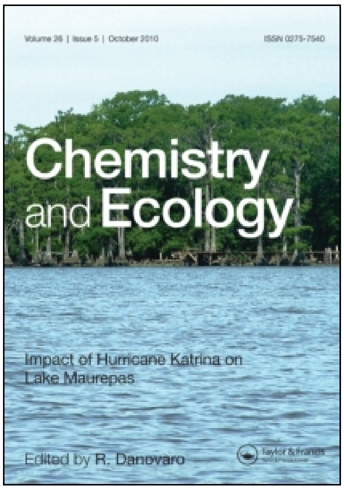

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Comparison between artisanal and industrial fisheries using ecosystem indicators

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COMPARISON BETWEEN ARTISANAL AND INDUSTRIAL FISHERIES USING ECOSYSTEM INDICATORS

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Artisanal fishery in the lagoon of Venice is a multi-target activity with an old tradition. It was the only fishing activity since a new one with most features of an industrial fishery flourished following the introduction of the Manila clam in 1983. To compare the two fishing activities, a set of ecosystem indicators (landings, catches, discards, biomass of the system, mean Trophic Level of the system and exergy) obtained by a model approach, was applied. The model used was a mass-balance model of the lagoon ecosystem developed with the software package Ecopath with Ecosim. The 73 scenarios obtained by changing the fishing effort of the two different fisheries were used to explore the impact of fishing activity on the ecosystem. The results showed that the two activities are strongly interrelated, even if they do not exploit the same resources, and that the mechanical clam harvesting is the driving force able to affect the ecosystem state fundamentally. All this produces a strong conflict between the two kinds of fisheries. The ecosystem and social optimisation depend mainly upon a reduction of clam fishery, while the optimisation of the economic aspects is strictly linked to the maintenance of this fishing activity.

Keywords: Artisanal fishery; Indicators; Dynamic model; Venice Lagoon

1 INTRODUCTION

The exploitation of a common property like fish has been demonstrated to be unsustainable as showed, on a global scale, by the stock depletion (Botsford *et al.*, 1997), the reduction of mean Trophic Levels (mTL) of the catches (Pauly *et al.*, 1998) and the marine habitat disturbances (Hall, 1999).

Notwithstanding, when correct procedures are not in place, the fishing industry is driven to search for new technologies that allow it to intensify the fishing effort. Thus, vessels are becoming larger and faster, use more expensive technologies and are catching fish in shorter periods of time, thereby broadening the gap between sustainability and fishing activities. All this produces an increasing number of people, involved in the exploitation of marine biological resources, lacking in training, experience and skills. It also generates conflicts for space

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and resources between different types of fishing activities, mainly between industrial and artisanal fishery (Allison and Ellis, 2001; Mathew, 2001).

In coastal areas, where small-scale and artisanal sectors are particularly rooted (FAO, 2000), conflicts between new and old fishing activities can be even greater. These modifications in the forms of fishing generate changes at an economic and social level (FAO, 2000; Ruttan *et al.*, 2000; Sumaila *et al.*, 2001), as well as on an ecological level.

The artisanal sector is particularly vulnerable as it often depends on fixed gears that are incompatible with towed equipment, such as industrial trawls. The solution is often clear – *e.g.* introduce management plans that separate the different kinds of gear in space and time – but enforcement may be difficult (FAO, 2000).

Greater interest from the international framework of policy regulation is given to coastal resources and conflicts between different kinds of fishery, 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 in which explicit proposals are made to protect and rehabilitate lagoons, nursery and spawning areas as far as possible. Moreover, the effects of fishing on targeted fish stocks and on the marine and coastal ecosystems have to be considered with an ecosystemic approach, as indicated by the Agenda 21 and the UN Fish Stocks Agreement (Mathew, 2001).

In such a complex framework, a potential core set of indicators are developed within many national and international organisations with the purpose of describing driving forces, pressures, state, impact and response of the ecosystem to the fishing pressure (Zenetos *et al.*, 2002).

Indicators for the ecological, economic and social effects of fishing are demanded, and a new interest in environmental changes, and not just in stocks changes, is required (Anonymous, 2000). These indicators can be used as a basis for the evaluation of fishing pressure, and applied in fishery management in order to reach an integrated policy characterised by the combination of the principles of fishery and ecosystem management under the shield of sustainability (Rice, 2000).

The Venice Lagoon is characterised by the presence of two fishing activities: on one side the artisanal fishery, multi-target and multi-gear and, on the other, the mechanical exploitation of the Manila clam (*Tapes philippinarum*, Adams and Reeve, 1850).

From the perspective of sustainable exploitation, bigger efforts have to be made to define and apply management strategies that can ensure the sustainable development of fishing, and the coexistence of the two types of fishing activities, in such a critical environment as the Venice Lagoon. Indicators must, therefore, highlight a reference direction making it possible to predict whether the indicator will increase or decrease under exploitation (Rochet and Trenkel, 2003).

The aims of this study are:

- To evaluate impacts and interactions of the two fishing activities in the Venice Lagoon by means of a modelling approach, in order to compare their influences on ecology, economics and society.
- To assess the applicability of indicators in relation to different kinds of fishing disturbance.
- To seek the fishing pressures that one by one maximise the social, economic and ecosystemic aspects.

1.1 Fishing in the Venice Lagoon

The Venice Lagoon is a sensitive area subjected to different kinds of anthropogenic pressures mainly due to industrial pollution, eutrophication and fishery exploitation. Among the fishing activities, artisanal fishery has a long tradition and, as revealed by the laws of the past centuries, it was managed wisely (Granzotto *et al.*, 2001); the introduction in the middle of the 1980s of a new exploitable resource (*T. philippinarum*), resulted in the appearance of a new form of fishery which, with a total lack of management strategies and control, quickly developed throughout most of the lagoon basin (Fig. 1).

A definition of small-scale artisanal fishery generally can be based on different types of categorisation (social, environmental, technological, size of the boat, size of the fished areas). In the Venice Lagoon, artisanal fishery may be defined as an activity based on an inevitable link between fisherman and lagoon, a result of centuries of traditions rooted in the past, and created by a profound knowledge that until the mid 20th century led to the use of more than 25 fishing techniques (Granzotto *et al.*, 2001). At present, however, only two kinds of artisanal fishing gears are used, both of the trap net family: a fyke net named

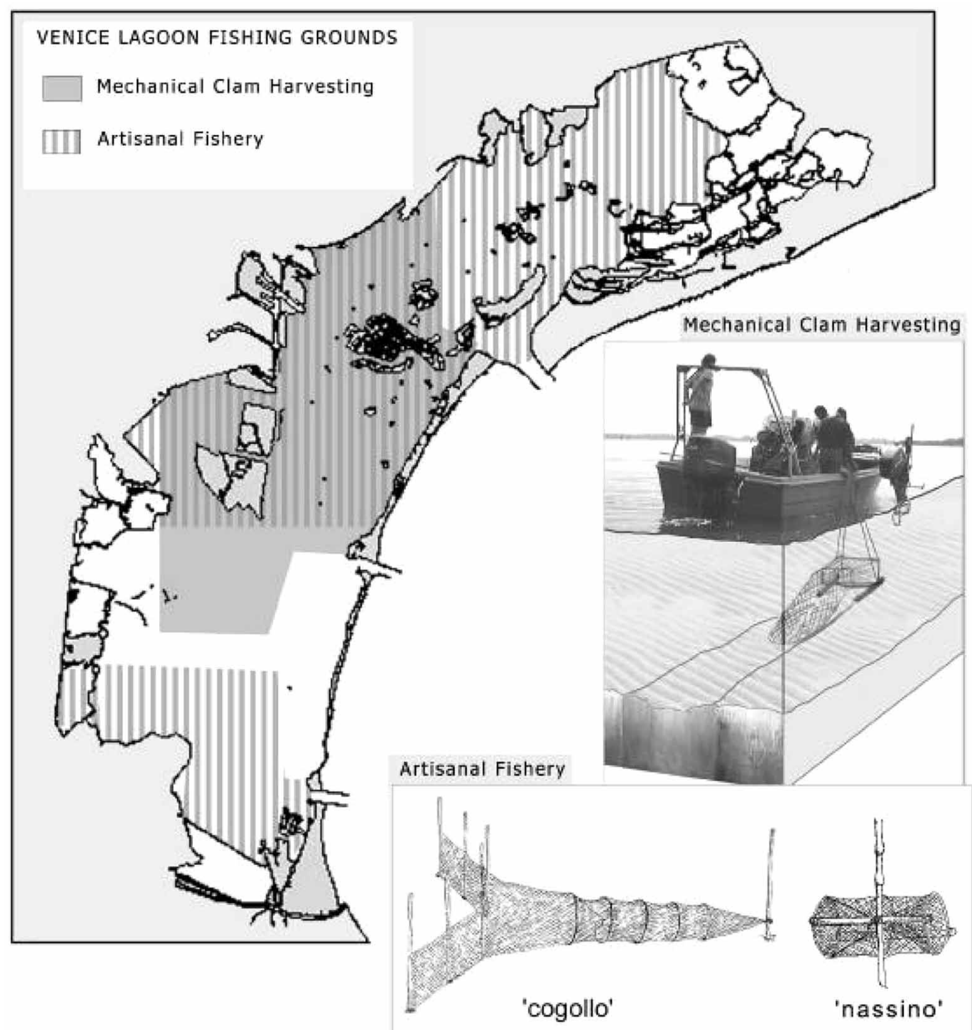

FIGURE 1 The location, distribution and extension of the fishing grounds relative to artisanal and mechanical clam harvesting in the Venice Lagoon.

'cogollo' used in shallow water, consisting of a leader about 40 m long that drives the fish towards four or more cone-shaped unbaited traps ending in funnel nets that are left and checked every 2–3 days (Fig. 1); and a double-funnel trap locally named 'nassino' or 'cheba' which is left and checked after 3 h.

Artisanal fishermen target a wide range of marine species including residents and migrants, depending on seasons, tide, and fishing grounds (Mainardi *et al.*, 2001). The mechanical clam harvesting is carried out by means of small boats with one or two supplementary 25 HP 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 clams: the latter are then collected inside the net. The boat is also equipped with a 300 HP engine for reaching the fishing ground in the lagoon. The mechanical collection, the high catches (40,000 mT/year) and the high quantities of discards, have led us to define this fishing activity as industrial fishery. Mechanical clam harvesting directly influences the bottom morphology and sediment biogeochemistry, disrupting habitat and resuspending sediment and organic matter (Pranovi *et al.*, 2003b). Moreover, this fishing activity forces the ecosystem into a less 'mature' state (Pranovi *et al.*, 2003a), and enhances the population of the target clam due to resuspension of organic material and the wide trophic spectrum of this species (Sorokin and Giovanardi, 1995).

The fish production in the Venice Lagoon was totally derived from artisanal fishery until the late 1980s (on average the catches landed at Chioggia fish-market for the period 1971–1981 were 2127 mT per year, corresponding on average to 8.52 million Euros). In 1999, the mechanical clam harvesting production of *T. philippinarum* amounted to 40000 mT (60 million Euros) while artisanal fishery was down to 629 mT (2.31 million Euros).

2 MATERIALS AND METHODS

The 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 biotic and abiotic components of the ecosystem by means of the flows of matter and energy, including the fishing activities with their catches, discards and other major features influencing 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 has been used here (Pranovi *et al.*, 2003a). In the model, the biological data are organised to estimate the average parameters and biomasses for the exploited areas, leading to a model that represents the 'average exploited habitat'. The biological components of the ecosystem were aggregated in 25 functional groups plus bottom sediment and organic matter in the water column (suspend organic matter, SOM) made up two detritus groups, for a total of 27 groups (see Pranovi *et al.*, 2003a, for the detailed description of the model components). The model also accounts for the mechanical clam harvesting, considering landings and discards and resuspension of the bottom sediments due to the fishing activity. Artisanal fishery is described by landings being the discards irrelevant. The model was built using energetic units, thus flows are in kJ m^{-2} $year^{-1}$ and biomass in kJ m^{-2}.

Starting with the mass-balance model, it is possible to change the fishing effort dynamically by using the Ecosim routine, obtaining simulations of ecosystem changes due to changes in the fishing pressure (Walters *et al.*, 1997; Pitcher *et al.*, 1999; Pitcher 2001). Using the model of the Venice Lagoon ecosystem for 1998, for which the fishing efforts are considered as baseline (*i.e.*, artisanal (F_A) and mechanical clam (F_T) relative fishing efforts are unitary), a set of simulations are obtained by opportunely changing the final fishing efforts. The simulations are done running the model for 30 years: a first period of 5 years with fishing efforts set at baseline values, 10 years with fishing effort linearly changing to the chosen final value, and 15 years keeping up the fishing effort constant leading the biomasses to reach the steady state. Changing the final fishing effort opportunely for the artisanal fishing (F_A), or the clam harvesting (F_T), several simulations result, each giving a final scenario of the ecosystem, from which the indices are taken.

Twenty scenarios were simulated with final artisanal fishing effort (relative to the baseline) ranging from $F_A = 0$ to $F_A = 2$ with increments of 0.1 and these scenarios were repeated for three series of relative clam fishing effort (F_T): $F_T =$ 0.0, 0.5 and 1.0 for a total of 60 scenarios. Maintaining $F_A = 1$, another 13 scenarios were simulated with F_T ranging between 0 and 1.3. The choice of stopping the F_T at 1.3 is made assuming that one of the main objects of a management policy of fishery in the Venice Lagoon is to reduce, not increase clam fishery, and exploring solutions with a high F_T can be useful because the actual starting level of $F_T = 1$ is already high: mechanical clam harvesting has strong interactions with bottom sediment and produces direct and indirect disturbances; moreover, the actual fishing effort is such that a square meter is exploited, on average, more than three time in a year (Pranovi *et al.*, 2003b).

The scenarios of the ecosystem at steady state obtained with different final fishing efforts make it possible to estimate several properties of the ecosystem, some of which are simply outputs of the model. However, since they are estimated by using an ecosystem approach (thus including direct and indirect effects of the fisheries on the whole trophic web, and the interactions between them), these estimates may be considered as ecosystem indicators of the effects of the fishery. The chosen indicators are: landings, catches, discards, biomass of the system, mTL of system and exergy. Landings, catches and discards are traditional indicators for the fishing activity. Biomass variability has been proposed as an indicator of fishing pressure (Duplisea *et al.*, 1997), while the mean trophic level of catches was proposed as an indicator of the effect of fishing on food webs (Pauly *et al.*, 1998). Exergy is often used as a goal function in ecosystem modelling as its increase is supposed to be linked to higher ecosystem maturity (Jørgensen *et al.*, 1995; Muller and Leupelt, 1998). Here, exergy is proposed as a global indicator that could summarise the state of the system in relation to the fishing pressure. The exergy coefficients proposed by Marques *et al.* (1997) are adopted.

Moreover, in order to evaluate the optimal fishing pressure in terms of ecological, economic and social benefits, a routine EwE was used to search for the optimum (Christensen *et al.*, 2000). This routine estimates the ecological optimum using, for each trophic group of the model, the inverse of the P/B as a weighting factor. The market price of each commercial species (referred to 1998) was used to optimise the fishing effort in economic terms, *i.e.* to estimate the maximum economic yield (MEY). The social benefits were estimated using the number of employers per unit of catch-value: we used 0.15 and 0.03 jobs/catch-value for artisanal and mechanical clam harvesting, respectively.

3 RESULTS

The catches of artisanal fishery obtained by changing the fishing effort, while maintaining constant $F_T = 1.0$, are reported in Figure 2. The changes in F_A regard the total artisanal fishing effort and not its quality (different pressure for different species) due to the ‘passive’

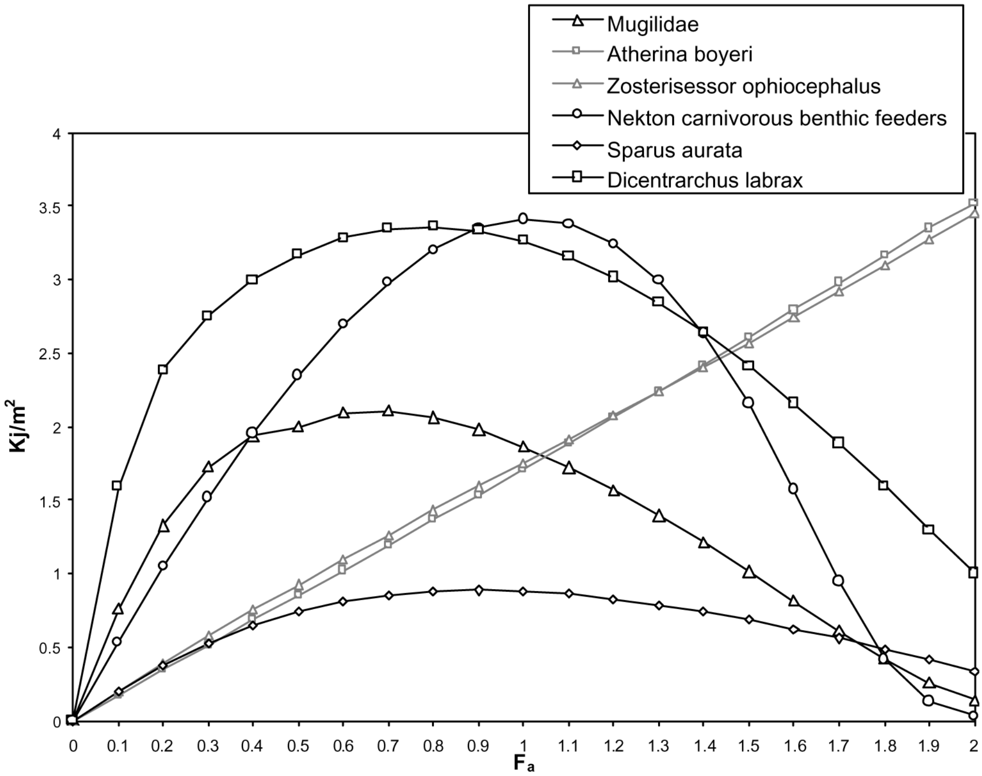

FIGURE 2 The artisanal fishery catches at a steady state estimated by the Ecopath with Ecosim model under different artisanal fishing efforts (F_A), maintaining the mechanical clam fishing effort constant at the current value ($F_T = 1.0$). Catches for different species are reported in energetic units (kJ m^{-2}), while no discards are modelled in the artisanal exploitation.

characteristics of this fishery. However, the model represents the lower availability of some fish species at higher F_A, thus giving the awaited dome shaped curve (Fig. 2) for the yield of these species. The catches at a steady state for simulations with F_A varying from 0.0 to 2.0 reveal that the maximum sustainable yield (MSY) is reached for each species at different values of F_A (some species, such as *Zosterisessor ophiocephalus* and *Atherina boyeri*, showed no maximum). The total catches of artisanal fishery varying F_A with relative fishing effort for clam harvesting set at three values ($F_T = 0$, $F_T = 0.5$ and $F_T = 1.0$) are reported in Figure 3. The maximum of the total yield for artisanal fishery (MSY_A) proved to be higher when $F_T = 0.0$ ($MSY_A = 24.52$ kJ m^{-2}) than when $F_T = 1$ ($MSY_A = 15.58$ kJ m^{-2}). Moreover, the MSY_A is obtained at different F_A depending on the F_T: lower values of F_T permits higher F_A efforts (with $F_T = 0$, MSY is at $F_A = 1.6$), on the contrary with $F_T = 1.0$ the MSY is obtained for $F_A = 1.1$.

Commercial catch and discard of mechanical clam harvesting at different fishing pressure (F_T) are shown in Figure 4. This fishing activity, slightly affected by the artisanal one, did not show a maximum yield for F_T within the range 0–1.3, while it may be observed that more than half of the total catch is discarded.

Figure 5 shows the total biomass in the environment (excluding detritus and SOM) at different fishing pressures: the biomass of the system decreases if both F_A and F_T are increased, although it appears to be strongly affected by mechanical clam harvesting.

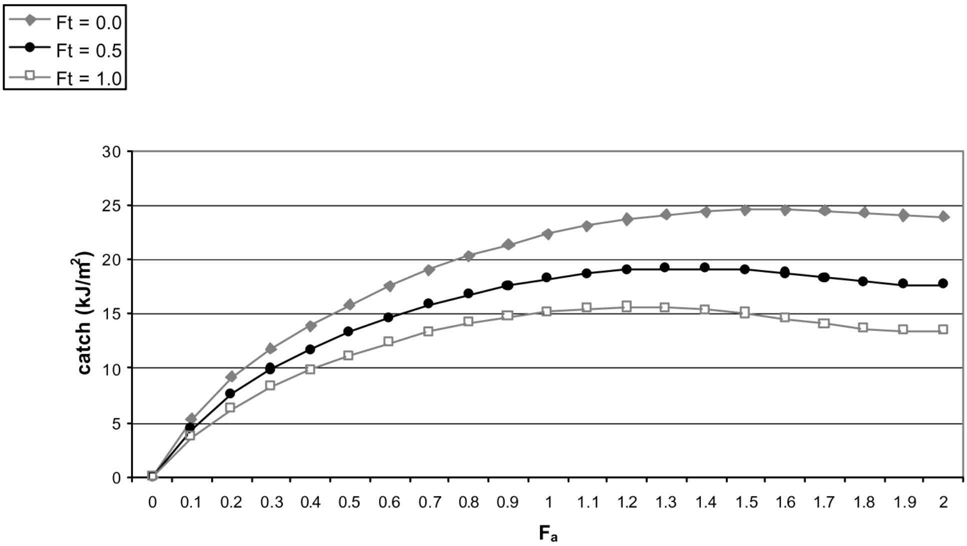

FIGURE 3 Total catches of artisanal fishery obtained changing artisanal fishing effort (F_A), under three scenarios of clam fishing pressure ($F_T = 0$, 0.5, 1.0).

The difference of biomass changing F_T from 0 to 1 (maintaining $F_A = 1$) is 17%, while changing F_A from 0 to 1 (maintaining $F_T = 1$) produces a change of the order of 2%.

Similarly, the increase of fishing effort for artisanal and mechanical clam harvesting results in a decrease in the mTL of the ecosystem organisms: these results are reported in Figure 6,

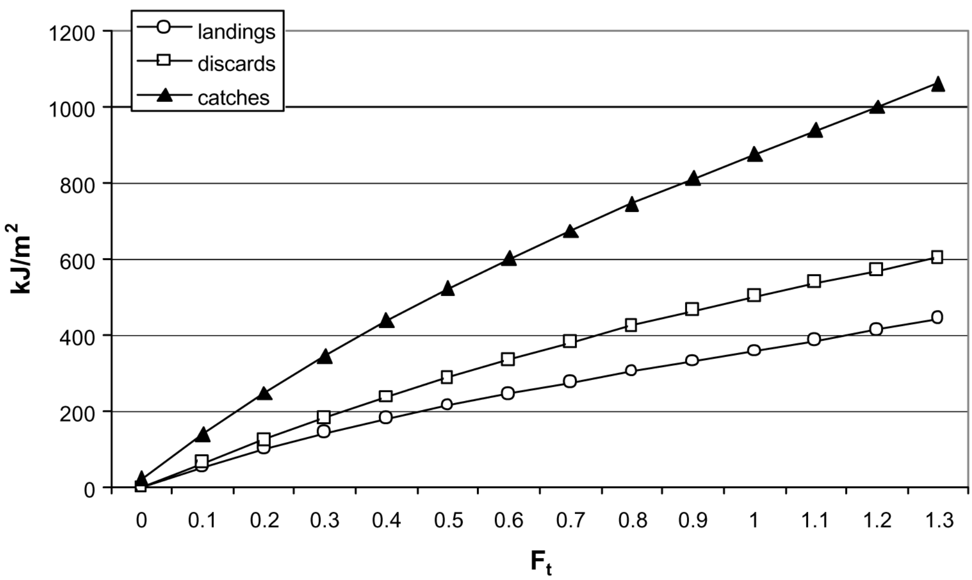

FIGURE 4 The mechanical clam fishery catches, divided into landings and discards, estimated as steady state values due to changes of clam fishing effort (F_T) from 0 to 1.3 with fixed current values for artisanal fishery ($F_A = 1.0$).

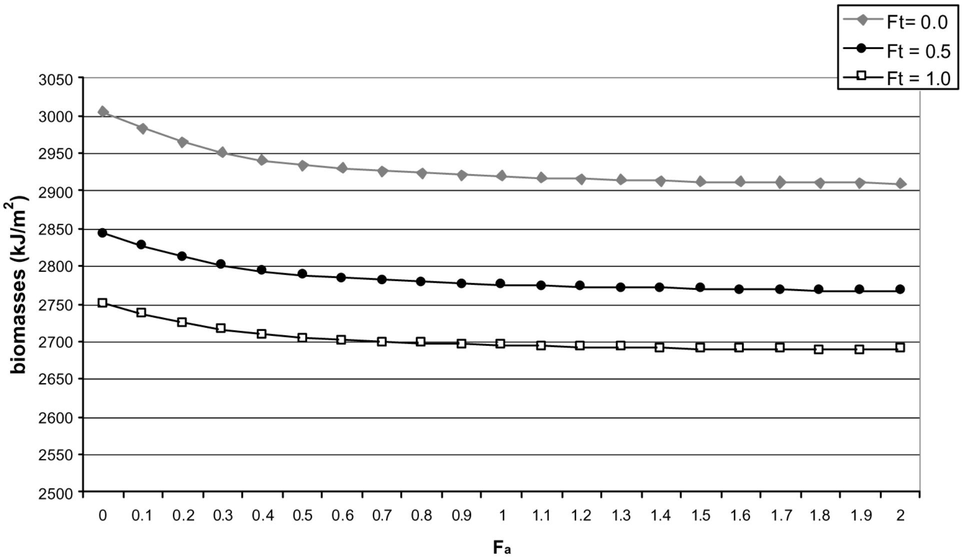

FIGURE 5 Total biomass of the ecosystem estimated at different fishing pressures. The scenarios by varying the artisanal fishing effort under three clam fishing efforts are explored.

where mTL shows values between 1.36 (for $F_T = 1$ and $F_A = 2$) and 1.51 (no fishing). Moving from $F_T = 0$ to $F_T = 1$ (with $F_A = 0$) there is a decrement of mTL of 0.09, while with $F_T = 0$ and F_A moving from 0 to 1 the simulation predicts a decrease of mTL of 0.04. Biomass and mTL of the system at different fishing pressure were also analysed, excluding the primary producers and the plankton communities, but no substantial differences emerged in the trend of the indices in relation to fishing effort.

The exergy estimations for different fishing pressures are reported in Figure 7. As for the other ecosystem indicators, exergy showed a decreasing trend when increasing one

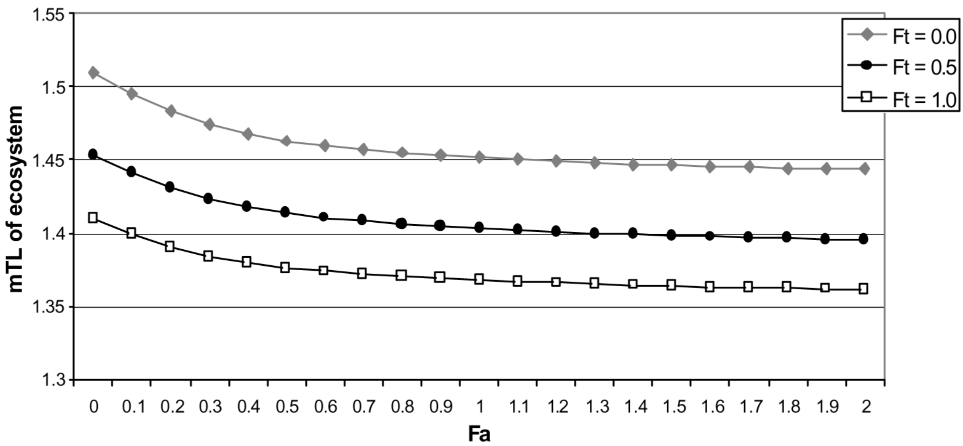

FIGURE 6 The mTL in the ecosystem as indices of ecosystem status health, estimated under different values for artisanal and clam fishing effort.

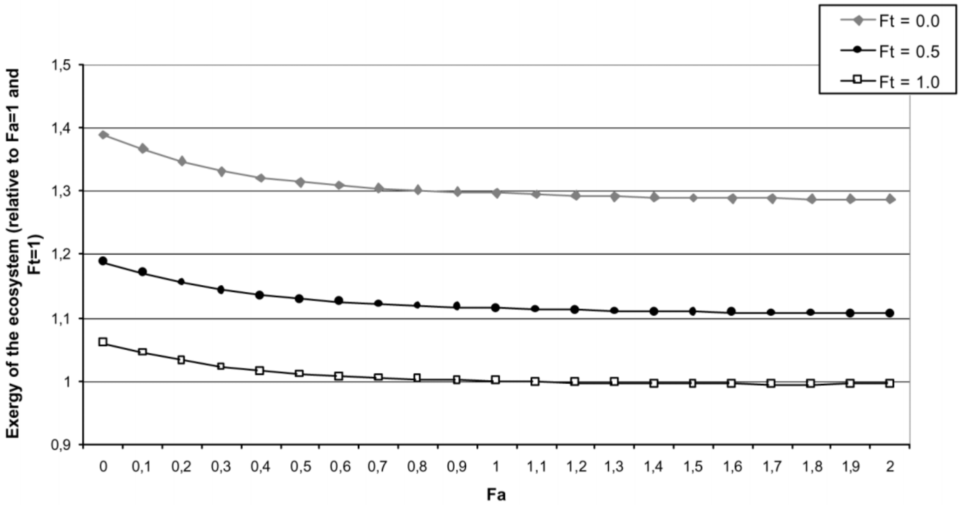

FIGURE 7 Exergy estimations based on the steady state results of the model at different exploitation rates. The exergy estimations are reported as values relative to the exergy of the actual status of the system ($F_A = F_T = 1.0$).

of the fishing efforts and stronger effects are linked to an increase of mechanical clam harvesting.

Since most of the indices do not show an absolute maximum value in the explored range of fishing pressures of artisanal and clam fishing, we argued that the comparison of the absolute change of the indices due to a relative change of the two fishing efforts is important. To measure the gradient, the monotone curves of the indices were fitted with a logarithmic function:

$$I = a + b * \log(F) \tag{1}$$

where I is the Index value obtained for different fishing effort (F). The coefficient b 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 two values of fishing effort (F′ and F″) one can write:

$$\Delta I = I' - I'' = a + b * \log(F') - [a + b * \log(F'')] = b * \log\left(1 + \frac{\Delta F}{F}\right) \tag{2}$$

Thus the absolute change of the Index (ΔI) is related through b to a relative change in the fishing effort ($\Delta F/F$). Therefore the coefficient b represents the change for different indices corresponding to the same relative change in the fishing effort ($\Delta F/F$), allowing to compare different indices and different fisheries.

The b values estimated for the different ecological indices are reported in Table I, where are also reported the ratios between the b coefficients estimated for the same index changing F_A and F_T. The ratio between the b coefficients indicate that the increase of the artisanal fishing effort produces negative changes in the ecosystem indices that are several times smaller than those produced by analogous changes in the clam fishing effort. The ratios between the changes produced by the two fisheries, measured by means of the chosen global indicators, highlight the fact that the impacts of mechanical clam fishery are greater than the artisanal

TABLE I Estimation of the Gradient of the Changes for Some Ecosystem Indicators estimated with Ecopath Results.

Variable	*Gradient**	*Explained variance R^2 (%)*	*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	(97.50)	5.0
F_A ($F_T = 1$)	−34.9	(96.41)	6.4
F_T ($F_A = 1$)	−224.7	(95.93)	1.0
		mTL in the Ecosystem	
F_A ($F_T = 0$)	−0.0404	(98.55)	1.9
F_A ($F_T = 0.5$)	−0.0356	(99.07)	2.1
F_A ($F_T = 1$)	−0.0290	(98.94)	2.6
F_T ($F_A = 1$)	−0.0753	(94.41)	1.0
		mTL in the Ecosystem (excluding PP)	
F_A ($F_T = 0$)	−0.0784	(99.50)	–
F_A ($F_T = 0.5$)	−0.0793	(99.85)	–
F_A ($F_T = 1$)	−0.0747	(99.95)	–
F_T ($F_A = 1$)	No monotone function: maximum at Ftap = 0.4		
		Exergy of the Ecosystem (referred to $F_T = F_A = 1$)	
F_A ($F_T = 0$)	−0.0608	(97.29)	4.3
F_A ($F_T = 0.5$)	−0.0498	(97.57)	5.2
F_A ($F_T = 1$)	−0.0381	(96.23)	6.8
F_T ($F_A = 1$)	−0.2591	(95.81)	1.0

Note: 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.
*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).

one. The highest difference of impact are highlighted by the ecosystem indices like total biomass (excluding primary producers) and exergy, for which clam fishery has effects respectively 6.4 and 6.8 times higher than artisanal fishery (Tab. I).

In Table II the fishing effort values obtained by means of Ecosim simulations searching for the optimum for each one of the three dimensions (ecosystem, social, economic) are reported. These are the efforts that have to be applied for reaching the optimum for only one of the three dimensions, depending on the objective of the fishery management. For society optimisation

TABLE II The Fishing Effort Value Obtained Simulating the Optimisation of the Three Dimensions (Economic, Social and Ecosystemic) by Means of Ecopath.

	Fishing effort	
Dimension	*Mechanical clam harvesting*	*Artisanal fishery*
Economic	1.6	0.3
Social	0.0	1.0
Ecosystemic	0.0	0.0

F_T must be equal to 0.0 and $F_A = 0.3$, for ecosystem optimisation both fishery activities have to be driven to zero. If the economic optimisation is the objective of the management, F_T must be enhanced to 1.6 and F_A must be driven to 0.3.

4 DISCUSSION

As stated by Link (2002), the doubt arises as to 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 for the mechanical clam harvesting), we may assume the first hypothesis as being realistic. However, as highlighted also in Pranovi *et al.* (2003a), this practice proves to be totally unsustainable, and recent evidence, such as the sharp reduction in clam production (about 40%) seems to confirm it (Boatto *et al.*, 2001).

In a management perspective we need to assess the direct and indirect effects produced by fishing activities on the lagoon ecosystem, distinguishing between artisanal fishery and mechanical dredging.

In this framework, the ability to evaluate the positive or negative performance of adopted management strategies becomes a key element.

Exploited communities are complex systems, therefore finding a single indicator that measures the effects of fishery will be difficult. An alternative approach is to examine multiple indicators to accumulate evidence (Garcia and Staples, 2000; Rice, 2000).

We then tackled the challenge of assessing fishing effects on communities that have long been exploited, without knowing their 'pristine' state (Jackson *et al.*, 2001). A way for assessing whether a community attribute is affected by fishing activity is to use a model approach. In this case the constraints imposed by the trade-off between complexity imposed by realism and simplicity necessary for precision (*e.g.* the clustering of species in trophospecies, Yodzis and Winnemiller, 1999), which could bias the results, is counterbalanced by the possibility of assessing the indicator performances in relation to different fishery scenarios (Walters *et al.*, 1997).

All this was applied to the Venice Lagoon ecosystems by using a mass-balance model and methods similar to those proposed for evaluate alternative hypothesis of management (see Back to the Future method in Pitcher, 2001).

The selected indicators are all evaluated at an ecosystem level and emergent properties are included for the assessment of the fisheries management policies. According to the classification proposed by Link (2002), they can be assigned to single species metrics (MSY), food web metrics (mTL) and system analysis metrics (total biomass, exergy). The MSY, a stock related indicator, is a traditional reference point (Gislason, 1999) that is criticized for its estimation problems, its appropriateness as a management goal, and the real difficulty to implement harvest strategies based on it (Mace, 2001). In the present study, MSY is estimated by means of a multi-species model, therefore the problem of the interaction between species and fishing is partly solved. Moreover the MSY for target groups is simultaneously calculated, allowing us to consider the trophic relations between the species (Hallowed *et al.*, 2000; Yodzis, 2001).

The results indicate that the present exploitation level by artisanal fishery is lower than the MSY even if for some target species the MSY has already been reached. Moreover it is strongly affected by F_T resulting in a strong indirect competition between the two fishing activities. In a management hypothesis based on MSY (F_A) as reference point, it would be more effective to act on F_T than on F_A.

The evaluation of MSY based on the catch-effort curve for clam harvesting resulted impossible, because of the phenomenon known as the 'Tapes paradox', *i.e.* the presence of a positive feedback between fishing activity and target species. The fishing activity, which usually acts as the major limiting factor for the exploited resources seems unable to limit clam density since it provides supplemental food to the target species through resuspension, and decreases competition, increasing the mortality of non-target species (Pranovi *et al*, 2003a).

The other indicators than the MSY are not related to any reference point and therefore can be interpreted on the basis of the rate of change of the indicator modifying fishing effort.

Total biomass in the environment is strongly affected by mechanical clam harvesting while changes due to the artisanal fishery are very small. Based on this indicator and considering that reducing biomasses to low levels could induce variability in yields and recruitment (Murawski, 2000), the importance of reducing F_T rather than F_A may be demonstrated. Variations of mTL of the species of the ecosystem are strongly driven by mechanical clam harvesting even if this fishing activity exploits a simple low TL species while artisanal fishery exploits a wide TL range of species (Libralato *et al*., 2003). Such a change, although small in absolute values, reveal high changes in the ecosystems as stated in Pauly *et al.* (1998), and Caddy *et al.* (1998).

The total catch of the clam fishery depends entirely on the effort of this fishing activity and is slightly affected by the artisanal one; conversely, artisanal fishery catches are highly and negatively affected by an increase in the clam fishing effort. More than half of the mechanical clam catch proves to be discarded.

The estimation of exergy confirmed mechanical clam harvesting as a major source of negative changes (exergy decrease) in the ecosystem at increasing fishing pressure. Although it showed similar patterns as the other indicators, exergy proved to be more sensitive, as shown by a more pronounced difference in the gradients caused by changes in the fishing pressures. Even taking into account the limitations due to the model approximations, the indicators here considered seem useful in describing the modifications induced by fishing effort variations, discriminating among different kinds of effects (*e.g.* direct and indirect ones).

As in the case of many ecosystem indicators, those considered may be influenced not only by effects of fishery but also by eutrophication and other kinds of disturbances (Rochet and Trenkel, 2003), but the model approach allows us to assess the effects due only to fishing activities.

According to Sacchi (2001) – who describes the Mediterranean fisheries as mainly small-scale type, involving small enterprises with little capital headed by a single person who often owns the production tool (vessel plus fishing gear) and controls the commercialisation network for this product to a certain extent – both the fishing techniques here considered would be classified as small-scale. The ‘industrial’ definition for the mechanical clam harvesting, arises when other factors are taken into account, such as the specialisation of the vessels on only one target species, the high level of technology for the fishery, and its high discard/commercial ratio.

The two different kind of fishing activities considered in this study probably represent the two extremes of the more than 45 fishing techniques used within the Mediterranean fishing industry (Sacchi, 2001). They belong, in fact, to the two main fishing methods: passive (fyke net) and active (clam dredge), which show great differences when the potential impact of the gear is considered: *e.g.* the interaction with the bottom morphology is the highest possible in the clam dredge (which produces a track 7–10 cm deep) and totally absent in the fyke net. In the comparison highlighted in the Venice Lagoon, and in consideration of the fishing activity, it is the mechanical clam harvesting that is the driving force able to determine the state of the whole ecosystem, as it has 3–6 times the impact of the artisanal fishery.

The main reason why mechanical clam harvesting proves to be the driving force is probably that it produces many indirect effects on all ecosystem sectors, *e.g.* a high discard incidence, many feedback loops (positive or negative), exploitation of a key species (Pranovi *et al.*, 2003a, b).

In this situation, the conflict between the two kinds of fishery become inevitable, even if there is no direct competition in terms of gear or resource but only a sharing of the exploited ecosystem. Landings of artisanal fishing prove to be deeply influenced by clam fishery. All this is increased by economic pressure which tends to increase the clam fishing effort reducing the artisanal one, as highlighted by the optimisation obtained in term of economic indicators.

This phenomenon is clearly visible in the comparison between the artisanal fishery income at the beginning of the clam exploitation (1991), about 29,300 Euros pro capita, and at the maximum clam exploitation rate (2001), about 23,400 Euros pro capita. So the artisanal fishermen, mainly the younger ones, were discouraged from continuing their traditional activity.

On the other hand, the social analysis confirmed the social value of artisanal fishery, which is strongly rooted in the coastal community, as reported also in other coastal areas (Al-Ansi and Priede, 1996; Sumaila *et al.*, 2001); in the Venice Lagoon, artisanal fishery employs 15 time more people, per weight of landings, than mechanical clam fishery, and for a given amount of landed value, it employs on average 3.2 times more people than the other fishing activity. Therefore, mechanical clam fishing, which is associated with high income, in reality affects the number of people employed in the artisanal fishery and the value of their landings.

5 CONCLUSIONS

This study aimed to describe the effects on the ecosystem in the Venice Lagoon of fishery, distinguishing between those caused by artisanal fishery and those caused by the industrial sort (mechanical clam harvesting).

The mechanical clam harvesting, which presents typical features of an industrial fishing activity, has been shown to affect the lagoon ecosystem deeply, and to interfere indirectly with the artisanal activity.

This inevitably produces a strong conflict between the two kinds of fishery, with the artisanal one potentially collapsing, which could have major implications for future management strategies in the Venice Lagoon.

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