Assessment and management of white mullet *Mugil curema* (Valencienne, 1836) (Mugilidae) fisheries of the south coast of São Paulo state, Brazil

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Abstract

There is intense fishing activity, mainly artisanal, in the Cananéia, Iguape and Ilha Comprida Estuarine System. White mullet (*Mugil curema*) is one of the local fishery resources and is usually caught with gillnets and fish traps. This study aimed to characterise the *Mugil curema* fisheries thereby underpinning the management of the species in the region. The study was developed with data collected from landings in the town of Cananéia, São Paulo state, Brazil, from 1995 to 2009. Production data, fishing effort and CPUE were used to assess the evolution of captures. The gillnets were characterised by interviewing fishermen from 16 communities in Cananéia. White mullet fishery has aroused the interest of fishermen in the region since the 80s and today it is one of the main products of artisanal estuarine fishery off the south coast of São Paulo. The major landings occur in the warmer months with fish traps and gillnets being the main fishing gear used. The largest catches occur in the spawning months of the species from October to April. The highest landings varied according to different fishing gear, showing differences primarily due to trade preferences and to the structure of the fishing gear. According to the index of abundance used in this study, the resource is overfished due to the progressive increase in fishing effort, so it is suggested that measures should be taken to control fishing effort, such as special fishing permits to catch white mullet, especially with gillnets. The current management measures neither meet the needs of fishermen nor the preservation of the resource, and must be reviewed in a participatory way with management agencies and the fishery sector, ensuring greater legitimacy and success in the sustainability of the activity.

Keyword: CPUE, white mullet, *Mugil curema*, artisanal fishery, São Paulo state.

Avaliação e gestão da pesca do parati *Mugil curema* (Valencienne, 1836) (Mugilidade) no litoral sul do estado de São Paulo

Resumo

No Complexo Estuarino Lagunar de Cananeia-Iguape-Paranaguá ocorre uma intensa atividade pesqueira, principalmente artesanal, tendo o parati (*Mugil curema*) um dos recursos pesqueiros, sendo capturado geralmente com redes de emalhe e cercos-fixos. O presente trabalho visa caracterizar a pesca do *Mugil curema*, trazendo subsídios para o ordenamento de sua exploração. O trabalho foi desenvolvido com os dados de desembarque no município de Cananeia, no período de 1995 a 2009. Utilizaram-se dados de produção, esforço pesqueiro e CPUE para avaliar a evolução das capturas, e a rede de emalhe foi descrita através de entrevistas com os pescadores de 16 comunidades de Cananeia. A pesca de parati despertou interesse dos pescadores da região a partir da década de 1980, sendo atualmente um dos principais produtos pesqueiros da pesca artesanal estuarina no litoral sul de São Paulo. Seus maiores desembarques ocorrem nos meses quentes, tanto com redes de emalhe, como outro aparelho de pesca denominado de "cerco-fixo". As maiores capturas ocorrem no período de desova da espécie entre os meses de outubro a abril. A diferença no período de maiores desembarques entre os aparelhos de pesca ocorreu principalmente devido a preferências comerciais e por causa da estrutura do aparelho. De acordo com os índices de abundância utilizados o recurso está em sobre-pesca, devido ao progressivo aumento do esforço pesqueiro, assim sugere-se que sejam tomadas medidas para controle do esforço pesqueiro, como permissões especiais para pescadores trabalharem na pesca do parati, principalmente com redes de emalhe. As atuais medidas de ordenamento não atendem os pescadores, nem a preservação do recurso, tendo de ser revistas de maneira participativa entre os órgãos gestores e o setor pesqueiro, garantindo maior legitimidade e sucesso na sustentabilidade da atividade.

Palavras-chave: CPUE, parati, *Mugil curema*, pesca artesanal, São Paulo.

1. Introduction

The main fishing resources in Brazil have long been overexploited, so that regulatory measures have been taken to prevent the collapse of fisheries (Peres et al., 2001). Some management measures are developed from common knowledge and long-term observation in traditional management systems, such as limited access, seasonal limits, protection of reproductive stocks or juveniles, among others (Berkes et al., 2006). Those measures do not often reach the goal to which they are created, that is, to preserve stocks.

Small-scale fisheries are of great social and economic importance in the fisheries sector, being responsible for a large number of jobs in coastal communities. According to IBAMA (2008), fishing contributes approximately 65.2% of national production of fish in coastal waters. From about 25 thousand vessels of the national fleet, around 23 thousand correspond to the small – scale fleet (Dias-Neto and Marrul-Filho, 2003).

The Cananéia, Iguape and Ilha Comprida Estuarine System is inserted in the Cananéia, Iguape and Paranaguá Lagoon Estuarine Complex off the coast of São Paulo state. This complex is one of the most important coastal ecosystems, recognised by scientists, environmentalists and international organisations, both for the abundance of exploitable living resources present there, but also for the immense natural reserve area formed by the Atlantic, the islands of Canaanite, and the Long Cardoso, and mangrove area, which must be preserved. An intense fishing activity occurs in this complex, mainly characterised as a small-scale fishery, operated by more than three thousand fishermen, from Iguape, Cananéia and Ilha Comprida cities, the region being the main fishing area in the lagoon-estuarine complex and adjacent coastal area (Machado et al., 2000; Mendonça and Katsuragawa, 2001).

The white mullet (*Mugil curema*) has become one of the main resources for the fishermen in the region, and it is usually caught with gillnets and fish traps (Mendonça, 2007). This species presents a wide world distribution, from the north of the U.S.A. to the south of Brazil, in the Pacific Ocean off the coast of Chile and off the west coast of Africa, that is, in subtropical and tropical regions, estuary areas where they spend most of their life cycle, where they feed, grow and undergo gonadal development (Anderson, 1957; Alvarez, 1976; Yañez-Araciba, 1976; Braga, 1978; Cervigon, 1996; Fonseca-Neto and Spach, 1998/1999; Baumar and Dodson, 2000; Baumar et al., 2003; Deus et al., 2007).

According to Cervigon (1996) *Mugil curema* is a typical inhabitant in lagoons of mangroves of muddy bottom, however, it can be found in the open sea and in the muddy bottom or in clear and transparent waters with sandy, rocky or coral bottom. The species has pelagic habits, being able to form small shoals of fish (Baumar and Dodson, 2000). As the species is found in the estuarine and coastal regions, it has became one of the important resources for the local communities, that always catch this species, which is an important source of income for them (Rocha et al., 2007).

This species is rarely reported in the statistics, because it usually occurs in the landings of small-scale fisheries. Due to the difficulty in monitoring this kind of fisheries, their yield is usually underestimated in the statistics and also in the number of registered boats (Mendonça and Miranda, 2008; Mendonça and Machado, 2010). According to the statistical system on the south coast of São Paulo state, which comprises all small-scale fisheries, white mullet landing is one of the highest (Mendonça and Miranda, 2008). Thus, the present paper aims to characterise the *Mugil curema* fisheries, in order to underpin their management in the region, and analyse the actual rules that incident on white mullet fishery with gillnets.

2. Material and Methods

The data were obtained in the town of Cananéia (São Paulo state, Brazil) from 1995 to 2009, from the landings of artisanal fisheries in Cananéia, Iguape and Ilha Comprida Estuary (Figure 1).

The data were collected at landing points, including fish markets and/or landing harbours, through daily interviews with fishermen during trading, or through the collection of bills of sale. Production data, fishing effort in effective fishing days, location and depth of capture were obtained in those interviews (Mendonça and Miranda, 2008).

White mullet (*Mugil curema*) fishery is mainly carried out with two types of gear: the fish trap and the gillnet. The fish trap is a fixed type of trap used to catch mullets (*Mugil curema* and *M. liza*), caitipa mojarra (*Diapterus* spp.), snook (*Centropomus* spp.) and others, described in Mendonça (2007).

The average monthly and annual production was obtained by dividing the sum of monthly values of white mullet landings with all fishing gear employed in the region that catch the product.

The catch per unit of effort (CPUE) is largely used as the relative abundance index in several fisheries in the world (Gatica and Hernandez, 2003). So, the CPUE was chosen as an indicator of the white mullet fisheries situation at the lagamar, based on the landings of fisheries that use gillnets in the area of the estuary.

The choice of this specific fishing gear was made in order to obtain a more accurate data on the fishing effort. The use of different fishing gear data can affect the estimates of CPUE and do not correctly reflect the abundance index (Petrere Junior et al., 2010).

The calculations of the CPUE in kilogrammes per fishing hours were estimated through the total monthly or annual production, divided by the total effort in fishing hours of all the fishermen that were active in the referred month or year. The annual CPUE was estimated by the total annual production divided by the total annual effort, and the average annual CPUE was obtained by the average of the monthly CPUEs. Analysis of Variance (ANOVA) was used to verify the significant differences in the average

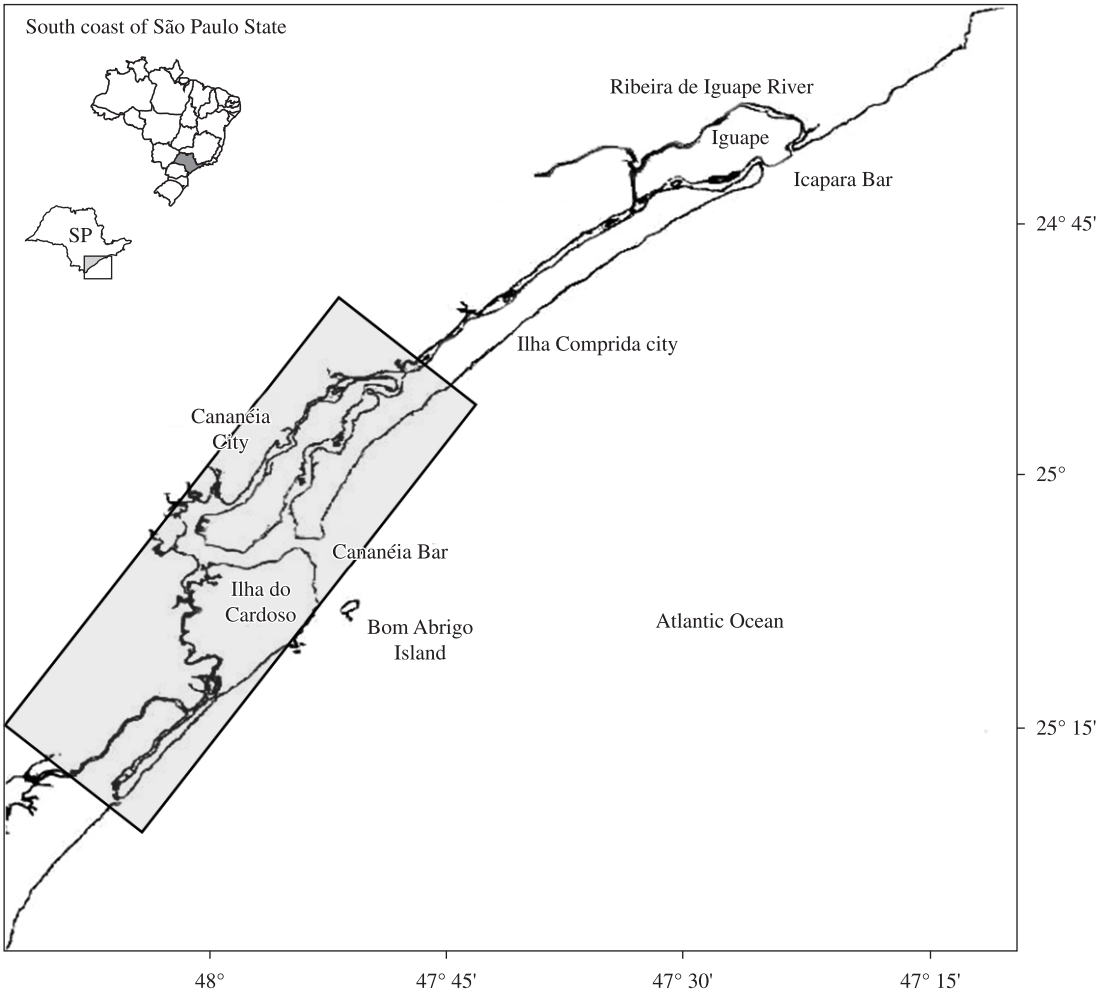

Figure 1. The Cananéia, Iguape and Ilha Comprida Estuary, with white mullet fisheries area (grey).

annual CPUEs, complemented by the Tukey test to indicate in which years these differences were more significant, to a significance degree of (a) of 5% (Callegari-Jacques, 2004).

Aiming at more reliability to the ANOVA, the analyses were complemented with the application of the F-test, in order to verify the significant differences among the annual CPUEs, comparing the annual CPUE trend line and the line zero of inclination, to a significance degree (a) of 5% (Zar, 2008).

For the analysis, the fishing effort in days was converted to hours, considering an average of four hours of work per day. The CPUE in kg/hour, was estimated dividing the total monthly (or annual) production by the total effort, in fishing hours, considering the active units in the month (or year). The annual average CPUE was obtained by the average of monthly CPUEs. The variance analysis (ANOVA) was used to verify the occurrence of significant differences in the average annual CPUEs, complemented by the Tukey test to indicate in which years these differences were more significant, to a degree of significance (a) of 5% (Callegari-Jacques, 2004). Aiming at obtaining more reliability for the ANOVA, the analyses were complemented with the application of the *t*-test to verify significant differences among the annual CPUEs, comparing the annual CPUE trend and the inclination line zero, to one degree of significance (a) of 5% (Zar, 2008).

The Propesq® (Ávila-Da-Silva et al., 1999) data bank was used to consolidate the biometric and production data.

The description of the fishing gillnet for white mullet, and their handling, was obtained through 65 interviews in 16 fishing communities in Cananéia, obtaining the size of the mesh used and length of the net. Some pictures were taken in order to better understand the fisheries and the handling of the equipment. Another important fishing gear to catch white mullet is the fish trap, described in Mendonça (2007).

3. Results

3.1. Description of gillnet fishing for white mullet

The gillnet for white mullet fisheries in Cananéia city has a mesh size of 60 mm (measured between opposite knots),

average length of 204 m (±133 m), to register gillnets from 40 to600 m. The height is approximately 2.5 m. From the fishermen who use gillnets, 36% have paddle boats, 19% boat type "bateira" (a motorised boat that operates on the coastal region) and 10% have a motor canoe.

The procedure used by fishermen is based on placing the encircling gillnet near the edge, in places of shallow depth, with the gill net filling the entire water column. Soon after, the fisherman enters this semicircle with the canoe and hits the water with the paddle, provoking the displacement of the fish along the shore toward the gillnet. This procedure is popularly called strike fishing or fishing seine.

3.2. Production and index of abundance

The result of 8,740 interviews on white mullet landings showed an average annual production of 33.3 t (± 7.2 t), with the highest landings in the period from October to April, although landings of white mullet are reported throughout the year (Figure 2).

During the studied period, there was alternation of fishing gear with higher production of white mullet. In the period from 1995 to 1999, the fish traps and gillnet landings showed similar production. In the period 2000-2004, fish traps were responsible for most of the white mullet landed, from 2005 to 2009, gillnets presented the highest landed volume (Figure 3). Yet landings of white mullet were reported in trawling for beach, beach seine and bottom long line, representing only 0.1% of production. There is a class of multi-gear, which fishing is conducted with more than one fishing gear. Also there is a category of indeterminate gears, when it was not possible to determine precisely the gear that the fisherman used, and these two categories account for 12.7% of the landings.

The monthly CPUE ranged from 1.5 to 49.2 kg/hour, when fishing with a gillnet. The monthly average CPUE ranged from 9.8 to 17.9 kg/hour, with the highest yields from February to April and the lowest in May and September (Figure 4). The annual CPUE ranged from 4.6 and 26.5 kg/hour, graphically showing a decline over the studied period (Figure 5).

The average annual CPUE, obtained by applying the ANOVA showed significant differences ($p = 0.05$) found for the fifteen years of study, being confirmed by applying the Tukey test showed for differences between

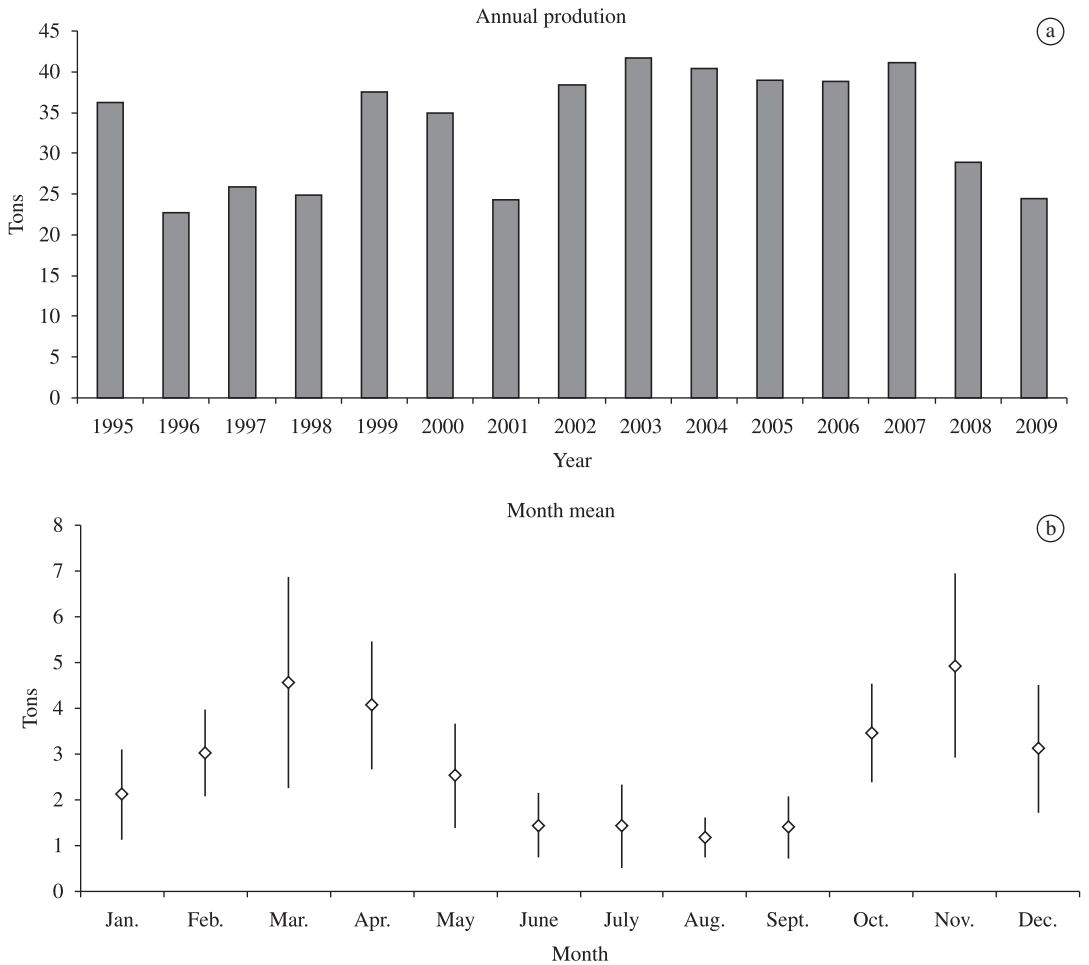

Figure 2. Annual production (a) and monthly mean (b) landed in the Cananea in *Mugil curema* in the period 1995 to 2009.

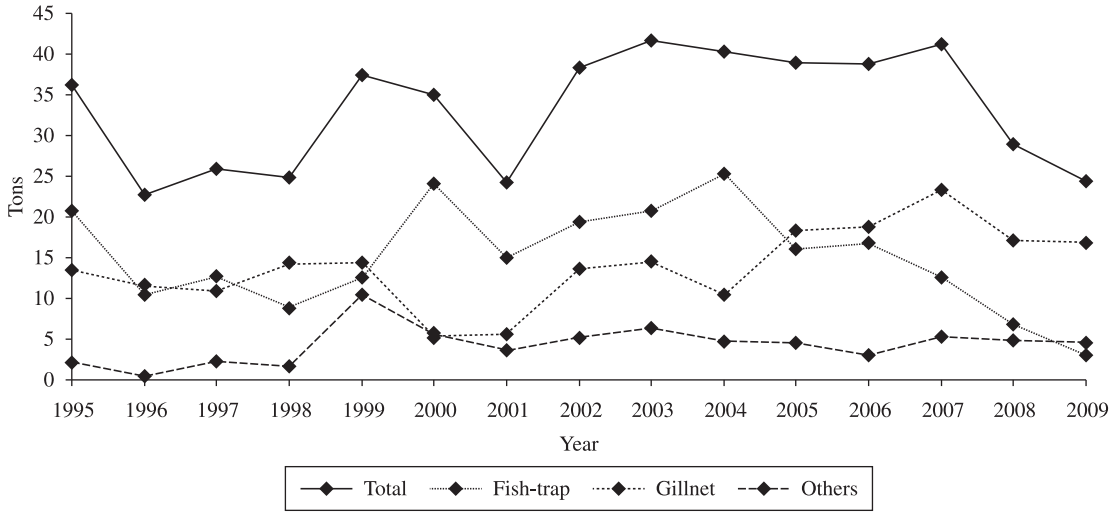

Figure 3. Landings of *Mugil curema* according to the fishing gear employed in the period 1995 to 2009.

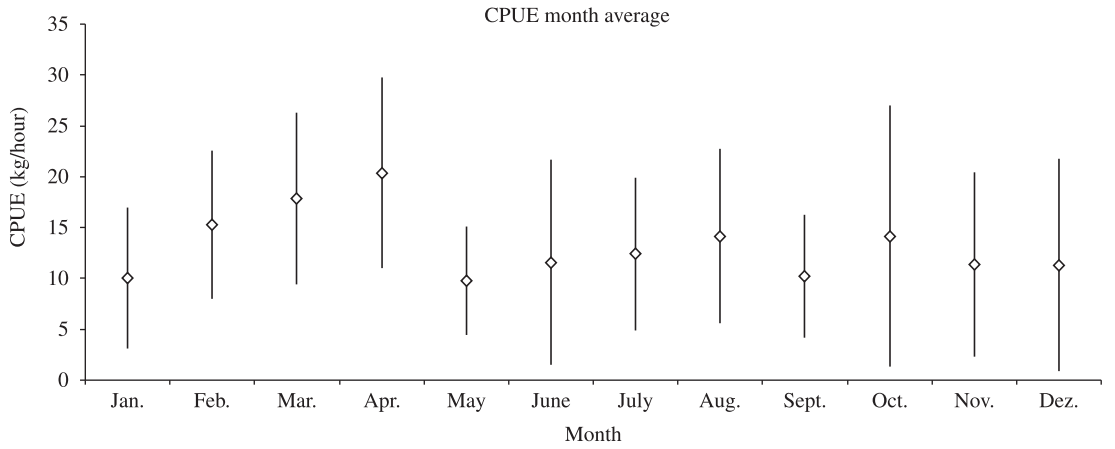

Figure 4. CPUE (kg/hour) monthly average of *Mugil curema* fishing with gillnets in Cananéia, in the period 1995 to 2009.

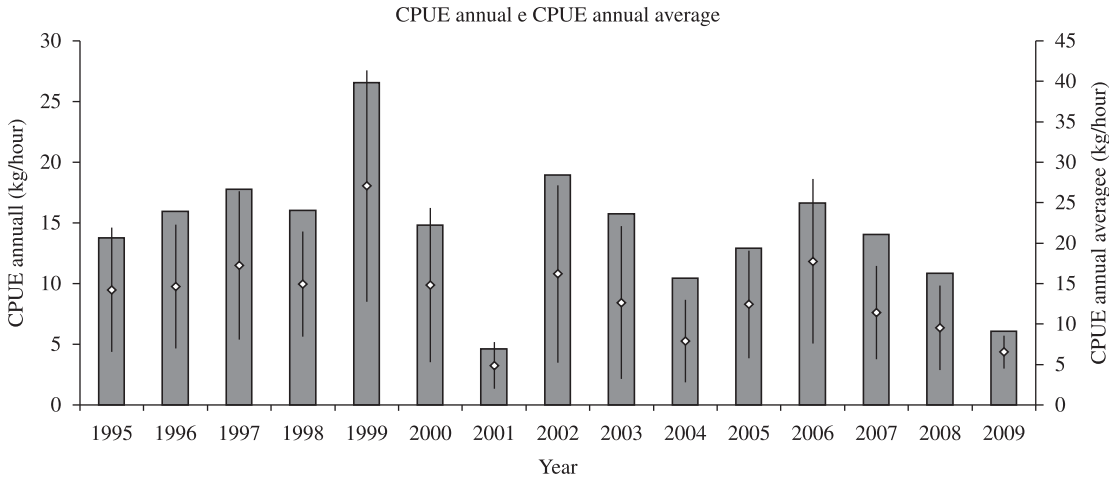

Figure 5. CPUE annual average and annual *Mugil curema* fishing with gillnets in Cananéia, in the period 1995 to 2009.

the years of highest yield (1999) and the years of lowest yield (2003-2005 and 2007-2009), indicating the decline of the index of abundance. The regression significance of CPUE over the years, evaluated by using variance analysis (F test) showed a slope significantly different from zero ($p < 0.005$), has indicated a reduction in CPUE since the beginning of the study.

The fishing effort (in fishing hours) decreases in the period from 1999 to 2001, and from 2002 on, showed a gradual increase until the end of the study, and in 2009 there was a large increase in the number of hours and fishermen. But the number of fishermen who annually unload white mullet in the Cananéia port had increased during the whole period (Figure 6).

4. Discussion

4.1. Evaluation of the captures

Throughout the studied period, the landings of white mullet grew until 2003, and from this moment on they became stable, declining over the last two years. Although abundant in the region, the species only aroused the interest of fishermen from the 80s on, when major production yields were registered (Mendonça, 2007). Since then, the white mullet has become the target species, primarily for gillnet, and subsequently for fish traps.

A clear seasonality is observed in the landings, with highest yields in the period from October to April (hot months). An increase in the number of shoals in this period is the result of the reproductive stage, when the white mullet migrates to spawn in the sea (Ferreira, 1989; Garcia and Bustamante, 1981; Ibanez and Benitez, 2004). According to Baumar et al. (2003) the reproductive period of *Mugil curema* occurs in different ways and according to geographical distribution, often with the occurrence of two reproductive peaks.

Although there are divergences in the studies on white mullet reproduction to determine the main spawning peak, either in spring (Anderson, 1957; Yañez-Araciba, 1976; Ibanez and Benitez, 2004; Albieri et al., 2010) or in the summer (Ferreira, 1989), usually the largest catches of the species off the southern coast of São Paulo occurs in the reproductive period, either by fish traps or by gill nets.

For different reasons, there are differences in the period of the highest landings depending on the fishing gear. They occur from October to December for the fish traps, and from February to April for the gillnet. From October to December the fish trap catches more white mullets because the fishing gear installed in the winter (May to September) is changed, in order to reduce the escape of smaller individuals, allowing the capture of fish, such as white mullet, caitipa mojarra (*Diapterus* spp.) and snook (*Centropomus parallelus*) (Mendonça and Katsuragawa, 2001). Landings are also influenced by the largest number of traps installed in the region, increasing the total landings of white mullet in the district (Mendonça, 2007).

The largest gillnet catches occur from February to April, period when little fishing resources are available in the estuary, so white mullet becomes the target species. The low capture of this species from October to January is due to the disinterest of fishermen in white mullet. In this period they aim their fisheries to other more profitable species such as acoupa weakfish (*Cynoscion acoupa*) and common snook (*Centropomus undecimalis*) (Mendonça, 2007).

This shows that market conditions also interfere with landings (Steele and Bert, 1998). Depending on the season,

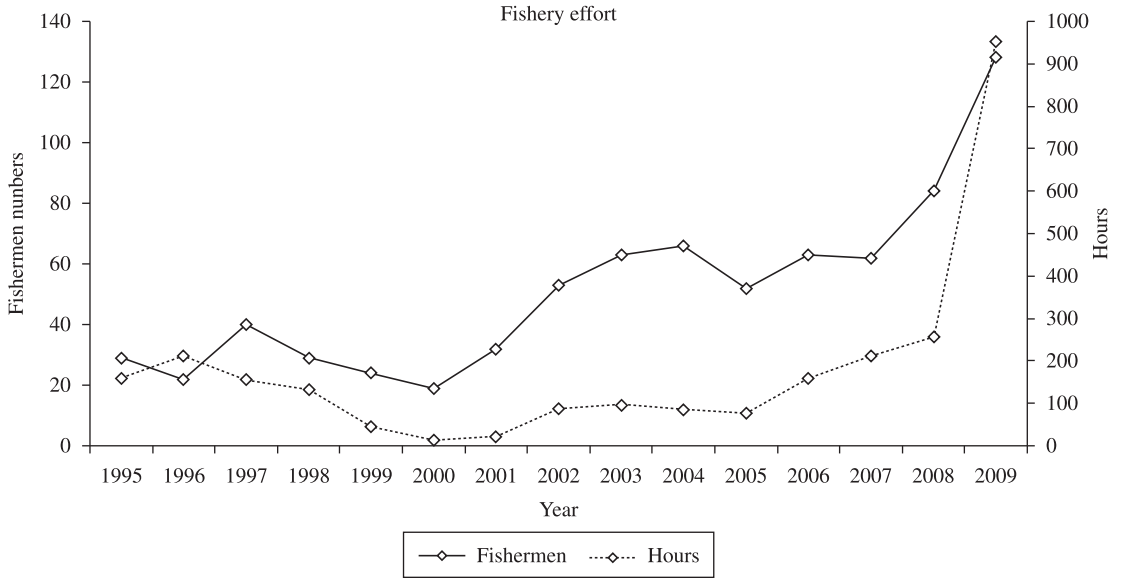

Figure 6. Fishing effort (in hours and number of fishermen) of *Mugil curema* fishing with gillnets in Cananéia, in the period 1995 to 2009.

the fishing effort is directed to more profitable fish, causing reduced landings of white mullet. Frequently economic conditions influence more on the local production than the levels of the stock (Moss, 1982). So the captures of white mullet are very low in some months, and high in others. Thus, the fluctuations in production are mainly due to the increased presence of fishermen looking for better sources of income (Mendonça et al., 2010).

Moller et al. (2004) pointed out potential limitations to the conventional methods of monitoring populations, warning that a complete independence between CPUE and the density of the stock is rare, but there is a direct and linear relationship between them. Still, for catches of white mullet, the CPUE proved to be a good indicator, as long as other information are taken into account, such as fishing effort (number of hours and fishermen), economic factors of the activity and the use of only one fishing gear. Similar to most of the coastal fishery resources of the country, white mullet has shown a decrease in its abundance index, caused by increased fishing effort in these 15 years studied.

Usually, when the abundance of the resource increases, the fishing activity intensifies rapidly, but when the abundance decreases, the fishing effort takes more time to decrease, causing negative impacts on the stocks and on the economy (Steele and Hoagland, 2003). The white mullet fishery is essentially artisanal. This kind of fishery has more limitations to increase the fishing effort, due to the low purchasing power of the fishermen to acquire more efficient fishing gear. But in the present study we observed that the number of hours spent in the capture has increased over the past four years, as they direct their fisheries at white mullet more often, and the number of fishermen has also increased. So, national fishing measures to control the fishing effort on white mullet, as for other species, must meet the maintenance of the abundance index.

4.2. Management of the activity

The concern with fisheries resources sustainability is the keynote for the managers in the region, as the entire area is committed to environmental preservation through the existing conservation units. The region has essentially one estuarine small-scale fishery, with little mechanisation (FAO Fisheries Department, 2003). Their main products are the estuarine oyster, the sea-bob-shrimp, the white mullet, the mullet, broadband anchovy and the Sciaenidae family (Mendonça and Miranda, 2008). It is verified in Brazil that the small-scale fisheries have greater conditions for sustainability (Cardoso, 2001). In addition it is easier to manage their resources because the fishermen have a greater identification and commitment to the activity than the professional in the fishing industry. The problems are mostly related to the structure of management agencies than in the fishery sector (Machado and Mendonça, 2007).

The fishery is operated with fish traps and gillnet, and both either lack management plans or are unsatisfactory. There is no management plan for fish traps off the southern coast of São Paulo, and the process of standardisation has been in preparation for over five years. In contrast, gillnet regulations led to claims, because the fishermen argue that the regulations do not conform to the reality and the specificity of this kind of fishing. Currently fishing for white mullet is regulated by IBAMA law number 42, March 15, 2001, which establishes the minimum mesh size of 70 mm for all kinds of fisheries with gillnets.

According to the current regulations, the use of gillnets with mesh size of 60 mm is prohibited. The fishing gear currently used is classified as gillnet (gillnet of waiting) and according to Ordinance number 42, the minimum size of mesh used by these gears should be 70 mm. But in 1987, then SUDEPE, belonging to the Ministry of Agriculture, national manager of fisheries in the period, published Ordinance number 29, on October 8, 1987, establishing the use of seine nets for white mullet fisheries, and the minimum mesh size of 60 mm. SUDEPE characterised the white mullet fisheries as seine, possibly considering not only the physical structure of the gear, but the procedure employed. This specification is not accepted by fishermen, who have demanded a change in the ordinance.

Ample discussion about white mullet fishery would have to be carried out, involving the evaluation of the resource itself and taking into account the specific type of fishing, seeking to establish rules for the effective planning of white mullet fisheries and to reduce conflicts with fishermen.

A management technique that can be used is co-management, which was defined by Jentoft et al. (1998) as the process of cooperation and participation in regulatory decisions made by user groups, government agencies and research institutions. It is believed that community involvement, embedded in the work of management, provides the fishing communities efficient recovery and control over their livelihoods (Schreiber, 2001). According to Domínguez-Torreiro et al. (2004), the involvement of users in fishing policies helps achieve greater economic efficiency in the exploitation of the resources. The forums created by the conservation units provide this type of technique, because they are composed of different segments of the sector.

In general, fishermen agree that there is an excessive fishing effort and that management actions help sustain the livelihoods of artisanal fisheries. The non-use of scientific and local knowledge in a complementary way, or when the latter is mistakenly overlooked, means there is a tendency to impose decontextualised norms, that by their illegitimacy will be increasingly disregarded. Therein lies the root of the problem that artisanal fishing is experiencing today (Schreiber, 2001; Paolisso, 2002). According to Moraes (2004), legislation is able to easily prohibit, but hardly promotes the management, so that legal instruments such as zoning, restrictive laws and decrees are necessary but not sufficient. This occurred when Ordinance number 42 was published and then established, in a general way, the minimum mesh size of 70 mm for gillnet, not taking into account the fishing procedures.

As Vetemaa et al. (2001) observe the situation of the stock of a fishery resource is a counterbalance between the abundance of the resource, fisheries practices and the number of fishermen. According to the index of abundance, the resource is overfished, so the control of fishermen and fishing nets should be given attention to, in order not to endanger the population of *Mugil curema*, thereby reducing their abundance.

Measures to control fishing effort, the sustainable socioeconomic activity and the environmental resource are essential. In this sense, the special fishing permits, upon registration, could function as a tool to control fishing effort. In turn, co-management would increase the efficiency of actions on fishing practices and control the number of users, reducing conflicts and giving legitimacy to the process, sustainably promoting the management of the resource.

Although the index of abundance has shown overfishing, the review of that ordinance and its adequacy for white mullet fisheries, the regulation of the mesh size of the nets for 60 mm, and the requirement of special license for the fishermen that use this fishing gear would help to limit fishing effort and make the fishery more sustainable.

5. Conclusions

White mullet fisheries (*Mugil curema*) aroused the interest of fishermen on the southern coast of São Paulo from the 80s on and it is currently one of the main products of estuarine artisanal fisheries in the region. The highest landings of the species occur in the warmer months, caught by fish-trap and gillnets as the main fishing gears. The highest captures occur in the spawning period of the species from October to April.

The difference in the period of highest landings among the fishing gears, has different reasons. Those landings were registered from October to December for fish-traps and from February to April for the gillnets. One of the reasons is the increased number of installed fish-traps in the estuary with a frame structure which reduces the escape of small individuals. The gillnets have lower landings from October to January because the fishermen directs its activities to more profitable resources, reducing the fishing effort on the white mullet.

According to the index of abundance used the resource is overfished. The gradual increase in fishing effort, both in fishing hours per year and the number of fishermen, suggests that measures must be taken to control fishing effort. One of the suggestions is the requirement of special permit for fishermen, upon registration, that might function as a tool to control fishing effort, mainly for fisheries with gill nets.

The activity is ruled by Ordinance number 42, March 15, 2001, which does not take into account the fisheries procedure for white mullet fisheries. It is suggested that this regulation must be revised or another norm must be edited taking into account the fisheries procedures, and thus giving another denomination for the activity, excluding white mullet fisheries from Ordinance number 42.

Finally, there are forums on the south coast of São Paulo discussing the local fishery that could be used to foster a participatory discussion with the fishery sector, using the co-management technique with community involvement. That technique would increase the effectiveness of actions on fishing practices and on the control of the number of users, reducing conflicts and giving legitimacy to the process, thus promoting the management of the resource in a sustainable way.

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