Daily variation of fishing effort and ex-vessel prices in a western Mediterranean multi-species fishery: Implications for sustainable management

Mohamed Samy-Kamal*, Aitor Forcada, José Luis Sánchez Lizaso

Departamento de Ciencias del Mar y Biología Aplicada, Universidad de Alicante, PO Box 99, Edificio Ciencias V, Campus de San Vicente del Raspeig, E-03080 Alicante, Spain

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A B S T R A C T

The daily variation of fishing effort and ex-vessel price was analysed to determine which day of the week is suitable to ban the fishery, as an alternative management measure to the one month seasonal closure. Thus, 10-years landings data were used from two representative trawling ports of the western Mediterranean: Dénia and La Vila Joiosa. Analysis of variance (ANOVA) was used to detect significant differences in fishing effort (total and by métier) and daily ex-vessel price of the main target species. Also, the economic loss produced by banning one day (the proposed measure) was compared to economic loss produced by the seasonal closure (the actual measure). Daily variation in the fishing effort was observed in La Vila Joiosa mainly due to higher effort at the end of the week devoted on crustacean métiers, while effort was similar among days in Dénia. The lowest mean prices for most target species were on Tuesday and Wednesday, and were higher on Monday and Friday. Banning one day per week (Tuesday or Wednesday), when market prices of target species are lower would reduce the double of effort than one month of seasonal closure, and likely without subsidies. However, the loss by banning all Wednesdays (approx. 50 days) was higher in both ports than one month, but lower than an equivalent two months closure.

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1. Introduction

For many reasons multi-species multi-gear fisheries (e.g. Mediterranean fisheries) present an immensely more difficult challenge for fisheries management than single species fisheries, combining management complexity, scientific uncertainty and political sensitivity [1]. Due to the diversity of both, the characteristics of fleet and the catch composition, the GFCM (General Fisheries Commission for the Mediterranean) has placed emphasis on the direct control of fishing capacity and effort rather than catch limitation as an effective way to reduce fishing mortality [2,3]. Measures to regulate fishing effort are the main measures used for the management of Mediterranean multi-species fisheries, in combination with other technical measures, i.e. minimum mesh and landing size or spatio-temporal closures [4]. The objective is trying to reduce the pressure on fish stocks by limiting the overall size of the fleet as well as the amount of time that the fleet can spend fishing. This includes: limiting the number of vessels (fishing licenses), limiting fishing capacity (total and individual power), and limiting the fishing time (seasonal closure, days in a week or hours in a day) [4]. Out of these, limiting the fishing time is one of the most effective ways to reduce the fishing effort.

Adopting the seasonal closure to limit the fishing time involves withdrawing the semi-industrial fleet (i.e. trawl fisheries) for a specified period (1–2 months depending on the port and the year). This normally generates problems, because it requires subsidies for vessels owners and crews to compensate this period without revenue, while it also may cause a drop in prices due the market imbalances [5]. Besides the burden of the subsidies on the administration, closure involves an additional problem in the Mediterranean fisheries that have been criticized as most of these subsidies have been transformed into structural compensations [5,6]. On the other hand, controlling the fishing effort by limiting the number of fishing days per week can have the opposite effect, because it keeps weekly earnings and may lead to short-term price increases by concentrating sales/purchases and could be adopted without subsidies.

* Corresponding author.
E-mail addresses: mohamedsamy@ua.es (M. Samy-Kamal), forcada@ua.es (A. Forcada), jl.sanchez@ua.es (J.L. Sánchez Lizaso).

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For these reasons, a recent surge of studies in the western Mediterranean has discussed the reduction of effort by banning fishing one more day per week (other than the week-end) instead of the seasonal closure [5,7,8]. This would result in approximately the double annual amount of effort reduction if compared with one month of closure; as well minimize the short-term negative economic effect of seasonal closure on market prices and therefore, on fishers income [5]. Also it is more acceptable by the fishing community to stop fishing one day than a whole month, and can be easily applied without additional costs of subsidies. However, the selection of which day has to be banned is still under discussion. Daily variation in fishing effort and first sale landings prices (also called ex-vessel prices) of the main target species, are important to consider in order to select the most suitable day to be banned.

The aim of this work is to analyse the daily variation of fishing effort and ex-vessel price to determine which day of the week is better to ban the fishery. The economic loss produced by banning

Fig. 1. Map of the study area (SW Mediterranean) showing the location of the two trawling ports studied: La Vila Joiosa and Dénia (Spain).
one day (the proposed alternative measure) is also compared to economic loss produced by seasonal closure (the actual measure: normally one month) to verify the economic effect of the proposed measure. This study was conducted in two important ports [3], Dénia and La Vila Joiosa, located in the south-western Mediterranean Sea off the coasts of Spain (Fig. 1).

2. Material and methods

2.1. Data collection

Along the Gulf of Alicante, there are 12 fishing ports that have traditionally been important fishing activity locations. This study was conducted in two of these ports, Dénia and La Vila Joiosa (Fig. 1). According to the number of trawlers, these two ports represent about 41% of the total trawlers operating on the Alicante coast [3]. Data records of daily auctions were obtained from the fishing guild of both ports for 10 years (2002 to 2011). For each fishing day, data on species landing weight (kg) and its first sale value (€) were available by vessel. Data were arranged in a two-way matrix of daily landings per vessel as samples (rows) and species landed as variables (columns). Sale value (revenue) is the result of quantity landed (kg) and ex-vessel fish price (price fetched by fishers per kg landed fish). The sale value (€) of each target species was divided by its landings (kg) to calculate the first sale price per kg (ex-vessel fish price). Vessels with sporadic landings events within the ports studied were excluded from the analysis, considering only those vessels registered in the ports studied (home port) to avoid possible biases in the data. Most of the vessels included had had activity throughout the period considered. The total number of collected samples (vessel/day) was 102,187 fishing days.

2.2. Data analysis

2.2.1. Daily variation of fishing effort and ex-vessel prices

A prior analysis of the fishing tactics in the fishery was conducted to determine the real effort directed at the species under study. Four principal métiers, trawlers targeting Red mullet (Mullus spp.), European hake (Merluccius merluccius), Norway lobster (Nephrops norvegicus) and Red shrimp (Aristeus antennatus), were identified using the multivariate analysis: hierarchical cluster, non-metric multi-dimensional scaling (nMDS) and the Similarity Percentage Analysis (SIMPER) routine [3,9]. To select the day to ban fishing, Analysis of Variance (ANOVA) was used to test for significant daily differences in fishing effort (total and by métier), expressed as mean number of vessels (vessel·day⁻¹), and also in the ex-vessel price (€/kg⁻¹) of the main target species using the whole set of data (10 years). The experimental design consisted of two factors: Day (5 levels, fixed) and Port (2 levels, fixed and orthogonal). An even number of samples was randomly selected to maintain our data balanced within each level of the factors considered in the experimental design. Thus, for fishing effort analysis with 417 replicates in each combination of levels of Day and Port factor, there were a total of 4170 observations. Meanwhile for ex-vessel prices of Red mullet, European hake, Norway lobster and Red shrimp with 2925, 5576, 2038 and 1809 replicates respectively; there were a total of 29,250, 55,760, 20,380 and 18,090 observations.

When the ANOVA F-test was significant, post hoc analyses were conducted using Student–Newman–Keuls (SNK) multiple comparisons [10]. Before (ANOVA) analysis, Cochran’s test was used to test for homogeneity of variance [11]. As transformations did not remove heterogeneity, analyses were performed on the untransformed data, with the F-test α-value set at 0.01, since ANOVA is more restricted to departures from this assumption, especially when the design is balanced and contains a large number of samples/treatments [12]. ANOVA was conducted by R statistical computing software [13] and the R’s package GAD [14].

2.2.2. Economic loss

The apparent economic importance of price may also be reflected in the daily landings value by vessel (referred herein as landings value per unit effort VPUE). It is therefore important to compare the value achieved by individual fishing vessels under different management strategies. An approximation was tested to analyse the economic loss, regardless the operating costs, produced by banning one day (based on the result obtained from the daily variation of both effort and prices) compared to economic loss produced by banning one month (the actual measure: seasonal closure). For each of the last three years (2009, 2010 and 2011) the mean VPUE (€·vessel⁻¹·day⁻¹) was calculated and multiplied by 22 days (the allowed fishing days by month). This was compared to the mean VPUE (€·vessel⁻¹·day⁻¹) of the proposed banning day also multiplied by 22 fishing days.

Furthermore, to find out if loss by banning the proposed day for the whole year (approx. 50 days) would be equal to loss produced by a month of closure, both were compared. The mean VPUE (€·vessel⁻¹·month⁻¹) was calculated considering that the mean value achieved in a month would be equal to the loss produced by ceasing the fishing for a month (seasonal closure). Consequently this was compared to the annual sum (approx. 50 days) VPUE (€·vessel⁻¹·day⁻¹) of the proposed banning day (selected based on the analysis described in Section 2.1). Finally, as the ex-vessel prices significantly decrease by the seasonal closure [5], an additional part of the loss produced by the closure was calculated as the difference between the VPUE (€·vessel⁻¹·month⁻¹) achieved before and after the closure.

3. Results

3.1. Daily variation of fishing effort

Daily variation in the total fishing effort, expressed as mean number of vessels per day, was observed in La Vila Joiosa mainly due to higher effort at the end of the week (Fig. 2B), while effort was similar between days in Dénia (Fig. 2A). In ANOVA, the two-way interaction Day and Port was significant (Table 1). SNK comparisons corroborated that no significant differences were observed between days in Dénia (Fig. 2A). However in La Vila Joiosa, mean number of vessels showed a significant gradual increase from Wednesday towards the end of the week (Fig. 2B).

Daily variation in the fishing effort also was different depending on the métier (Fig. 3). Red mullet and European hake métiers showed very slight effort changes among days in both ports (Fig. 3A–D). However differences in the mean number of vessels were clear between both ports. ANOVAs did not detect any significant differences among days in both ports, but showed significant differences between the two ports (Table 1). For Norway lobster and Red shrimp métiers, very mild changes were observed in Dénia (Fig. 3E and G), while in La Vila Joiosa a gradual increase was observed along the week, with clear higher fishing effort on Thursday and Friday (Fig. 3F and H). These results were corroborated by ANOVA (Table 1), showing significant the two-way interaction Day and Port for both métiers. Analysing the SNK comparisons for Norway lobster métier, although no significant differences were detected in Dénia, the fishing effort on Thursday and Friday were significantly greater in La Vila Joiosa (Fig. 3E and F). On the other hand, for Red shrimp métier SNK comparisons detected that fishing effort was significantly higher on Friday than the rest
of the week in Dénia (Fig. 3G), while in La Vila Joiosa fishing effort showed a significant gradual increase (Fig. 3H) with higher effort on Thursday and Friday.

### 3.2. Daily variation of ex-vessel prices

Daily variation was observed in the mean ex-vessel price of all target species, with quite similar patterns at both ports (Fig. 4). Generally, the lowest prices were observed in the middle of the week (Monday: M, Tuesday: T, Wednesday: W, Thursday: Th, and Friday: F).

In Dénia, SNK comparisons detected significant differences in the total landing value by vessel or VPUE (€/vessel$^{-1}$ day$^{-1}$) and standard error in the two ports: Dénia (A) and La Vila Joiosa (B). Student–Neuman–Keuls (SNK) pairwise comparisons among days of the week (Monday: M, Tuesday: T, Wednesday: W, Thursday: Th, and Friday: F).

#### 3.3. Economic loss

In the last three years (2009, 2010, and 2011) the daily landings value by vessel or VPUE (€/vessel$^{-1}$ day$^{-1}$) averaged about 1188.9 € in Dénia and 1469.4 € in La Vila Joiosa (Table 2). This means that the value of landings lost produced by ceasing the fishing during the whole month (22 fishing days) averaged 26,155.84 € in Dénia and 32,326.85 € in La Vila Joiosa. According to results in the previous sections, the most suitable day to ban the fishery would be Wednesday. Therefore, the daily landings value (€/vessel$^{-1}$ day$^{-1}$) in Wednesday averaged about 1159.02 € in Dénia and 1384.84 € in La Vila Joiosa. Consequently a reduction in 22 fishing days in Wednesday (the same effort reduction than a monthly closure) averaged 25,498.38 € in Dénia and 30,466.52 € in La Vila Joiosa losses in value of landings. This is about 2.36% to 5.65% value of landings loss reduction, respectively, compared to a month of closure. Furthermore, due to price reduction of the main target species after the seasonal closure [5], an additional value of landings and profit losses (assuming no changes in costs), about 2645.12 €, was observed in Dénia, and 2946.52 € in La Vila Joiosa, which is 13.53% to 14.76% respectively of the monthly VPUE (€/vessel$^{-1}$ month$^{-1}$). Finally, the sum of value of landings of all Wednesdays (approx. 50 days) was about 36,153.46 € in Dénia and 41,024.42 € in La Vila Joiosa, which is clearly higher than the monthly value of landings (Table 2), but lower that a more equivalent two months closure (approx. 44–45 days).

### 4. Discussion

In this study, the analysis of the ex-vessel prices of the main target species in the western Mediterranean trawl fishery and the effort directed to each one, using a large data set, allows to obtain reliable conclusions on the most suitable day to ban the fishery. The significant daily variation in prices was observed for the main target species in the study area. Normal market drivers, i.e. supply, demand and quality normally determine the ex-vessel demand and price [15,16]. However, Swartz [17] suggest that in many fisheries prices are relatively inelastic to supply, and vice versa, due to the weak correlations between catch rates and achieved price [17]. Bastardie [16] also suggest that prices more strongly influence fishermen than the prospect of large catch abundance. The lowest mean ex-vessel prices for most target species were on Tuesday and Wednesday, and were higher on Monday and Friday, with some exceptions. Likewise other works in western Mediterranean, for Red shrimp, Guillen and Maynou [7] considered that in Tuesday is the most powerful vessels) is heading to the deep resources, mainly Red shrimp available for these vessels [3,19]. Because of the distance between La Vila Joiosa port and the fishing ground, this fleet segment (vessels) tend to stay for two or three days outside their home port and normally back on Thursday or Friday. This can explain the higher mean number of vessels observed at the end of the week in La Vila Joiosa. However, this is not the case of Dénia where all vessels return every day to the port. On the other hand,

Fig. 2. Daily variation in the total fishing effort, expressed as mean number of vessels (vessel $\cdot$ day$^{-1}$) and standard error in the two ports: Dénia (A) and La Vila Joiosa (B). Student–Neuman–Keuls (SNK) pairwise comparisons among days of the week (Monday: M, Tuesday: T, Wednesday: W, Thursday: Th, and Friday: F).
Table 1
Results of analysis of variance (ANOVA) with 2 factors (D: Day; P: Port) for mean number of vessels (total fishing effort and by métier) and for mean ex-vessel price by target species: Red mullet, European hake, Norway lobster and Red shrimp. D.f.: degrees of freedom; MS: mean square; F: F value. Dash (–) indicates that there is no transformation, where levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001. (a) indicates that there is no homogeneity of variance, the level of significance being **p < 0.001.

### Fishing effort (mean number of vessels)

<table>
<thead>
<tr>
<th>Sources of variation</th>
<th>D.f.</th>
<th>Total effort</th>
<th>Red mullet métier</th>
<th>European hake métier</th>
<th>Norway lobster métier</th>
<th>Red shrimp métier</th>
<th>F versus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MS</td>
<td>F</td>
<td>MS</td>
<td>F</td>
<td>MS</td>
<td>F</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>3476.38</td>
<td>152.49**</td>
<td>6.69</td>
<td>0.65</td>
<td>39.60</td>
<td>2.37</td>
</tr>
<tr>
<td>P</td>
<td>1</td>
<td>82,411.86</td>
<td>3614.92**</td>
<td>3132.13</td>
<td>304.96***</td>
<td>188,009.59</td>
<td>1065.63</td>
</tr>
<tr>
<td>D x P</td>
<td>4</td>
<td>3554.86</td>
<td>155.93**</td>
<td>6.88</td>
<td>0.67</td>
<td>35.42</td>
<td>2.12</td>
</tr>
<tr>
<td>Residual</td>
<td>4160</td>
<td>22.80</td>
<td>10.27</td>
<td>– a</td>
<td>– a</td>
<td>16.70</td>
<td>3.10</td>
</tr>
<tr>
<td>Transform</td>
<td>– a</td>
<td>–</td>
<td>–</td>
<td>– a</td>
<td>– a</td>
<td>– a</td>
<td>– a</td>
</tr>
</tbody>
</table>

### Ex-vessel fish prices

<table>
<thead>
<tr>
<th>Sources of variation</th>
<th>Red mullet</th>
<th>European hake</th>
<th>Norway lobster</th>
<th>Red shrimp</th>
<th>F versus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D.f.</td>
<td>MS</td>
<td>F</td>
<td>D.f.</td>
<td>MS</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>378.85</td>
<td>38.17**</td>
<td>4</td>
<td>1318.83</td>
</tr>
<tr>
<td>P</td>
<td>1</td>
<td>6295.72</td>
<td>634.29**</td>
<td>1</td>
<td>5442.10</td>
</tr>
<tr>
<td>D x P</td>
<td>4</td>
<td>80.56</td>
<td>8.12**</td>
<td>4</td>
<td>116.97</td>
</tr>
<tr>
<td>Residual</td>
<td>29,240</td>
<td>9.93</td>
<td>55,750</td>
<td>5.76</td>
<td>20.370</td>
</tr>
<tr>
<td>Transform</td>
<td>– a</td>
<td>–</td>
<td>– a</td>
<td>– a</td>
<td>– a</td>
</tr>
</tbody>
</table>
the significant difference in the mean number of vessels between both ports is simply because La Vila Joiosa port has more vessels than Dénia related with a larger continental shelf available for trawling.

Moreover, fishers may adopt alternative strategies (métiers) that are perceived to be more profitable given species prices and predicted catch value [20]. Daily variation was observed only for both Norway lobster and Red shrimp métiers. The similarity of fishing effort between days in both, Red mullet and European hake métiers, whereas there is a higher effort observed at the end of the week for both, Norway lobster and Red shrimp métiers, confirms the previously mentioned reason of distance and fleet dynamics in

Fig. 3. Daily variation in the total fishing effort, expressed as mean number of vessels (vessel day⁻¹) and standard error by métier: (A, B) Red mullet, (C, D) European hake, (E, F) Norway lobster and (G, H) Red shrimp in the two ports: Dénia (left) and La Vila Joiosa (right). Student–Neuman–Keuls (SNK) pairwise comparisons among days of the week (Monday: M, Tuesday: T, Wednesday: W, Thursday: Th, and Friday: F).
Fig. 4. Daily variation in the mean ex-vessel price (euro kg⁻¹) and standard error of the main target species: (A, B) *Mullus* spp., (C, D) *Merluccius merluccius*, (E, F) *Nephrops norvegicus* and (G, H) *Aristeus antennatus* in the two ports: Dénia (left) and La Vila Joiosa (right). Student–Neuman–Keuls (SNK) pairwise comparisons among days of the week (Monday: M, Tuesday: T, Wednesday: W, Thursday: Th, and Friday: F).
Table 2
Comparison between the economic loss produced by the seasonal closure (actual management measure) and by banning a day (Wednesday) per week (proposed alternative measure).

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean VPUE (€/vessel-day)</th>
<th>Multiplying by 22 days</th>
<th>Mean VPUE in Wednesdays (€/vessel)</th>
<th>Multiplying by 22 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>975.20</td>
<td>21,454.49</td>
<td>21,691.70</td>
<td>218,970.00</td>
</tr>
<tr>
<td>2010</td>
<td>1785.80</td>
<td>39,571.66</td>
<td>39,962.80</td>
<td>883,920.00</td>
</tr>
<tr>
<td>2011</td>
<td>2653.59</td>
<td>58,983.98</td>
<td>60,274.53</td>
<td>1,325,697.00</td>
</tr>
</tbody>
</table>

loss produced by the closure: calculated as the difference between the VPUE (€/vessel-month) before and after the closure.
considering the current existence of seasonal closures and subsidies, it seems a bit difficult that the current management could be changed smoothly to a reduction of fishing days per week without subsidies. In this sense, future analysis is needed to assess the acceptance of this measure by the fishing community and the viability of adopting such measure without subsidies.

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