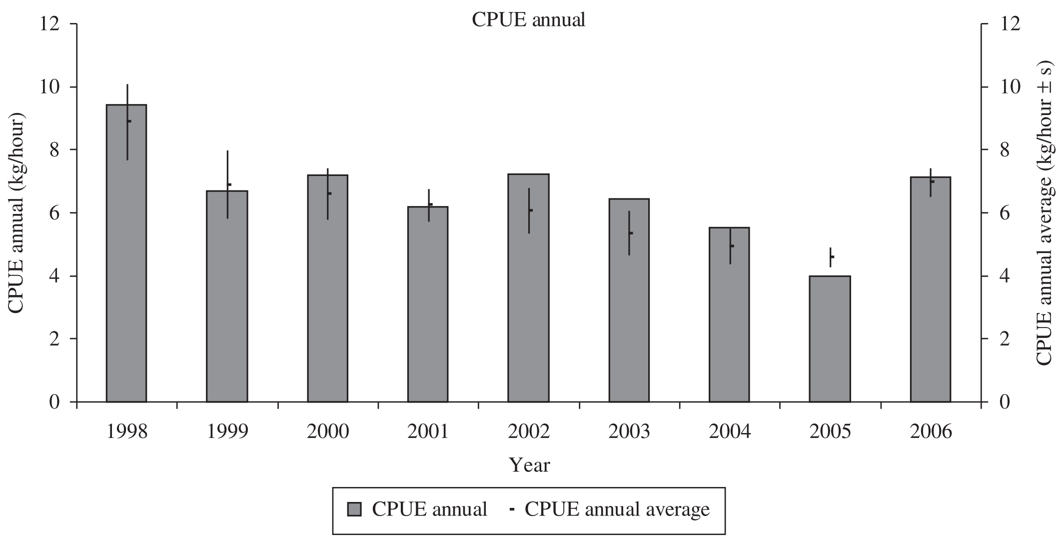

Figure 5. Capture for unit of effort (kg/hour) annual between January 1998 and December 2006.

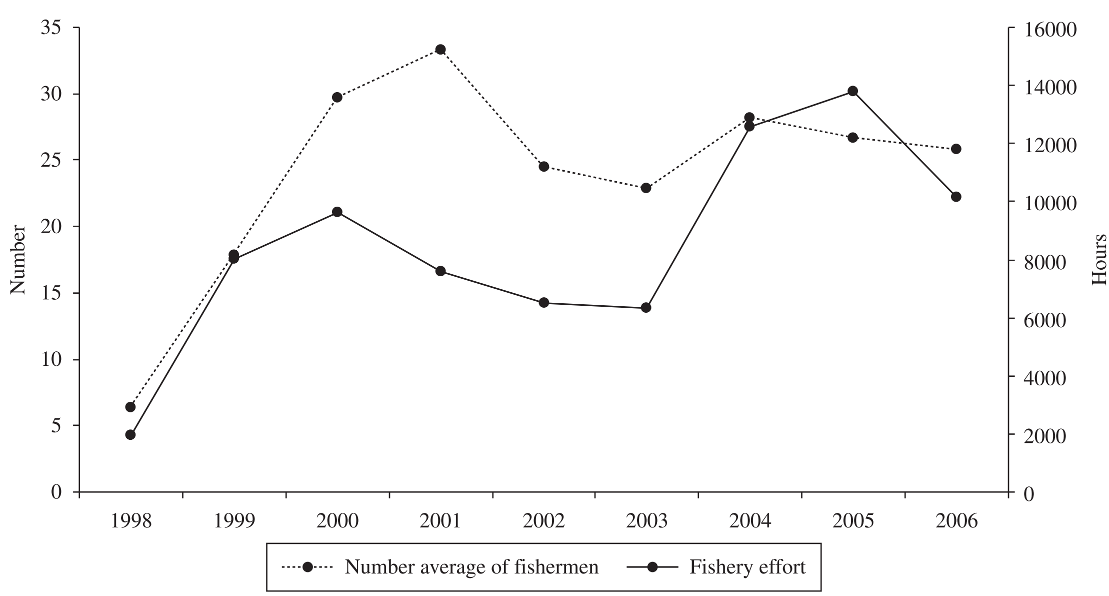

Figure 6. Number average of fishermen and fishery effort (in hour) annual between January 1998 and December 2006.

five hours. This decrease was due to commercial constraints, with sales occurring only three times a week, and in smaller quantities from August 2005 on, resulting in a reduction of the period spent fishing and in the number of fishing days per week.

Until 2001, there had been an increase in the average monthly number of blue crab fishermen and in the number of work hours. The average monthly number of fishermen ranged from 6 ± 3.7 in 1998 to 33 ± 9.8 in 2001. From 2002 on, this Figure stabilised at 25 fishermen per month. The monthly number of blue crab fishermen showed marked variation, certain months having very few and others having several active fishermen (Figure 6).

Considering the period from January 1998 to December 2006, the total number of blue crab fishermen showed a marked increase, from 34 fishermen recorded in 1998 to 163, in 2000 (highest number of fishermen recorded, stable from then on). While from 2001 on the number of active fishermen decreased, the number of blue crab fishing days increased - from two to three days per week in 1998 to five days per week by July 2005. This increase resulted in a higher pressure over the resource, reaching a peak of 13,776 fishing hours in 2005 (Figure 5). From August 2005 to December 2006, the effort decreased, as a consequence of less fishing days and work hours.

A total of 31,302 specimens of *C. sapidus* were sampled during the landings from 1998 to 2005. Males were clearly predominant over this period, except in January 1999 (χ^2 test; p = 0.05), 26,552 males (84.8%) and 4,750 females (15.2%) having been recorded. The male average width was 9.8 cm (±1.4 cm), and that of the females was 9.2 cm (±1.4 cm).

4. Discussion

4.1. Blue crab (Callinectes sapidus) fisheries evaluation

Fishing resources in Brazil are either overexploited or in drastic decline, due to the lack of clear policies for the industries, the high pressure over the resources and the environmental degradation of the Brazilian coastal areas, leading to stagnation or reduction of extractivist fisheries (Cergole et al. 2005). In Brazil, blue crab fisheries are barely considered in the official statistic reports, and there is little reliable data about the produce, hampering any attempt at analysing and following-up on the catches.

However, on the southeastern coast of São Paulo the activity is monitored; the area harbours one of the main professional fisheries in the region, from which several families earn their living (Mendonça and Barbieri, 2001). Another very important fishing resource in the region is the broadband anchovy (*Anchoviella lepidentostole*); its season starts in spring, but fishermen earnings are not significant until the summer, when the catches and the sales increase. Therefore, in spring, several fishermen turn to the blue crab as a promising resource, to bridge the gap of the broadband anchovy low-profit period (Mendonça et al., 2000; Barreto et al., 2000). This observation indicates how the market scenario may interfere with the landings (Tagate, 1965 apud Steele and Bert, 1998) and change the focus to more profitable resources. A possible consequence is a decrease in landings during low-profit periods as well as fluctuations in fishing effort and landings. Quite often economic factors have more influence on the local produce than the resource population level itself (Moss, 1982), some months showing almost no catches and others showing intense activity of blue crab fisheries. Therefore, the shifting profile of the activity yield on the south coast of São Paulo is mainly due to the variable number of fishermen looking for sources of income.

As shown by the CPUE variation, lower catches are observed in the estuary during winter, possibly indicating an absence of individuals in the fishing areas of the estuary and available to the fisheries. Yet, a spatially differentiated distribution may occur in the estuary between mature and immature individuals, because youngers tend to stay in shallower places with more organic material, and they are not available to the fishery (Murphy et al., 2001; Severino-Rodrigues et al., 2001).

Severino-Rodrigues et al. (op. cit.) studied the blue crab fishery in the Santos-São Vicente estuary and on the coast of São Paulo and recorded the highest level of production in autumn-winter, i.e. the opposite to the findings in the Cananéia-Iguape estuary. However, Steele and Bert (1998) observed higher catches off the Florida (US) coast in summer. Such differences in production periods may have occurred in association with market conditions – at the Santos-São Vicente estuary, for instance, the produce is directly sold to the tourists visiting the region, whereas at the Cananéia-Iguape estuary, sales are mainly to food supply distribution centres (CEAGESP/CEASA) (Mendonça and Hilberath, 2004) – and may also be influenced by the migration patterns of the species at each site.

From 1998 to 2004, the CPUE showed a significant decrease indicating a drop in production and population losses. The main cause for this trend was the increased fishing effort over the period, i.e., in addition to a higher number of fishermen, they also go fishing blue crab more often during the week. From 2005 on, an increase in the abundance indexes is observed, as the fishing effort decreases from August 2005 on, with a reduction in fishing time and number of days dedicated to the activity. The result was a recovery of the stock.

Changes in salinity, pluviometric indexes and temperature also interfere with the catches (Severino-Rodrigues et al. 2001). This may be linked to the lifecycle of the *Callinectes sapidus* that enters the estuary in the warmest season for carapace change and copulation. According to Chagas-Soares (1995), the rainiest periods are in the second half of the year and coincide with the highest catches, since the blue crab species analysed presents a high tolerance to salinity shifts, being found in inner parts of the estuary, where salinity is lower.

The predominance of males in the landings, even in months with a higher presence of females in the environment (spring-summer), is due to the selective pressure from fishermen, since males are larger and more valued in the market. Despite this selective pressure, studies show that the species usually presents differentiated distribution according to the environmental conditions, males occurring in higher numbers in lower salinities, while females are present in higher numbers in more saline environments, since they migrate to open seas for spawning (Perry and Mcilwain, 1986; Murphy et al., 2001).

The blue crab fisheries in the estuary showed an annual decrease in the CPUE up to 2004, characterising the fall in the production and also in the relative abundance of the resource. From 2005 on, with the decrease in the fishing effort, this trend reverted, increasing the abundance index. Even though fisheries are not intent on catching females, either from awareness of their importance for the species conservation or due to the low market value of females, we may conclude that the fisheries activity has an impact on the blue crab population in the estuary. The increase of the catch effort will affect the stock, and may cause a more drastic reduction over the years to come, as observed in several areas of blue crab fisheries around the world (Steele and Bert, 1998; Murphy, 2001, Paolisso, 2002).

4.2. Management of the activity

The region studied is one of the most conserved in the State of São Paulo, in contrast with other blue crab fishing areas, where degradation represents a major problem for the management of estuarine fishing activities (Severino-Rodrigues et al., 2001; Schreiber, 2001; Paolisso, 2002). However, the drop in the abundance index from 1998 to 2004 shows that the resource is endangered, especially because the fishing effort is above a sustainable level. It is therefore necessary to take measures for the reduction of this effort, as occurred in the years 2005 to 2006 regulated by market factors that forced fishermen to decrease their catches and their active time.

Measures focused on effort regulation and reinforcing sustainability are essential for the maintenance of the fisheries stock. Since market conditions are very unstable, they may either stimulate or discourage the fishing effort, which also bears a close relation to the conditions of other fisheries and the demand for the product.

Improvements in fishing gear efficiency, shifts in fishing effort, environmental factors, life cycle of the species and the conditions of other fisheries have had an influence on the blue crab production (Perry and Mcilwain, 1986; Steele and Bert, 1998). The last variable mentioned is clearly decisive in the case of Cananéia, Iguape and Ilha Comprida, since the status of the broadband anchovy fishery is a major determinant of the shifts in fishing effort on the blue crab population. The increased number of fishermen and the improvement in efficiency of fishing gear, resulting in additional fishing effort, are also major issues in the management and maintenance of the resource.

Two components are required for the maintenance of any type of fishery: the fishing produce and the socio-economic conditions for the development of the fishery. To achieve the desired goal of a sustainable fishery it is necessary to develop monitoring and regulatory instruments. The purpose of monitoring fishing activities is to guide the decision-making process and to implement rules to maintain a minimum level of the resource that ensures the survival of the activity. Current regulations applicable to fisheries mostly consider the technical and economic aspects of environmental maintenance and economic development (Pezzoli, 1997 in: Gallagher et al., 2004), with decisions based mainly on passive monitoring and slow actions, rather than proactive and concrete assessment of investments, applied technology and fishery policies (Gallagher et al., op. cit.). In most areas of the country, we are far from having any management policy, due to the lack of information and, as a consequence, a lack of an organised industry setup.

Among the most widely used management techniques worldwide is co-management. This was defined by Jentoft et al. (1998) as "the collaborative and participatory process of regulatory decision-making among representatives of user-groups, government agencies and research institutes". There is a general belief today that the involvement of the community, embedded in the actions of management, allows fishing communities a more efficient recovery of the control over their livelihood (Schreiber, 2001). User involvement in policy elaboration helps achieve higher economic efficiency in the exploitation of fishing resources (Domínguez-Torreiro et al. 2004).

As a rule, in several kinds of fisheries, fishermen agree that activity is intensive and believe that science and regulatory measures may help support the continuity of artisanal fishing. When scientific and traditional knowledge are not used in a complementary way, or when the latter is unfortunately disregarded, there is a trend towards the imposition of out-of-context rules. Illegitimate rules tend to face repeated non-compliance, which is at the root of the current crisis affecting artisanal fishing (Boisneau and Mennesson-Boisneau, 2001; Schreider, 2001; Paolisso, 2002). Legislators can easily prohibit, but they hardly promote management. Instruments such as zoning, laws and restrictive decrees are necessary, but not sufficient (Moraes, 2004).

Since the decrease of the blue crab catches in the estuary is not related to the loss of environmental productivity, usually caused by the environmental degradation, actions to regulate the fisheries would be sufficient to maintain the resource and the activity. In addition, participative management would increase the regulatory efficiency of the blue crab fisheries in the estuary, decreasing conflicts and validating the actions taken. The technical information presented in this paper with adjustments to the socioeconomic and cultural reality of the fishermen might lead to a sustainable form of administration of the resource.

5. Conclusions

Blue crab (*Callinectes sapidus*) fishing in the Cananéia, Iguape and Ilha Comprida estuary has presented a notable decline over the past few years, indicating high levels of fishing effort of the resource, without a corresponding response of the produce. The increase in fishing effort beyond the sustainable level for the population's biologic balance was corroborated by the positive response of the abundance index to the decreased effort observed in 2005 and 2006.

The lack of regulatory control of the fishing effort and the disorganised fluctuation of the admission rates of fishermen in the blue crab fishing activity led to the abovementioned effort increase. Measures are required to stop admitting fishermen into the activity. Another option to decrease the effort is the implementation of prohibition periods (called "defeso") in the months with higher temperatures, between September to January, to a maximum period of three months, when females enter more intensively the estuary for reproduction and when there is a concomitant higher number of fishermen in activity. Finally, the admission of fishermen could be limited and regulated through a fishermen register and special licenses, which should keep the number of people involved in this activity at levels consistent with sustainable resources, preventing the increase in productive units, and giving priority to previously active fishermen.

For the abovementioned measures to be effective, they must be discussed with industry representatives and must be supported by technical information, aiming at the adjustment of the policies to be implemented; the early involvement of fishermen in the regulatory process leads to more effective rules and improved sustainability results for the resource in study. Co-management is one of the most important measures, and assumes the joint participation of blue crab fishermen, government authorities, and academia from where research data may be made available. Implied is the management of the resource through an integrated approach including ecological, social, economic and cultural dimensions.

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