# Comparison between Artisanal Fishery and Manila Clam Harvesting in the Venice Lagoon by Using Ecosystem Indicators: An Ecological Economics Perspective

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## Summary

Artisanal fishery in the Venice lagoon is a multi-target activity with a long tradition. It was the main fishing activity till the late ’80s when, after the introduction and spread of the Manila clam (*Tapes philippinarum*), the mechanical clam harvesting started. A mass-balance model of the lagoon ecosystem was developed using the Ecopath with Ecosim software. 73 scenarios, obtained by changing the fishing effort of the two different types of fishery, were used to explore their impact on the ecosystem. A set of indicators was applied in order to compare the two fishing activities. The results obtained showed that the two activities are strongly interlinked, even through they don’t exploit the same resources. The mechanical clam harvesting could reasonably be considered to be the driving force; it is capable of determining the state of lagoon ecosystem. The above mentioned factors create a lot of conflict between the two types of fishery.

**Keywords:** Artisanal fishery, Indicators, Dynamic model, Venice Lagoon, Fishing impact, Social and economic value

**JEL Classification:** Q01, Q22

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## Introduction

From ancient times, fishing has been a major source of food for humanity, and a provider of employment and economic benefits to those engaged in this activity (FAO, 1995). But the exploitation of a common-property, like fish, is revealing to be unsustainable as is shown, on a global scale, by the phenomena of stock depletion (Botsford *et al.*, 1997), reduction of the mean Trophic Levels in the catches (Pauly *et al.*, 1998), and marine habitat disturbances (Hall, 1999).

Notwithstanding all the above, when the correct procedures are not in place, the fishing industry is driven to search for new technologies, thus producing an intensification of the fishing effort. Consequently fishing vessels are becoming larger and faster, are using more expensive types of technology and are catching fish in shorter periods of time, thus enhancing the gap between sustainability and fishing activity (Mathew, 2001). These factors are producing an increasing number of people involved in the exploitation of marine biological resources, who lack training, experience and skills. This gap can result in a lack of 'traditional ecological knowledge' leading to an unsustainable exploitation of the living resources. On the contrary, artisanal fishery requires more experience and is usually based on a strong link between fishermen and the ecosystem, all these drive to a sustainable exploitation activity.

The coexistence of technological and artisanal fisheries can also generate conflicts concerning space and resources, (Allison and Ellis, 2001; Mathew, 2001). In coastal areas, where small-scale and artisanal activities are particularly rooted (FAO, 2000), conflicts between new and old types of fishery can be even bigger. These modifications in fishery structures drive changes at an economic and social level (FAO, 2000; Ruttan *et al.*, 2000; Sumaila *et al.*, 2001) other than at an ecological level; they can result in conflicts between the "old" and "new" activities. The artisanal sector is particularly vulnerable, as it often depends on the use of set gears, which are incompatible with towed gears, such as those used by industrial trawlers.

The international framework of policy regulations is giving greater interest to coastal resources and fishery conflicts in order to enforce the sustainable development of human activities. Coastal communities and their customary practices are accorded special recognition by the Code of Conduct for Responsible Fisheries (FAO, 1995) where explicit suggestions are also given in order to obtain the protection and rehabilitation, nursery and spawning areas, in so far as is possible. The importance of artisanal and small-scale fishery to employment, income and food security Is also recognised in the above Code.

Therefore, fishery management has to take into account not only sound research concerning the ecosystem, but also the socio-economic component of the system.

Indicators for the ecological, economic and social effects of fishery are demanded, and a new interest in environmental changes, rather than merely in stock changes, is required (Anonymous, 2000). These indicators could be used as a basis for the evaluation of fishing pressure, and applied in fishery management, in order to create integrated policies, characterised by the combinination of the principles of fisheries and ecosystem management, under the shield of sustainability. The indicators have, therefore, to include a reference direction, allowing for the prediction of whether the indicator will increase or decrease due to exploitation (Rochet and Trenkel, 2003).

In such a complex framework, a potential core set of indicators have been developed within many national and international organisations, with the aim of describing the driving forces, pressures, states, impacts on and responses of the ecosystem to fishing activity (Zenetos *et al.*, 2002). However, the economic and social patterns also have to be clarified, in order to achieve an understanding of all these pressures and for the correct management tools.

### *Fishery in the Venice Lagoon*

The Venice Lagoon is a sensitive area subjected to different kinds of anthropogenical pressures, from industrial activity to resource exploitation. With regard to this last aspect, small scale fisheries have a long tradition also in terms of management (Granzotto *et al.*, 2001) but the introduction, in the middle of the 80s, of the Manila clam (*Tapes philippinarum*) induced major changes concerning every dimension of the lagoon (ecological, economic, and social). From the perspective of sustainable exploitation, a greater effort has to be made to define and apply management strategies which can assure the sustainable development of fishing activities, and the coexistence of the two types of fishing activities, in an environment as crucially important as the Venice Lagoon.

According to Mathew (2000), the definition of artisanal fishery can be based on different categories: the social, environmental, and technological features, the boat size, and the fishing ground size. As regards the Venice Lagoon, the small-scale fishery can be defined as artisanal , because of the strong link between the fishermen and their environment, resulting from centuries of traditions rooted in the past. This traditional knowledge led, to the utilization of more than 25 types of fishing technique up to the middle of the 20th century, (Granzotto *et al.*, 2001). At present, only two kinds of static fishing gear are still used: a fishing trap called ‘cogollo’ which is a fyke net and another type of gear called ‘nassa’ (Fig.1). Artisanal fishers target a wide range of marine species, including both residents and migrants, depending on the seasons, the fishing grounds and the tide (Mainardi *et al.*, 2002).

On the contrary, mechanical clam harvesting is a monospecific fishing activity, carried out using of small boats with 25HP engines, positioned outboard amidships (Fig. 1). The fishing grounds are shallow water areas, where the propeller can reach the bottom, resuspending the sediment and the clam, which are then collected inside a following net. This type of boat is also equipped with a 300HP engine, for the purposes of reaching the fishing ground in the lagoon.

According to Sacchi (2001), the Mediterranean fisheries are described as mainly small scale in type. They are comprised of small enterprises, with little capital, run by artisans who often own the production tools (vessel plus fishing gear) and to a certain extent control, to a certain extent the commercialisation network regarding this product. Both the fishing techniques considered here can be classified as artisanal. However, mechanical clam harvesting can also be classified as 'industrial fishery', as this classification is used when other factors, such as the fact that these vessels catch only one target species, the high level of technology used in the process, and its low commercial/discard ratio are taken into account.

The two different kinds of fishing activities considered in this study are located at the two extremities of more than 45 types of fishing techniques used in the Mediterranean Sea (Sacchi, 2001). Nevertheless, these two methods are those principally used here: i.e. passive (fyke net) and active (clam dredge). However, major differences can be seen regarding potential impact of the gear, *e.g.* the interaction with the bottom morphology is the highest possible regarding the clam dredge (which produces a 7-10 cm deep track) and is totally absent when using a fyke net.

As stated by Link (2002), it is doubtful whether we are "attempting ecosystem management in a fisheries context or fisheries management in an ecosystem context". At present, in the Venice Lagoon, given the complete absence of a real fishery management (mainly with respect to mechanical clam harvesting), the first hypothesis has been assumed to be realistic. But, as is also highlighted in Pranovi *et al.* (2003a), clam harvesting can be seen to be totally unsustainable, and recent evidence, such as a sharp reduction in clam production (about 40%, Boatto *et al*., 2001), seems to confirm this hypothesis.

In this context, a change in perspective is needed, which will introduce an ecosystem-based type of management, capable of ensuring the maintenance of the 'ecosystem health and sustainability' (NMFS, 1999) or the 'ecosystem state sustainability' (Link, 2002).

In order to achieve this goal, an estimation of all the effects (both direct and indirect) produced by the fishing activity on the ecosystem becomes essential. Moreover, from a management point of view, it could also be useful to distinguish between the effects induced on the environment by the different types of fishing activity.

The adoption of an ecosystem-based approach to fishery management is now among the principal objectives of policy makers. However, fulfilling this objective is dependent upon a number of factors, including the ability to evaluate the performance, either positive or negative, of these management strategies.

Exploited communities are complex systems and very few indicators are exclusive to the question of fishing impact. Therefore, finding a single indicator which measures the effects of fishing will be difficult. An alternative approach is to examine multiple indicators jn order to accumulate evidence (Garcia and Staples, 2000; Rice, 2000).

Now we are faced with the challenge of assessing the fishing effects on communities which have been exploited for a long time, without knowing their 'pristine' state (Jackson *et al.*, 2001). In this situation, according to Rochet and Trenkel (2003), there are three ways of assessing whether a community is affected by fishing: (1) examine whether it is currently changing and if so, whether this change can be ascribed to fishing; (2) develop a theory concerning the value of the attribute in an unexploited system and predict the effects of fishing on it; this will allow for an inference, from the observed patterns, as to whether the system is affected by fishing or not; (3) alternatively, an empirical reference system can be developed, by gathering indicator estimates from many communities.

Probably it is possible to locate another way which passes through the simulation obtained by the modelling approach. In this case, the constraints imposed by the trade-off between the complexity imposed by the realism and simplicity necessary for precision (*e.g.* the clustering of species in trophospecies, Yodzis and Winnemiller, 1999), which might bias the results, could be counterbalanced by the possibility of assessing the indicator performances in relation to different fishing scenarios (Walters *et al.*, 1997).

In this framework, starting with a mass-balance model, describing the Venice Lagoon ecosystems, some indicators concerning the impact of fishing activities on the ecosystem state and functioning were calculated, in order to compare artisanal type fisheries with industrial ones. This procedure gave us the opportunity to assess their applicability and to evaluate the resolution power concerning the different kinds of effects.

The aims of this study were:

- to assess the ecosystem impacts and the interactions between the two fishing activities;
- to assess the applicability of different indicators, in relation to the fishing disturbance;
- to explore different scenarios obtained in order to optimize individualy the social, economic and ecosystem aspects of fishing impacts.

## *Materials and Methods*

A description of the ecosystem was done by means of a mass-balance model, developed using Ecopath and Ecosim software (EwE, Christensen *et al.*, 2000). The model makes it possible to represent both the biotic and abiotic components of the ecosystem, by means of the flows of matter and energy, including the fishing activities and major features which influence the flows between the ecosystem components (Christensen and Walters, 2000). Thus, the model makes it possible to explore the impact of the fishing activities, described as a part of the ecosystem, on the biological communities through both direct and indirect effects (Pauly *et al.*, 2000).

A published model describing the Venice Lagoon ecosystem in 1998 was used here (Pranovi *et al.*, 2003a). In this model, the biological data are organised in such a way as to estimate the average parameters and biomasses regarding the exploited areas, thus creating a model which represents the “average exploited habitat”. The biological components of the ecosystem were aggregated into 25 functional groups, plus the bottom sediment and organic matter present in the water column (Suspend Organic Matter, SOM) which comprised two detritus groups, giving a total of 27 groups (see Pranovi *et al.*, 2003a for a detailed description of the model components). The model also takes the mechanical clam harvesting into account, considering the landings and discards, and the resuspension of the bottom sediments resulting from the fishing activity. Artisanal fishery is described in terms of the landings, as the discards are irrelevant. The model was built using energetic units; thus the flows are in kJm$^{-2}$ year$^{-1}$ and the biomass in kJm$^{-2}$.

20 scenarios were simulated, their final "artisanal fishing effort" ($F_A$) ranged from $F_A$ =0 to $F_A$ =2 relative to the baseline, with increments of 0.1; these 20 scenarios were then repeated three times with relative "clam fishing effort" ($F_T$): $F_T$ = 0.0, 0.5 and 1.0 obtaining a total of 60 scenarios. Other 13 scenarios were simulated with $F_T$ ranging between 0 and 1.3 and $F_A$ = 1. The decision to stop the $F_T$ at 1.3 was made by assuming that one of the main objectives of a management policy in the Venice Lagoon is to reduce, not increase, the clam fishing. Therefore, the search for solutions using a low $F_T$ can be useful, because the actual starting level of $F_T$ =1 is already high. Mechanical clam harvesting has strong interactions with the bottom sediment and produces both direct and indirect disturbances. The actual fishing effort is such that, on average, a square meter is exploited more than three time a year (Pranovi *et al.*, 2003b).

The next step was to explore which effects the fishery can have when we attribute their monetary values, to all the species involved in the fishing activity..Therefore the quantities were multiplied by the market values. The prices adopted relating to the year 1998 in the economic scenarios, and transformed into euros relating to the 2001, were obtained from the fish market at Chioggia. Only the commercial species are brought to the fish market and are priced; the non-commercial species which are directly or indirectly involved in the fishing activity, do not have a market value. Therefore in order to measure the economic externalities of the fishery, we need to attribute an hypothetical value to them. The price attribution regarding the non-commercial species and groups is made on a bioenergetic basis, starting from the assumption that the energy flows are a way of describing the ecosystem. The energy flows are defined by means of the Trophic Level (TL) of the species, which is the average number of passages through the trophic chain, from the primary producers and detritus, up to a given organism (Lindeman, 1942).

As regards each species or group of species, either commercial or non-commercial, it was possible to determine a TL value (or the energy cost to the ecosystem in supporting it). On the basis of the average market price of the commercial species belonging to the same TL, it was possible to obtain a price for each TL and therefore also attribute a price to the non-commercial species with a comparable TL.

The indicators here selected were all evaluated at an ecosystem level and are included in the emergent properties of the ecosystem which can be measured; according to Link (2002), they can be grouped as single species metrics (MSY), food web metrics (mean Trophic Level) and system analysis metrics (total biomass, exergy).

Landings, catches and discards are traditional indicators concerning fishing activity. The biomass variability is proposed as an indicator of the fishing pressure (Duplisea et al., 1997), while the mean trophic level of the fishery catches is proposed as an indicator of the effect of fishing on the food webs (Pauly et al., 1998). Exergy is strictly defined as the amount of work the system can carry out when it is brought into thermodynamic equilibrium with its environment (Jørgensen, 2000). As can be seen from the above definition, exergy is dependent on both the environment and the system, not solely on the system. Therefore exergy is not a state variable, as, for example, are both free energy and entropy. Exergy is often used as a goal function in ecosystem modelling, as an increase in its value is supposed to be connected with the presence of a higher ecosystem maturity (Jørgensen et al., 1995; Muller and Leupelt, 1998). In this paper, exergy is proposed as a global index, which can be used to estimate the state of the system in relation to fishing pressure.

Since most of the indices do not give an absolute maximum value regarding the explored range of fishing pressures concerning artisanal and clam fishery, we decided that a comparison between the absolute change in the index, due to a relative change in the two fishing efforts, is important. In order to measure the gradient, the monotone curves of the index were fitted with a logarithmic function:

$$I=a+b*\log(F) \qquad (1)$$

where I is the Index value obtained for the different fishing efforts (F). The *b* coefficient of the regression curves is thus strongly linked with the gradient of the index. In fact, taking the values of the index (I' and I'') estimated for the two fishing effort values (F' and F'') one can write:

$$\Delta I=I'-I''=a+b*\log(F')-[a+b*\log(F'')]=b*\log(1+\Delta F/F) \qquad (2)$$

Thus, the absolute change in the Index (ΔI) is related, through *b*, to a relative change in the fishing effort (ΔF/F). Therefore the *b* coefficient represents the change regarding different indices which corresponds to the same relative change in the fishing effort (ΔF/F), which allows for a comparison between different indices and different fisheries.

Moreover, in order to evaluate the optimal fishing pressure in terms of the ecological, economic and social benefits, an EwE routine was used to look for the optimum (Christensen *et al.*, 2000). This routine estimates the ecological optimum using the inverse of the P/B as a weighting factor regarding each trophic group of the model.

## ***Results***

The artisanal fishery catches obtained by changing its fishing effort, while maintaining a constant $F_T$=1.0, are reported in Fig. 2. The changes in the $F_A$ concern the total artisanal fishery catch and not the quality (different pressures for different species) due to the "passive" characteristics of this type of fishery. However, the model illustrates the lower availability of some fish species at a higher $F_A$, thus giving the expected dome shaped curve (Fig. 2) regarding the yield from these species. The catches at a steady state for the simulations, with an $F_A$ varying from 0.0 to 2.0, reveal that the maximum sustainable yield (MSY) regarding each species is reached at different values of $F_A$ (some species, such as *Zosterisessor* *ophiocephalus* and *Atherina boyeri*, indicated no maximum yield). The total artisanal fishery catches obtained by varying $F_A$ within three different scenarios regarding clam fishing presusre ($F_T$= 0, $F_T$= 0.5 and $F_T$= 1.0) are reported in Fig. 3. The maximum of the total yield for the artisanal fishery ($MSY_A$) proved to be higher when the $F_T$ = 0.0 ($MSY_A$ =24.52 kJ $m^{-2}$) than when the $F_T$=1 ($MSY_A$=15.58 kJ $m^{-2}$). Moreover, the $MSY_A$ was obtained at different $F_A$s depending on the $F_T$: the lower values of the $F_T$ allowed for greater $F_A$ efforts. with $F_T$=0 the $MSY_A$ is reached at $F_A$=1.6. On the contrary, with an $F_T$ = 1.0, the $MSY_A$ is obtained for $F_A$=1.1.

The variation in the species composition of the artisanal catch, depending on whether the $F_A$ remains at a level of $F_T$=0.5 is reported in Fig. 4.. The artisanal type of fishery as indicated in the figure, is a multitarget fishery, and the biomass composition shows wide variations. With an increase in the $F_A$ the catches of some species, proportionally increase too while others, such as Nekton carnivorous, *Dicentrarchus labrax*, and Mugilidae, after an initial increase, started to decrease.

The catches and discards concerning mechanical clam harvesting at different fishing efforts ($F_T$s) are shown in Fig. 5. This fishing activity didn't indicate a maximum yield for the $F_T$ within the 0-1.3 range, while it can be observed that more than half of the total catch was discard. In Tab. 1 the economic impacts of clam fishery are reported: discard economic values are ($F_T$ =0.5 and $F_T$ =1.0) 57-59% of the landings.

Fig. 6 shows the total biomass in the environment (excluding primary producers (b)) during different fishing efforts. The biomasses in the system decrease by increasing both the $F_A$ and $F_T$, but the system is driven mainly by mechanical clam harvesting, infact the biomass difference between the $F_A$=1 and $F_T$=0 scenario and the $F_A$=0 and $F_T$=1 scenario is 17%, while changing the $F_A$ from 0 to 1 produce a change of only 2%.

Similarly, an increase in the fishing effort regarding both artisanal and mechanical clam fishery produces a decrease in the mean trophic level (mTL) in the ecosystem (Fig. 7) where the mTL shows values between 1.36 (for $F_T$=1 and $F_A$=2) and 1.51. When moving from $F_T$ =0 to $F_T$ = 1 (with $F_A$ =0) there is a decrease of 0.09 in the mTL, while between the scenarios with $F_A$ =0 to $F_A$ =1 (with $F_T$ =0) the simulation predicts a decrease of mTL of 0.04.

The MTL in the system under different types of fishing pressures was analysed with the exclusion of the primary producers and the plankton communities, but no substantial differences emerged in the trend of the index in relation to the fishing effort. The mTL of the artisanal catch is reported in Fig. 8; the mTL variations are linked to both the artisanal and mechanical fishery.

The exergy values regarding the different fishing pressures are reported in Fig. 9. As was found with the other ecosystem indicators, the exergy showed a decreasing trend when one of the fishing efforts increased. The stronger effects relate to an increase in the mechanical clam harvesting.

In order to indicate a reference direction for those indicators which have no reference points, their relative gradients were considered. The *b* values estimated for the different ecological indices are reported in Table 2, where the ratios between the *b* coefficients estimated for the same index when changing the $F_A$ and $F_T$ are also reported. The *b* coefficients indicate that an increase in the artisanal fishing effort produces negative changes in the ecosystem indices, which are several times smaller than those produced by analogous changes in the clam fishing effort.

In order to also explore the performance of these simulations from an economic point of view, the biomasses were multiplied by their monetary value. The landing values for each scenario are represented in Fig. 10; the trends are similar to those indicated for the total biomass landed by the artisanal fishery. It is possible here to roughly quantify the economic loss to artisanal fishery due to the mechanical clam harvesting, that can reach 40 %, when we compare the $F_T$=1 and $F_T$=0 scenarios (with $F_A$=2). In Fig. 11 the species value composition of the artisanal fishery landings are reported. The values for single species or groups of species varied widely, depending on the fishing effort. The value of the total catch with low $F_A$ values were dominated *Dicentrarchus labrax*, *Atherina boyeri*, Nekton carnivorous, and crabs, while *Sparus aurata*, *Zosterisessor ophiocephalus*, Mugilidae and shrimps were not important when determining the total value. With an increase in the $F_A$, squid and flat fish also became more important. With an $F_A$ of between 1.5 and 1.6, the higher values were attributed to *Atherina boyeri* and crabs, thus reflecting the species composition of the total biomass.

The fishing effort profile obtained by means of Ecopath simulations, searching for the optimum respect to economic, social, and ecosystemic points of view for each one of the three variables are reported in Table 3. As regards the social and ecosystemic optimizations, the $F_T$ is required to be equal to 0.0, the fishery exploitation by the mechanical clam harvesting resulted as fundamental only in terms of the economic optimization ($F_T = 1.6$). In order to obtain as ecosystemic optimization, both types of fishing effort have to be equal to zero.

## *Discussion*

The MSY, a stock related indicator, is a traditional reference point (Gislason, 1999) which is often criticized because of the estimation problems contained in it, its weakness as a management goal, and the difficulty in effectively implementing harvesting strategies based on this strategy (Mace, 2001). In this paper the MSY was estimated using a multi-species model; in this way the problem of the interaction between the species and the fisheries was partially solved. The MSY regarding the target groups was simultaneously calculated, thus allowing us to consider the trophic relationship between the species.

The total artisanal fishery catch related to its MSY proved to be even higher than the actual catch obtained using the $F_A$=1, and was strongly driven by the $F_T$, while for some species the MSY had already been reached. If these resources were managed using basing on the MSY target reference point, the reduction or enhancement of the artisanal catch would be more dependent on the $F_T$ than on the $F_A$.

An evaluation of the MSY, based on the catch-effort curve regarding clam harvesting, was not possible to cary out, because of the phenomenon known as 'Tapes paradox' (Libralato *et al.*, 2002), where the stock does not show any decline even if the fishing effort is doubled to $F_T$ =2. The fishing activity, which can be the main limitation for the resource directly affected by it, seems to be unable to limit the clam biomass, since the fishing provides food for the target species by means of resuspension and decreases competition, thus increasing the mortality rate of the non-target species (Pranovi *et al.*, 2003a).

The other indicators, in contrast to the previous one, are not related to any reference point. Therefore, they could be useful when looking for a reference direction, towards which the parameter moves, depending on the fishing effort.

The biomasses in the environment are strongly affected by mechanical clam harvesting, while the effects of artisanal fishery have proved to be very small. Based on this index, and considering that reducing the biomasses to low levels also generates effects in terms of commercial stocks by inducing greater variability in the yields and recruitment (Murawski, 2000), the importance of reducing the $F_T$ rather than the $F_A$ can be seen.

Moreover, the variations in the mean Trophic Level in the ecosystem are strongly driven by mechanical clam harvesting, which also influences the mTL in the artisanal catches.

Clam fishery total catches depend on the effort of this fishing activity and are slightly affected by the artisanal one, conversely artisanal fishery catches are highly and negatively affected by an increase of the clam fishing effort. The MSY of mechanical clam harvesting is not reached because of the "Tapes paradox" and because we choose to stop the simulation at $F_T$=1.3.

Even when taking into account the limitations of the model approximations, the indicators here considered would seem to be useful when describing the modifications induced by variations in the fishing effort, by being able to discriminate among the different kinds of effects produced (*i.e.* direct or indirect ones).

As regards many of the ecosystem indicators, those considered here could be influenced not only by the effects of fishing, but also by eutrophication and other kinds of disturbance (Rochet and Trenkel, 2003). Hovewer, the model approach used here allowed us to carry out separate analyses, depending on the different types of disturbance.

The comparison highlighted the fact that in the Venice Lagoon the driving force which determines the state of the whole ecosystem is mechanical clam harvesting, which has a 3-6 times greater impact than artisanal fishery. One of the main reasons for this is, probably, that it produces a lot of indirect effects in all parts of the ecosystem - *e.g.* a high discard incidence, many feedback loops (either positive or negative), the exploitation of key species (Pranovi *et al.*, 2003a,b).

In this situation, a conflict between the two kinds of fisheries becomes inevitable, even if there is no direct competition regarding gear or resources, but merely a sharing of the exploited ecosystem.

This phenomenon is clearly visible in the comparison between the income from artisanal fishery at the beginning of the clam exploitation (1991, about 29,300 € pro capita), and at the maximum clam exploitation rate (2001, about 23,400 € pro capita). Therefore the artisanal fishermen, mainly the younger ones, were discouraged from continuing with this traditional activity and many of them moved to the mechanical clam type of fishery.

In the Venice Lagoon, artisanal fishery employs, per weight of landings, 15 times more people than mechanical clam fishery, and, regarding a given amount of the landed value, artisanal fishery employs, on average, 3.25 times more people than mechanical clam fishery. This simple social analysis confirms the high value of artisanal fishery, which is strongly rooted in the community, as has alos been reported regarding other coastal areas (Sumaila *et al.*, 2001; Al-Ansi and Priede, 1996).

Mechanical clam fishery is a high income activity, but we have to take into account that it also has a negative impact on society. When we translate the ecosystem changes into monetary terms, it can be seen that mechanical clam fishery is intrinsically uneconomic in character, and the expenditure regarding the society is higher than the value of the income; it also has direct effects on artisanal values.

In order to analyse how prices at the fish market reflect the efficiency of the fishing activities, we also compared the value of the annual landings in 2001, obtained by multiplying the market prices of the single species in 1979, 1991 and 2001 respectively by the species biomasses. The landing quantities in 2001, with the exception of *Tapes philippinarum*, were better evaluated if the prices in 1979 were applied. This shows that the seafood prices are not attributed searching for the most efficient combination.

We are faced with the question asked by Costanza (1996): “What external influences are needed and when should they be applied in order to achieve an optimum economic system via evolutionary adaptation?”.

With the purposes of conducting a cost-benefit analysis of the management of fishery in the Venice lagoon, not only the landed value and the cost of the two activity, have to be considered but also the cost for society, which is the externalities. By means of these, simulations, an initial approximation of the cost to society is given, based on the quantity of discard, *i.e.* species or groups of species, which are either directly, or indirectly, involved in fishing activities.

## *Conclusions*

This study allowed for a description of the effects on the ecosystem of the fishing activities in the Venice Lagoon, distinguishing between those caused by artisanal fishery and those caused by the industrial type (clam dredging).

Mechanical clam harvesting, which has the typical features of an industrial fishing activity, was shown to deeply affect the lagoon ecosystem, indirectly interfering with the artisanal activity.

These factors inevitably produce a strong conflict between the two kinds of fishery, with the potential danger that artisanal fishing will disappear. Moreover, it produces enormous stress within the ecosystem and disrupts the economic and social features of the local community.

This is an underestimate of the total externalities of fishing activity in general, in a the future study, a more comprehensive evaluation of the problem will be given, which will also evaluate the impact on non target species such as the benthic species.

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Table 1 – Average value and biomass of discard, landing and total catch derived from mechanical clam harvesting ($F_T$ =0.5 and $F_T$ =1) expressed as €/m$^2$.

| | | **$F_T$=0.5** | | **$F_T$=1.0** | |
|---|---|---|---|---|---|
| | | % | | % | |
| Value €/m$^2$ | discard | 57,36 | 0,37 | 59,12 | 0,66 |
| | landing | 42,63 | 0,27 | 40,87 | 0,45 |
| | **total catch** | **100** | **0,64** | **100** | **1,12** |
| quantity kJ/m$^2$ | discard | 57,26 | 289,08 | 58,46 | 504,24 |
| | landing | 42,73 | 215,77 | 41,53 | 358,2 |
| | **total catch** | **100** | **504,86** | **100** | **862,54** |

Table 2 - Estimation of the gradient of the changes for some ecosystem indicators estimated with Ecopath results. The gradient (change of the indicator due to changes in the fishing effort) is estimated using a logarithmic relationship. The ratios between the gradient due to changes in clam fishing effort ($F_T$) and small-scale fishing effort ($F_A$) are evidenced, showing that the impact of mechanical clam harvesting is always higher than the artisanal one.

| Variable | Gradient * | Explained Variance (R2) % | Changing factor referred to F Clam (relative change $F_T$ / $F_A$ ) |
|---|---|---|---|
| | | **Total Biomass (excluding detritus)** | |
| $F_A$ ($F_T$=0) | -56.0 | ( 98.54 ) | 3.5 |
| $F_A$ ($F_T$ =0.5) | -45.6 | ( 98.79 ) | 4.3 |
| $F_A$ ($F_T$ =1) | -35.9 | ( 98.42 ) | 5.5 |
| $F_T$ ($F_A$ =1) | -195.5 | ( 98.37 ) | 1.0 |
| | | **Total Biomass (excluding primary producers)** | |
| $F_A$ ($F_T$ =0) | -56.0 | ( 97.07 ) | 4.0 |
| $F_A$ ($F_T$ =0.5) | -45.3 | ( 97.496 ) | 5.0 |
| $F_A$ ($F_T$ =1) | -34.9 | ( 96.407 ) | 6.4 |
| $F_T$ ($F_A$ =1) | -224.7 | ( 95.928 ) | 1.0 |
| | | **Mean Trophic Level in the Ecosystem** | |
| $F_A$ ($F_T$ =0) | -0.0404 | ( 98.551 ) | 1.9 |
| $F_A$ ($F_T$ =0.5) | -0.0356 | ( 99.071 ) | 2.1 |
| $F_A$ ($F_T$ =1) | -0.0290 | ( 98.939 ) | 2.6 |
| $F_T$ ($F_A$ =1) | -0.0753 | ( 94.41 ) | 1.0 |
| | | **Mean TL in the Ecosystem (excluding PP)** | |
| $F_A$ ($F_T$ =0) | -0.0784 | ( 99.499 ) | - |
| $F_A$ ($F_T$ =0.5) | -0.0793 | ( 99.854 ) | - |
| $F_A$ ($F_T$ =1) | -0.0747 | ( 99.947 ) | - |
| $F_T$ ($F_A$ =1) | No monotone function: maximum at $F_T$ = 0.4 | | |
| | | **Exergy of the Ecosystem (referred to $F_T$ = $F_A$ =1)** | |
| $F_A$ ($F_T$ =0) | -0.0608 | ( 97.291 ) | 4.3 |
| $F_A$ ($F_T$ =0.5) | -0.0498 | ( 97.57 ) | 5.2 |
| $F_A$ ($F_T$ =1) | -0.0381 | ( 96.233 ) | 6.8 |
| $F_T$ ($F_A$ =1) | -0.2591 | ( 95.805 ) | 1.0 |

* coefficient b of the equation $y=a+b*\log(x)$ with Y as fishing effort and X as the variable investigated (the fraction of explained variance is reported)

Table 3 – Results obtained searching for the optimum for each one of the three sectors (economic, social and ecosystem).

| | **Fishing effort** | |
|---|---|---|
| **Optimum** | Mechanical Clam harvesting | Artisanal Fishery |
| Economic | 1.6 | 0.3 |
| Social | 0.0 | 1.0 |
| Ecosystemic | 0.0 | 0.0 |

Figure 1

The location, distribution and extension of the fishing grounds in relation to the artisanal and mechanical clam fisheries in the Venice Lagoon. The fishing gear and techniques are also shown in this figure.

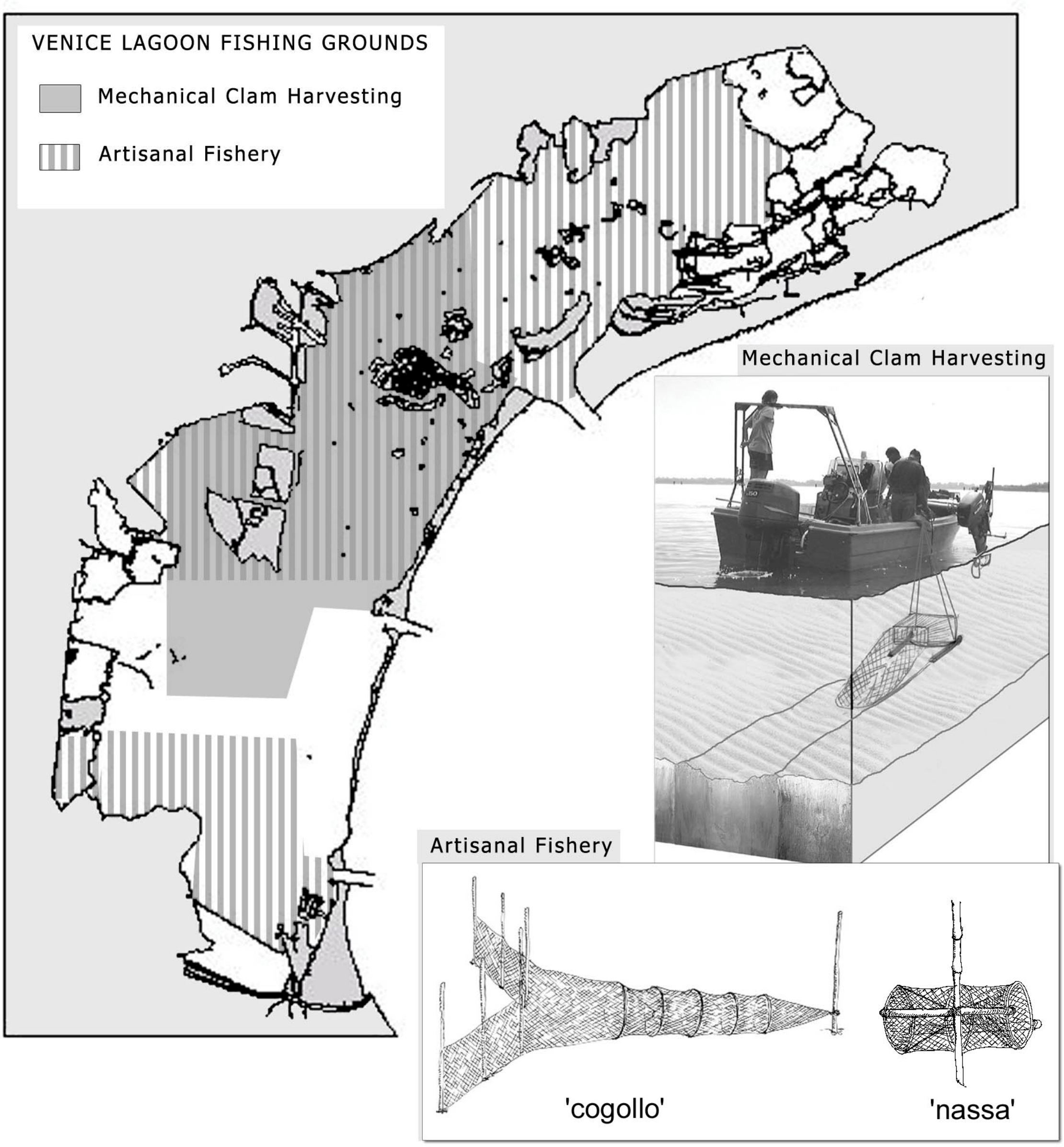


Figure 2

The artisanal fishery catches, at a steady state, estimated using Ecopath with Ecosim model, considering different artisanal fishing efforts ($F_A$), maintaining the mechanical clam fishing effort constant to the actual value ($F_T$=1.0). The catches for the different species are reported in energetic units (kJ $m^{-2}$), while artisanal exploitation the discard is not considered.

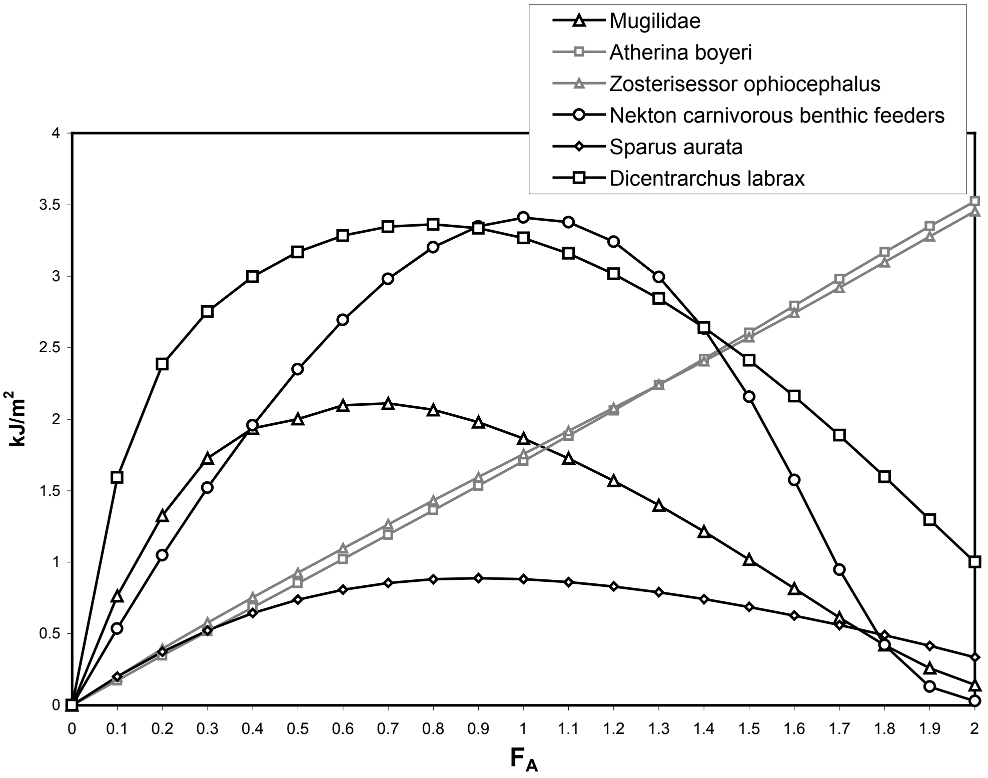


Figure 3

Total landings of artisanal fishery obtained by changing the artisanal fishing effort ($F_A$), under three scenarios of clam fishing pressure ($F_T$=0, 0.5, 1.0).

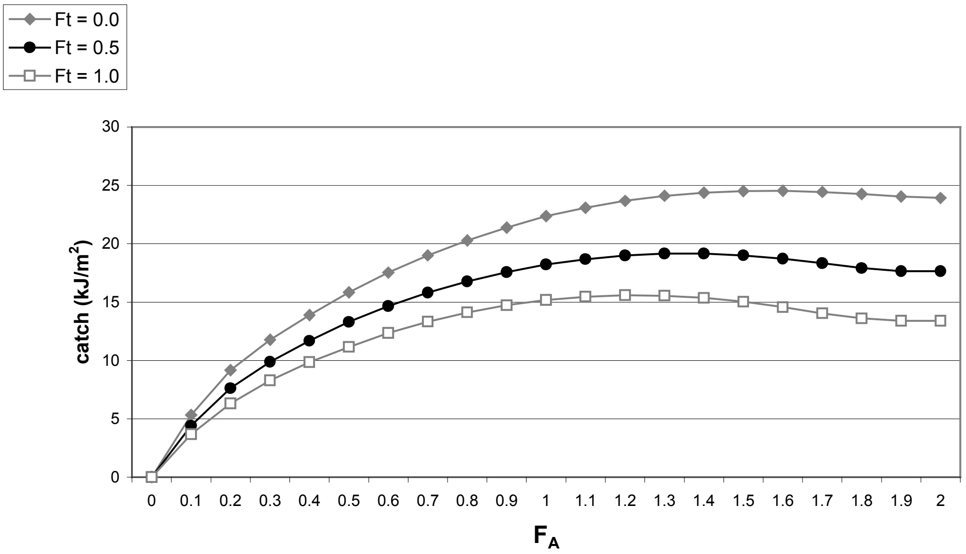


Figure 4

Species composition of artisanal fishery catches related to artisanal fishing effort variations and mantaining the mechanical clam harvesting fishing effort at 0.5 level.

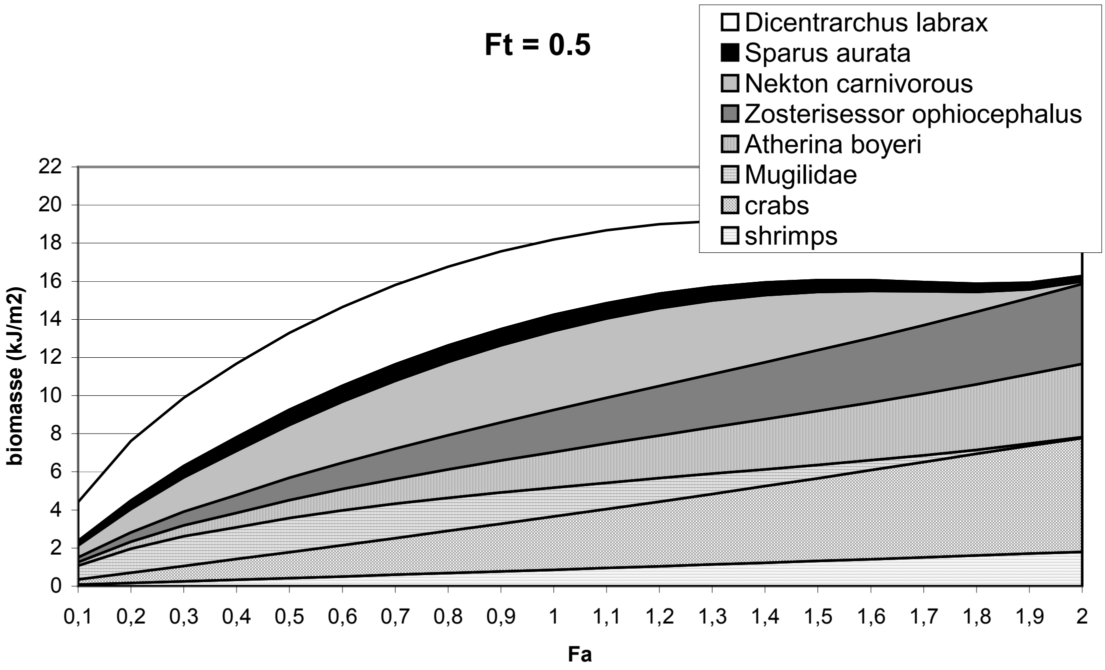


Figure 5

The mechanical clam fishery catch, divided into landings and discard, estimated as steady state values, due to changes in the clam fishing effort ($F_T$) from 0 to 1.3, with a fixed actual value for artisanal fishery ($F_A$=1.0).

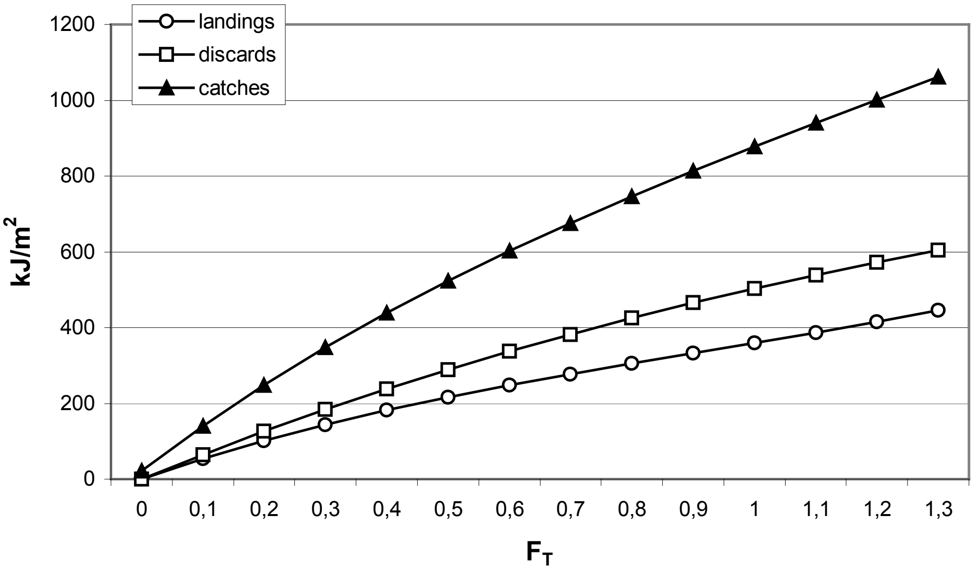


Figure 6

Total biomass of the ecosystem (a) with and (b) without primary producers, estimated at different fishing pressures. The scenarios obtained by varying the artisanal fishing effort, considering three types of clam fishing effort, are explored.

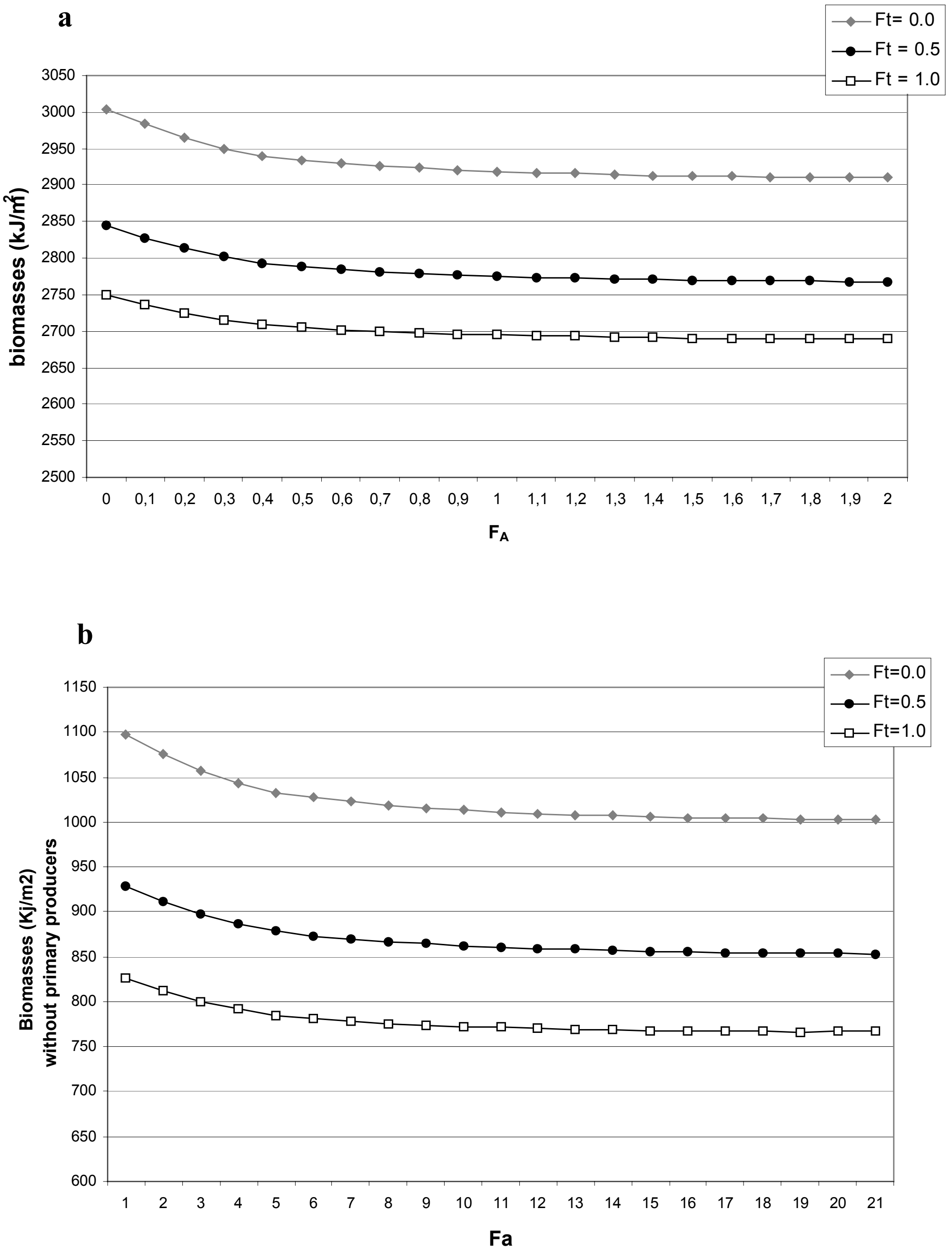


Figure 7

The mean trophic level in the ecosystem, as an index of the ecosystem status, estimated considering different values for artisanal and clam fishing efforts.

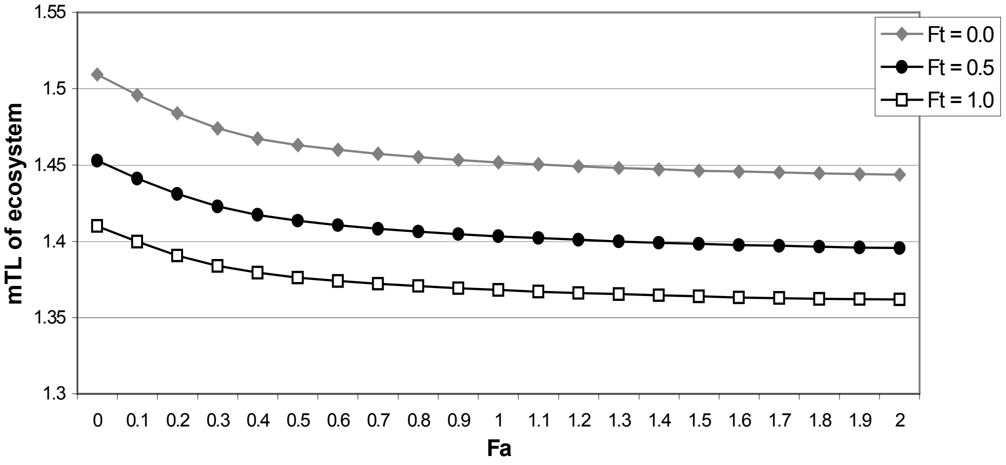


Figure 8

The mean trophic level of the artisanal catch, as an index of health of the ecosystem, estimated considering different values for both artisanal and clam fishing efforts.

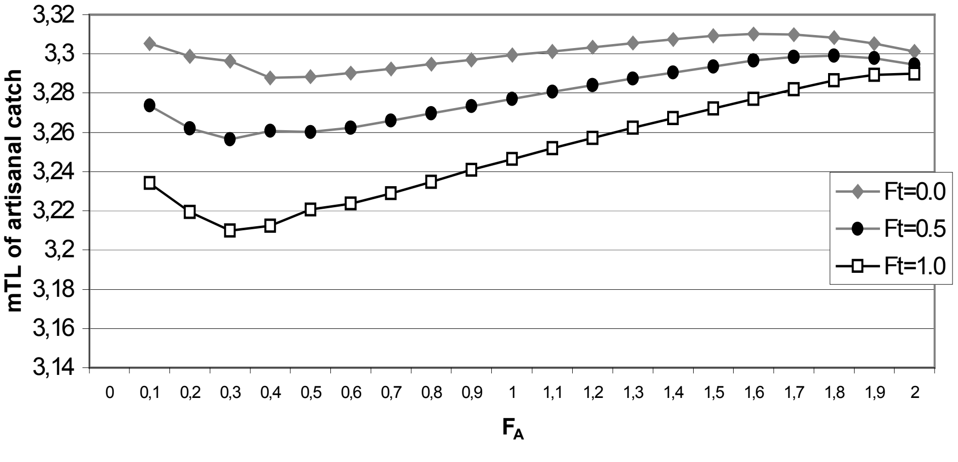


Figure 9

Exergy estimations, based on the steady state results of the model at different exploitation rates. The exergy estimations are reported as values relative to the Exergy of the actual status of the system ($F_A = F_T = 1.0$).

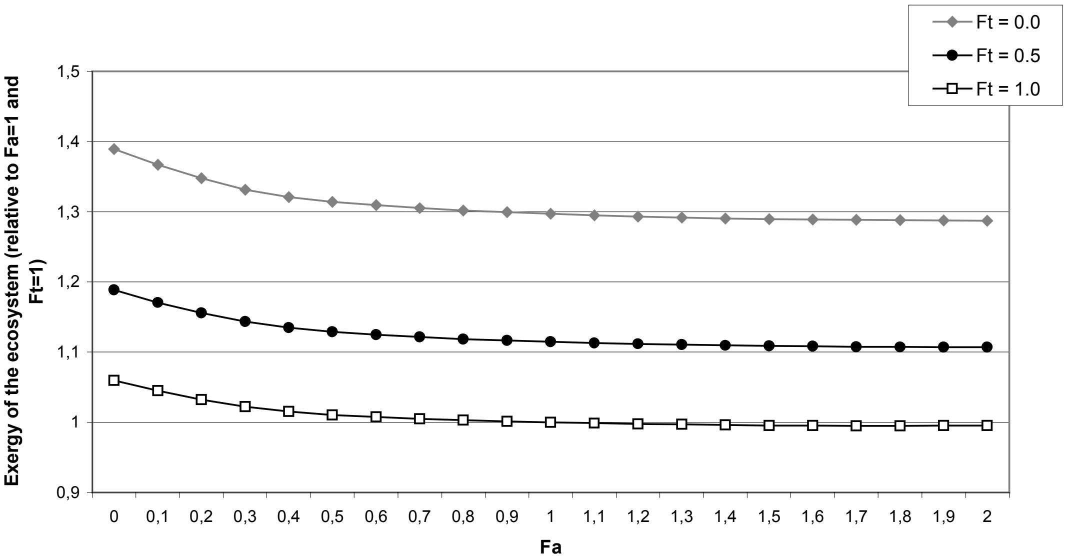


Figure 10

Total value of landings by artisanal fishery, estimated considering different artisanal and mechanical fishery fishing efforts.

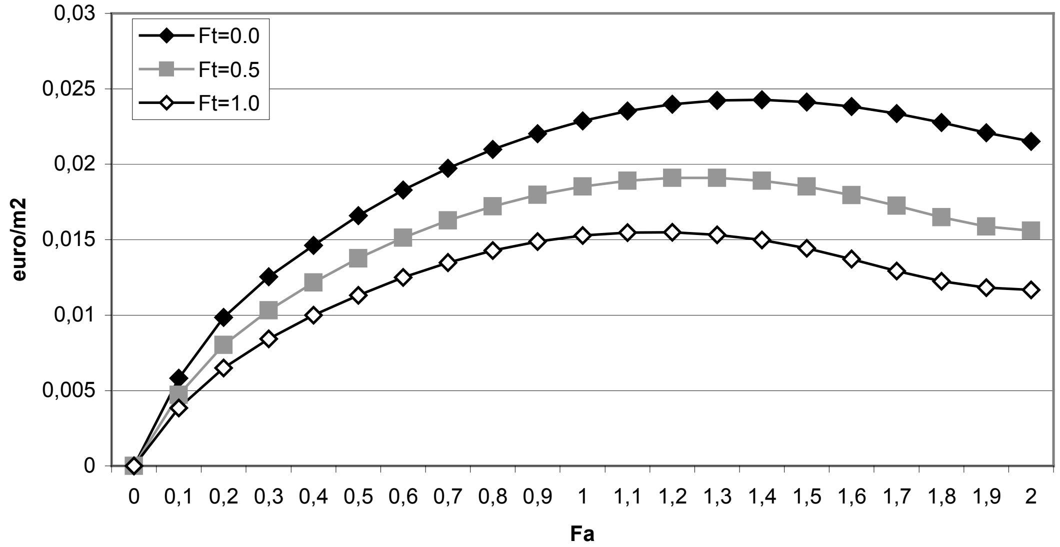
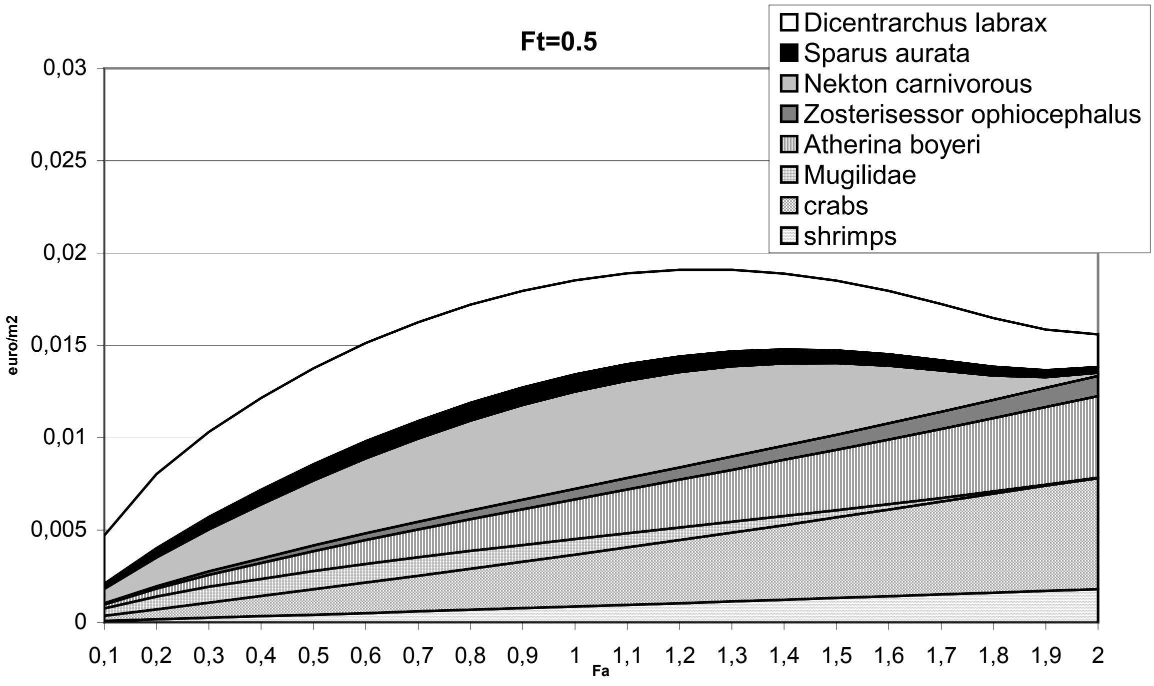


Figure 11

Species composition of value of landings obtained for $F_T$ =0.5 and $F_A$ varying from 0.0 to 2.0.



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(lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002
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