# An activity-based decision support system to evaluate the economic viability of fisheries management tools for the small pelagic species in the northern Adriatic Sea[1]

EDI DEFRANCESCO*, SAMUELE TRESTINI*

Jel classification: Q22, Q12, C15

**Abstract**

*The literature has not deeply explored–through an activity-based approach–the economic viability of fisheries at the fishing unit level by simultaneously modelling the monthly dynamic of the different landings of fishing units and the ex-vessel market prices.*

*This research aims to partially fill this gap by developing an activity-based stochastic decision support system for the main small pelagic species–European anchovy (*Engraulis encrasicolus*), European sardine (*Sardina pilchardus*) and mackerel (Scomber spp.). This model is able to simulate the income effects from different fishery policies and the individual fisherman's strategies.*

*The overall results show that there is high variability in the economic impacts from the fisheries management tools, which primarily depend on: i) the adopted fishing method, ii) the monthly landings dynamics, iii) the relevant fixed costs, and iv) the low ex-vessel market prices and their instability due to the weak bargaining power of the fishermen and the buyers' and final consumers' limited willingness to pay for small pelagic species. From a policy point of view, the uncertain profit for the fishing unit's owner and the unstable crew wages suggest that any proposed management tool at this micro-level should be carefully evaluated to complement the area-scale and the enterprise level evaluation.*

**Keywords:** *sustainable fishing, fishing unit economic viability, small pelagic fishery.*

**Résumé**

La littérature scientifique n'a pas exploré en profondeur la viabilité économique des unités de pêche, en modélisant simultanément la dynamique mensuelle de pêche des différentes unités et les prix du poisson à la criée.

L'objectif du présent travail est de combler partiellement ce vide en mettant au point un système stochastique d'aide à la décision appliqué aux principaux petits pélagiques– Anchois européen (*Engraulis encrasicolus*), Sardine européenne (*Sardina pilchardus*) et Maquereau (*Scomber* spp.).

Ce modèle permet de simuler les effets du revenu générés par les différentes politiques de la pêche et par les stratégies individuels des marins pêcheurs.

Les résultats de l'étude montrent une forte variabilité des impacts économiques en fonction des outils de gestion des unités de pêche. Cette variabilité dépend surtout des méthodes et des dynamiques mensuelles de pêche, de l'importance des coûts fixes, des bas niveaux des prix et de leur instabilité imputable au pouvoir contractuel limité des pêcheurs et à faible disposition des consommateurs à payer davantage pour des espèces pélagiques de petite taille. D'un point de vue politique, le profit incertain du propriétaire de l'unité de pêche et l'instabilité des salaires des équipages suggèrent d'évaluer avec attention chaque outil de gestion à la micro-échelle proposée – pour compléter l'étude à une échelle supérieure de zone de pêche et au niveau des entreprises.

**Mots-clés:** pêche durable, viabilité des unités de pêche, pêche des petits pélagiques.

## 1. Introduction

Small pelagic fisheries are a relevant fishing activity in the Mediterranean Sea. Approximately 72,000 Mt of European anchovy (*Engraulis encrasicolus*), European sardine (*Sardina pilchardus*) and mackerel (*Scomber* spp.) stocks were caught in 2009 (Irepa, 2009). These species account for 45% of the overall fishery products landed by the entire Italian fleet, but only 16% of the total value of landings. The limited share in value is primarily due to the consumers' low willingness to pay for either fresh or processed small pelagic species and, consequently, to the low ex-vessel prices for these species.

In the northern Adriatic Sea—which accounts for 35% of the total Italian small pelagic landings—the mid-water pair trawling fishery (*volante*) is the prevailing fishing system, while the small scale seasonal purse-seine system (*circuizione*) is primarily adopted in the Trieste gulf area. The mid-water pair trawling fishing system involves a relatively small number of vessels (1% of the Italian fishing fleet), with a larger share in terms of the overall gross tonnage (5.7%) and the total engine power (4.4%). This fishing system is also characterised by high vessel productivity; this productivity is ten times higher than the average in volume and nearly four times higher in value. In recent years, the profitability of the mid-water pair trawling fisheries has been negatively affected by: i) increased input costs (43% over the total revenues in 2009), mainly due to fuel costs (approximately 50% of overall input costs, according to Irepa 2009); ii) declining trends in the ex-vessel prices, and iii) increased price volatility. Despite the adopted management mechanisms for sustainable fisheries, in recent years, fishing companies have increased their productivity level as a reaction to their declining and fluctuating incomes.

Under these market conditions, different management tools for sustainable fishing—as well as the individual fishing company catch management decisions—must be carefully evaluated and monitored. In particular, the environmental, economic and social sustainability of policies and management strategies are generally

*Dipartimento Territorio e Sistemi Agro-forestali – Università degli Studi di Padova, Viale dell'Università 16, 35020 Legnaro (PD) Italy

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monitored at the fishing area level and/or at the entire fishing enterprise level. This approach is generally useful when long-term fishery choices are evaluated, e.g., changes in the fishing system or in the target species. However, the impact on the economic and social viability of the fishery activities resulting from any management mechanism for sustainable fisheries also needs to be evaluated at the fishing unit level, i.e., the fishing company's decision-making level, in the short-medium term. Moreover, the effects of these management tools on income may vary at the fishing unit level depending on the different tradition-based fishing methods (*mestieri*) operating in each ex-vessel market (*marineria*).

Overall, the economic viability of a fishery is affected, on the one hand, by the fishing system productivity—which depends on the adopted technology and the resource availability—and, on the other hand, by the market prices of the inputs and outputs. Several bio-economic models have been reported by the literature that attempt to simulate the sustainability of fisheries at an area scale (Accadia and Spagnolo, 2006; Ulrich *et al.*, 2002; Lleonart *et al.*, 2003) or the effects of sustainable fishing policies and tools (Maynou *et al.*, 2006; Silvestri and Maynou, 2009). The profitability and social viability of fishing companies have also been analysed (Withmarsh *et al.*, 2000; Withmarsh *et al.*, 2002; Withmarsh *et al.*, 2003; Surìs-Reguerio *et al.*, 2002; Le Floc'h *et al.*, 2008). However, to our knowledge, there is no activity-based approach used in the literature to deeply explore the economic viability of fisheries at the fishing unit level by simultaneously modelling the monthly dynamic of the different fishing units' landings and the ex-vessel market prices.

Our research aims to partially fill this gap by developing an activity-based stochastic decision support system capable of simulating the effects of different fishery policies and individual fishermen, or local scale, self-governance strategies on the fishing unit's economic results. In particular, the considered effects are: i) the monthly landings, ii) the ex-vessel market prices for local products, iii) the revenues, and iv) the ship-owner and crew incomes. The model provides detailed results for the main pelagic species, and it separately models the most relevant fishing methods (mid-water pair trawling and purse-seine fisheries) operating in the northern Adriatic Sea *marinerie* (Chioggia, Rimini, Trieste and Marano Lagunare), taking into account the different traditional criteria of risk and income sharing between the ship-owner and the crew.

The next two paragraphs describe the model structure, the stochastic variable estimates and the data. The following section presents an example of the model's estimated results for a *volante*, which operates in the Chioggia ex-vessel market. The paper then concludes by considering some policy and organisational issues.

## 2. Methodology

The Monte Carlo stochastic simulation model aims to evaluate the social and economic viability of small pelagic fisheries, and it is consistent with the approach proposed by Withmarsh *et al.* (2000).

The main characteristics of the fishing unit decision support system are:

a) Exogenous deterministic variables provided by the model's end user (input variables) as follows: i) the fixed and variable costs of the fishing system, and ii) the consideration of a detailed fishing day calendar in a given simulation; this calendar describes the established temporary restrictions on fishing activities in the area or the individual ship-owner's decisions.

b) Three stochastic estimated variables as follows: i) the ex-vessel market volumes for local products (differentiated by small pelagic species), ii) the corresponding monthly prices observed in the market, and ii) the daily landings of a given fishing unit.

These variables are endogenous in the model. However, the underlying time series data and estimates must be updated periodically, primarily when structural breaks occur. The total ex-vessel quantity monthly forecasts for each species are estimated by a classical time series decomposition and by an ARIMA model (Box and Jenkins, 1976). The time series approach is generally preferred for its fitting and forecasting accuracy for fisheries production (Stergiou *et al*., 1997; Shitan *et al*., 2008; for small pelagic species see, for example, Lloret *et al*., 2000; Gutierrez-Estrada *et al*., 2007 and Tsitsika *et al*., 2007) when no overexploitation occurs, as is the case for the main pelagic species in the Mediterranean Sea (DEDUCE, 2007). In other words, the total landings are not estimated by a regression approach based on bio-economic models—which relate the volumes to bio-environmental factors and the fishing effort (Spagnolo, 2008)—however, the model could easily incorporate them when available.

The expected ex-vessel market prices for local products are obtained by estimating an inverse demand function for each species using deflated observed monthly prices (Bell, 1968; Barten and Bettendorf, 1989; Mulazzani and Camanzi, 2011 for small pelagic species in an ex-vessel market of the Adriatic Sea). The links between ex-vessel markets has been tested by a covariance analysis (Greene, 2000).

The individual fishing unit's landings have been randomly selected from past observed daily catches in a given month, and the overall monthly forecasts in volume have been adjusted by taking into account i) the planned number of fishing days in the month, depending on the fishery management policies and the individual fishing unit decisions, and ii) the estimated overall landings of the month in the *marineria*.

c) Differentiated results are provided by the model for the most diffused tradition-based income sharing systems between the ship-owner and the crew (the so-called *alla parte* sharing system) in the northern Adriatic Sea *marinerie*. Actually, the overall crew wages are not generally defined on a fixed basis but rather on the economic results of the fishing unit's activity for the month. In other words, the crew at least partially shares the risk of the fishing activity with the fleet owner, i.e., after an assured minimum monthly wage. Figure 1 shows how the *alla parte* sharing system operates in Chioggia, Rimini and Marano Lagunare *marinerie* (Inail, 2005), where mid-water pair trawling fishery is practiced. The crew income is determined in two steps: i) a proxy of the value added (*monte maggiore*) is obtained by subtracting the most relevant variable costs (fuel, lubricants, marketing costs, packaging, food, ice) from the total revenue, and ii) 50% of the *monte maggiore* covers the ship-owner fixed costs (maintenance and repairs, insurance, overhead and depreciation costs) and provides him a profit, while the remaining 50% (*monte minore*) is distributed among the members of the crew according to their role on board, following tradition-based rules.

In the case of the Trieste purse-seine fisheries, a different sharing system is adopted. The main variable costs are subtracted from the total revenues, excluding fuel and lubricant costs, which are less relevant for this small-scale fishing method. The *monte maggiore* is divided into unit quotas. Four quotas are generally allocated to the fishing company, Two quotas cover the ship's fixed costs and the remaining quotas are distributed to each crew member; the individual quotas range from 0.5 to 2, according to the member's role on board.

While the ship-owner's profitability is a crucial indicator when evaluating the long term economic viability of the fishing activity, the crew income is a critical factor both in the long term and in the short term. An adequate crew income assures the fishery social sustainability and guarantees that a qualified crew will be available to the ship-owner.

d) The results are expressed in a final user-friendly way (graphs and "best-case", "expected median" and "worst-case" summary tables), despite the stochastic structure of the model.

## 3. Data

The 2005-2010 monthly ex-vessel market production for the main pelagic species has been directly taken from the ex-vessels markets' databases and has been transformed into daily averages per month. The modelling and forecasting procedures have been executed using Demetra+ 1.02 software. The current monthly market prices—from the same data sources—have been adjusted by the fish product wholesale inflation index. The individual fishing units' daily landings have been provided by the fishing enterprises.

The fishing units' structural data, the 2011 fixed and variable costs and the income sharing rules have been based on direct interviews with ship-owners and other stakeholders. Table 1 summarises the main characteristics of the mid-water trawl fishing unit of Chioggia (*FU-C*), whose simulated economic results are reported in the following section. This two-paired boats fishing method is described in Silvestri and Maynou (2009). The 2011 *FU-C* fishing days have been estimated by taking into account both the established temporary restriction of fishing activities (Mipaaf, 2011: 44 days in August-September, 8 in October and 8 in November) and the estimated number of working days lost due to bad weather conditions and boat maintenance (24 days: the observed days lost in 2009). Consequently, the overall number of yearly fishing days considered is 169.

Table 1 - *Chioggia fishing unit FU-C main characteristics.*

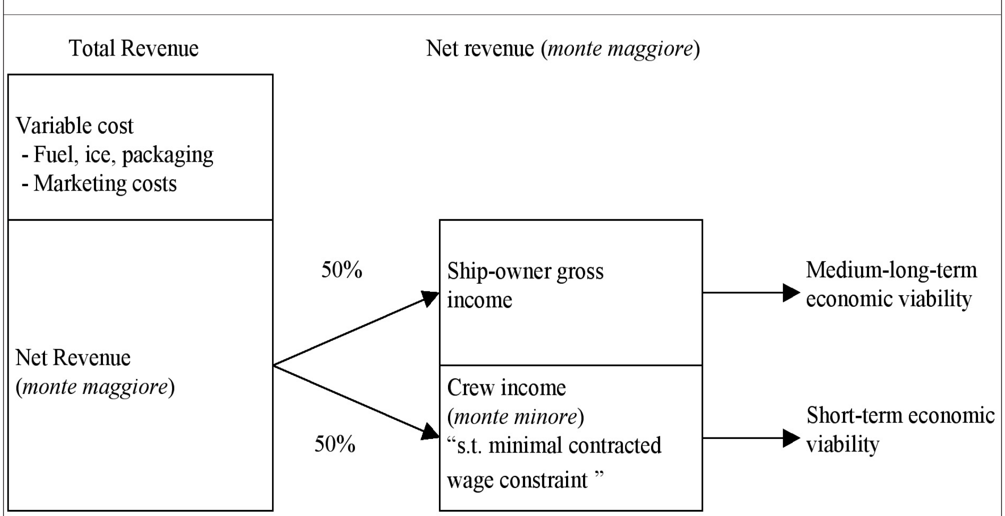
| | Length (m) | GT | KW |
|---|---|---|---|
| Ship 1 | 23,58 | 166 | 428 |
| Ship 2 | 24,80 | 166 | 428 |

Source: Fleet Register, 2011.

## 4. Results and discussion

The ARIMA model fitting results and the main statistics on the residuals of each species' average daily volumes per month—sold in the different ex-vessel markets—are reported in Tables 2 and 3. Different dummy variables have been included in the model to take into account the effects of the holidays and of the fisheries management tools (based on restrictions of the fishing days) on the monthly landings. The statistically significant dummy coefficients are: i) European anchovy and mackerel in the Chioggia market, European sardine in Marano Lagunare and mackerel in Trieste: TD6, i.e., a different coefficient per each day of the week and ii) European sardine in the Rimini market: TD1, i.e., coefficients differentiating the week-end from the other days.

Figure 1 - *Tradition-based income sharing system between the ship-owner and the crew in most northern Adriatic Sea* marinerie.



The statistics on the residuals and the structure of the additive estimated models are reported in Tables 1 and 2. However, the models include an increased number of outliers (AO, LS and TC[2]) and the results are weaker in the smallest markets (e.g., Trieste) and when considering minor target species (mackerel), i.e., when major volatility is observed in the overall landings.

Table 2 - *Statistics on the residuals of the ARIMA estimated models: Chioggia and Rimini ex-vessel markets average daily per month volumes by species.*

| | Chioggia | | | Rimini | | |
|---|---|---|---|---|---|---|
| | **Anchovy** | **Sardine** | **Mackerel** | **Anchovy** | **Sardine** | **Mackerel** |
| **Logarithm** | No | No | No | No | No | No |
| **ARIMA** | (0,1,1)(0,1,1) | (0,1,1)(0,1,1) | (0,1,0)(0,1,1) | (0,1,1)(0,1,1) | (1,0,0)(0,1,1) | (0,0,1)(1,0,1) |
| **Regressors (*)** | TD6 | | TD6 | | TD1 | |
| **Outliers** | LS[8-2006] | TC[11-2008] | AO[9-2005]<br>AO[8-2006]<br>LS[7-2008] | TC[3-2008]<br>AO[6-2008] | AO[9-2004] | AO[6-2007]<br>TC[7-2008]<br>TC[5-2007]<br>TC[11-2008] |
| **Normality of the residual (P-value)** | | | | | | |
| Mean | 0,8839 | 0,9234 | 0,6504 | 0,2566 | 0,1670 | 0,9508 |
| Skewness | 0,2366 | 0,6730 | 0,4336 | 0,8523 | 0,7441 | 0,0163 |
| Kurtosis | 0,5497 | 0,0499 | 0,0677 | 0,4516 | 0,2489 | 0,0478 |
| Normality | 0,3276 | 0,0242 | 0,0384 | 0,9204 | 0,5669 | 0,0423 |
| **Independence of the residuals (P-value)** | | | | | | |
| Ljung-Box | 0,0281 | 0,8733 | 0,7167 | 0,9277 | 0,6098 | 0,7162 |
| Box-Pierce | 0,2275 | 0,9617 | 0,9184 | 0,9889 | 0,8380 | 0,8922 |
| Ljung-Box on seasonality | 0,0574 | 0,5496 | 0,2498 | 0,7537 | 0,7305 | 0,3409 |
| Box-Pierce on seasonality | 0,1645 | 0,7072 | 0,4187 | 0,8401 | 0,8470 | 0,4523 |
| **Linearity of the residuals (P-value)** | | | | | | |
| Ljung-Box on residuals^2 | 0,8291 | 0,1916 | 0,2459 | 0,9531 | 0,1085 | 0,2120 |
| Box-Pierce on residuals^2 | 0,9554 | 0,4847 | 0,5630 | 0,9886 | 0,3891 | 0,4489 |

(*) TD6 - a coefficient per each working day of the week; TD1 –coefficients differentiating week-ends from the other days.

Table 3 - *Statistics on the residuals of the ARIMA estimated models: Marano Lagunare and Trieste ex-vessel markets average daily per month volumes by species.*

| | Marano Lagunare | | | Trieste | | |
|---|---|---|---|---|---|---|
| | **Anchovy** | **Sardine** | **Mackerel** | **Anchovy** | **Sardine** | **Mackerel** |
| **Logarithm** | No | No | No | No | No | No |
| **ARIMA** | (0,0,1)(1,0,0) | (0,1,1)(0,1,1) | (0,1,1)(0,1,1) | (0,1,0)(0,1,1) | (0,0,1)(0,1,0) | (0,0,1)(1,0,1) |
| **Regressors (*)** | | TD6 | | | | TD6 |
| **Outliers** | TC[6-2005]<br>AO[6-2007] | | AO[10-2004]<br>AO[5-2007]<br>AO[10-2006] | | AO[7-2004]<br>TC[7-2008]<br>AO[6-2004]<br>AO[6-2008]<br>AO[4-2007]<br>AO[6-2010]<br>AO[8-2005] | AO[5-2006]<br>AO[6-2007]<br>AO[8-2004]<br>TC[5-2010]<br>AO[6-2004]<br>AO[4-2007]<br>AO[7-2006]<br>AO[5-2009]<br>TC[6-2009] |
| **Normality of the residual (P-value)** | | | | | | |
| Mean | 0,8891 | 0,9934 | 0,9341 | 0,9994 | 0,7568 | 0,9166 |
| Skewness | 0,4340 | 0,3037 | 0,5790 | 0,8354 | 0,0147 | 0,5907 |
| Kurtosis | 0,9434 | 0,4611 | 0,1076 | 0,0000 | 0,0580 | 0,5734 |
| Normality | 0,6802 | 0,3079 | 0,0696 | 0,0000 | 0,0433 | 0,4269 |
| **Independence of the residuals (P-value)** | | | | | | |
| Ljung-Box | 0,1269 | 0,7213 | 0,3909 | 0,6029 | 0,6343 | 0,2304 |
| Box-Pierce | 0,3074 | 0,8539 | 0,6375 | 0,7799 | 0,8350 | 0,4428 |
| Ljung-Box on seasonality | 0,1940 | 0,6579 | 0,3657 | 0,2354 | 0,0069 | 0,0595 |
| Box-Pierce on seasonality | 0,3786 | 0,7190 | 0,5766 | 0,3510 | 0,0358 | 0,2130 |
| **Linearity of the residuals (P-value)** | | | | | | |
| Ljung-Box on residuals^2 | 0,1939 | 0,5409 | 0,1984 | 0,0232 | 0,0026 | 0,0002 |
| Box-Pierce on residuals^2 | 0,4226 | 0,7896 | 0,3944 | 0,1161 | 0,0237 | 0,0080 |

(*) TD6 - a coefficient per each working day of the week.

The inverse demand model estimates (Table 4) are highly statistically significant, and the slope coefficients of the linearised models have the expected signs. Moreover, the differentiated models' estimates are coherent with the different ex-vessel markets' structures: Chioggia and Rimini are mixed markets where both local and national products are sold to local, national and international customers; Trieste, however, is a mixed market where mainly local products are sold to local customers, and Marano Lagunare is a local market only, both from the supply side and the demand side.

The landings volume coefficient is not market-specific for European anchovy and mackerel, highlighting a homogeneous price-quantity relationship (*lnkg*) in the overall ex-vessel markets. The effect of the European sardine ex-vessel quantity on price differs substantially between Rimini (*lnkg_rm*) and Marano Lagunare (*lnkg_ma*), while it is the same for Chioggia and Trieste (*lnkg_ch_ts*), despite the different size of the markets. In the case of the double-logarithmic functional form, the reciprocal of the estimated volume-coefficient is the constant demand elasticity, which is highly elastic in our case as reported by Bose (2004), Park *et al.* (2004) and Mulazzani and Camanzi (2011) for other ex-vessel markets. This result is due to the relevant bargaining power of the buyers operating in the analysed markets. In the Chioggia European sardine market, the elasticity of demand for the local product is lower than in the other ex-vessel markets because there is more limited substitutability between the local landings and products of different origin. Overall, the observed weak bargaining position of the fishermen in the different ex-vessel markets could be improved by establishing a network between the markets, with the goal of increasing the fishermen's power in negotiating prices.

As previously indicated, the remaining portion of this section examines the simulated impact of the 2011 fisheries management tool on the primary economic results of the fishing unit *FU-C*, which operates in Chioggia, and provides detailed results for the two main target species: European anchovy and European sardine.

Model forecasts have been ex-post validated by compar-

[2] AO – additive outlier, which affects an isolated observation; LS – level shifts, which implies a permanent step change in the mean level of the series; TC- transitory change, which transitorily affects the level of series after a certain point in time (Kaiser and Maravall, 2000)

Table 4 - *Ex-vessel markets inverse demand model estimates by species.*

| | European Anchovy | | European Sardine | | Mackerel | |
|---|---|---|---|---|---|---|
| Variables (*) | B | P-value | B | P-value | B | P-value |
| constant | 0,635 | 0,000 | 2,500 | 0,000 | 1,224 | 0,000 |
| rm | -0,129 | 0,024 | -1,805 | 0,000 | 0,307 | 0,000 |
| ts | 0,654 | 0,000 | -2,030 | 0,000 | 0,801 | 0,000 |
| ma | 0,326 | 0,000 | -1,060 | 0,004 | 0,856 | 0,000 |
| lnkg | -0,046 | 0,000 | - | - | -3,2E-05 | 0,002 |
| lnkg_ch_ts | - | - | -0,203 | 0,000 | - | - |
| lnkg_rm | - | - | -0,069 | 0,036 | - | - |
| lnkg_ma | - | - | -0,088 | 0,000 | - | - |
| Adj. $R^2$ | 0,611 | | 0,367 | | 0,422 | |
| Functional form | Double-Log | | Double-Log | | Semi-Log | |

(*) ch= Chioggia, rm=Rimini, ts=Trieste, ma=Marano Lagunare.

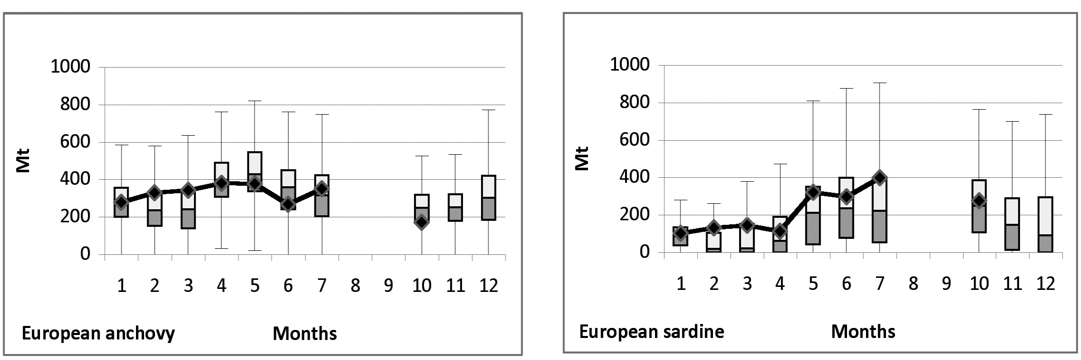
ing the model estimates with the overall observed volumes and prices from January to October 2011 in the ex-vessel market of Chioggia (Figure 2 and Figure 3), with satisfactory results in terms of volumes. The weaker predicting ability for market prices in the late spring and summer is due to the unexpected dramatic fall in the demand for local product from Spanish processing companies (Mulazzani and Camanzi, 2011).

The estimated *FU-C* European anchovy and European sardine monthly landings are reported as a box-plot to provide a final user-friendly description of their variability (Figure 4). In summer months, the overall landings are higher because of better weather conditions and increased demand for fish. However, the dynamics of the landings in the different months is different between the two species: European anchovy catches are concentrated in the first and in the last part of the year, while European sardines prevail in the central months, which is also a consequence of the fishermen's fishing strategies. The two species progressively separate their schools as the water temperature increases; thus, the catching strategies can be targeted on a given species.

Overall, the estimated average *FU-C* crew wages per month and per fishing day—expressed in unit terms (one '*parte*')–(Figure 5) varies significantly over the year as a consequence of the tradition-based income sharing system between the ship-owner and the crew. Consequently, monthly wages are strictly related to the fishing unit revenue and reach their lowest levels from December to March, while increasing in the central part of the year, with a maximum in June-July before the interruption of fishing activity for the recovery of the biological stocks. However, the best daily average wages are observed in October and November—immediately after the catching restriction period—when the daily catching activity intensifies. These strong average wages are also due to the fishing unit catching strategy, which is designed to assure an adequate short-term income to the crew.

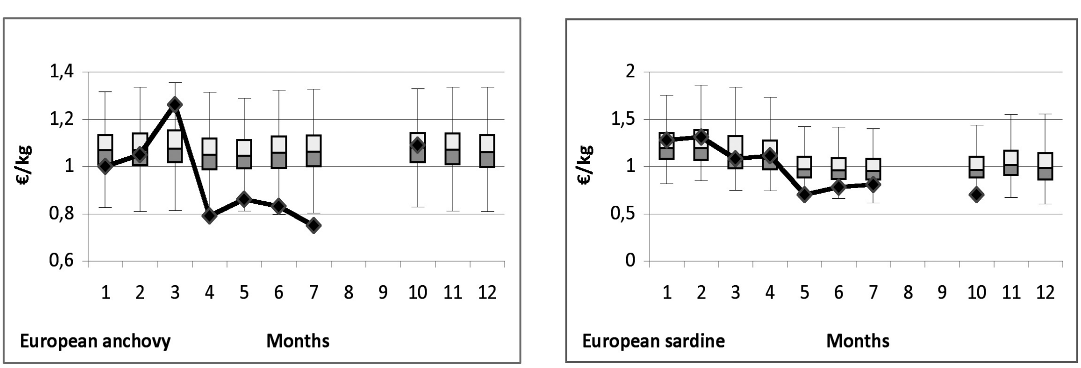
The fishing unit ship-owner annual profit has been estimated under 'worst-case', 'expected median' and 'best-case' scenarios (Table 5). In the 'expected median' scenario, the estimated yearly profit of the ship-owner is slightly negative, showing approximately a

Figure 2 - *Predicted volumes (box-plot) and observed volumes (line): Chioggia ex-vessel market (2011).*




Source: Our estimations and Chioggia ex-vessel market data.

Figure 3 - *Estimated prices (box-plot) and observed prices (line): Chioggia ex-vessel market (2011).*




Source: Our estimations and Chioggia ex-vessel market data.

Figure 4 - *European anchovy and European sardine landings monthly estimates by the Chioggia fishing unit FU-C (2011).*

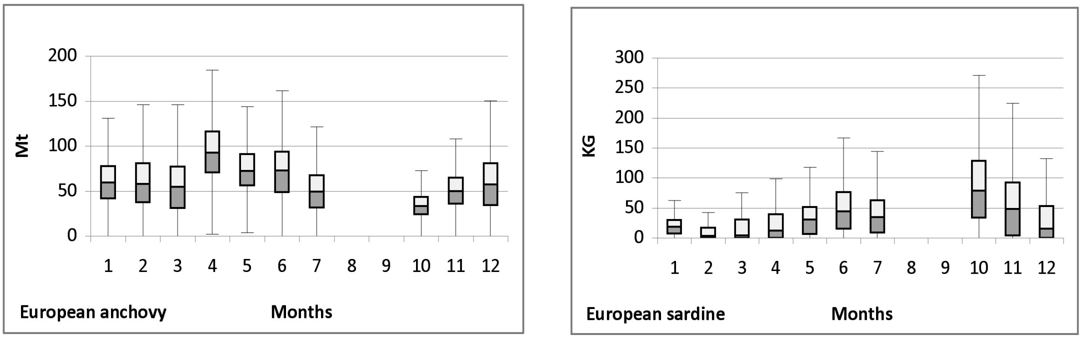
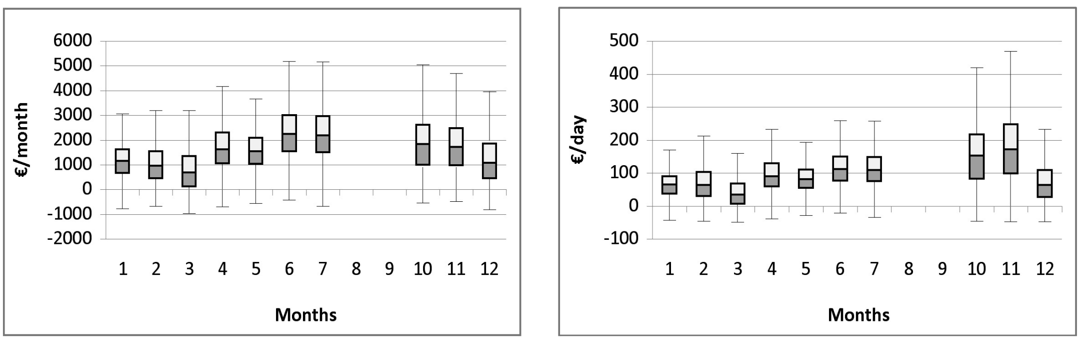



Figure 5 - *Estimated* FU-C *crew income per month (left) and per fishing day (right) (average* 'parte' *in Euros) (2011).*




45 thousand Euros loss in the worst-case and a 34.5 thousand Euros profit in the best-case scenario. The simulated results highlight the uncertainty regarding the ship-owner's expected economic results, which are caused by i) the revenue variability from both the landings and the ex-vessel market prices—as has been observed in the real market during the 2011 central months—and ii) the large amount of vessel and equipment depreciation costs (approximately 70% of ship-owner fixed costs). As a consequence, the medium-term economic sustainability of the fishing activity could be assured when the interest on bank loans are limited—as assumed in this case—while it could be threatened in the long run.

*Table 5 - Ship-owner's estimated annual profit: Chioggia* FU-C *mid-water pair trawling fishing unit (.000 Euros).*

| Values per fishing unit | Scenarios: Worst-case | Median | Best-case |
|---|---|---|---|
| Production value | 1023,7 | 1129,7 | 1220,0 |
| *Main variable costs* | *488,5* | *506,0* | *521,8* |
| "Monte maggiore" | 535,2 | 623,7 | 698,2 |
| *Crew net revenue* | *267,6* | *311,8* | *349,1* |
| Ship-owner Gross Income | 267,6 | 311,8 | 349,1 |
| *Maintenance* | *77,5* | *77,5* | *77,5* |
| *Depreciation* | *221,4* | *221,4* | *221,4* |
| *Insurance* | *2,2* | *2,2* | *2,2* |
| *Interests on loan* | *10,2* | *11,3* | *12,2* |
| *Other* | *1,0* | *1,1* | *1,2* |
| Total ship-owner costs | 312,4 | 313,6 | 314,6 |
| Profit before taxes | -44,8 | -1,7 | 34,5 |

## 5. Conclusions

An activity-based stochastic decision support system aiming to simulate the effects from the management tools of different fisheries has been presented with a micro-level focus: a specific small pelagic fishing unit in a given ex-vessel market. The model provides detailed results for the primary species for the main fishing systems (*volante* and *circuizione*) and for the main ex-vessel markets of the northern Adriatic Sea (Chioggia, Rimini, Trieste and Marano Lagunare). The model takes into account the different traditional income sharing systems between the ship-owner and the crew.

The overall results at the fishing system level show the high variability of the economic impacts of the fisheries' management tools. This variability primarily depends on the adopted fishing method, the monthly landings dynamics, the relevant fixed costs, the low ex-vessel market prices and the price instability due to the weak bargaining power of the fishermen and the consumers' limited willingness to pay for small pelagic species. From a policy point of view, the uncertain profit of the fishing unit's owner and the unstable crew wages suggest that any proposed management rules at this micro level should be carefully evaluated to complement the area-scale and the enterprise level evaluation. The proposed reform of the Common Fisheries Policy (EU Commission, 2009 and 2011) appears to be primarily oriented towards a long-term area-scale approach when evaluating the environmental, social and economic sustainability policy instruments for fisheries to try to confront the relevant overfishing problems of many target species. Given the fact that the main ship-owner's short- and medium-term decisions are considered at the fishing unit level, the impact of the management tools also have to be evaluated at this micro level. Tools that are effective when evaluated at the area scale could provoke unexpected negative effects at the fishing unit level and could stimulate strategies that have a negative impact on the fish resource. For example, our results show how the actual fishing effort regime—limiting the days the fishing units can operate—can increase the amount of subsequent daily catches when the fishing restrictions end to assure an adequate income to the ship-owner and the crew. Under given market conditions, some small scale fishing systems might be put out of the market by more intensive fishing methods.

Moreover, the fishermen's volume-oriented strategies are also a consequence of the low ex-vessel market prices. Our results suggest that the fishermen's weak bargaining position in the individual ex-vessel markets could be improved by establishing a network between the markets, aiming to increase their power in negotiating prices.

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