Report on assessment of the ICT system environmental efficacy

WP4	**Pilot application and assessment of the econometric model for SP fisheries**
Activity 4.3	**Assessment of the ICT system environmental and economic efficacy**
D.4.3.1	**Report on assessment of the ICT system environmental efficacy**
Responsible PP	**PP1 – CNR-IRBIM**

DELIVERABLES 4.3.1

Report on assessment of the ICT system environmental efficacy

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EXCECUTIVE SUMMARY

Small pelagics, particularly anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*), are the most important species for the Adriatic fishery sector. In the last decades, these stocks registered a strong decrease in biomass and a high fishing pressure. Consequently, a number of regulations have been developed with the aim of restore these stocks and sustain the fishing activity. Nevertheless, the state of these stocks does not seem improving.

The ITACA project is introduced in this context by promoting the use of a bio-econometric model aimed at reducing catches and increasing fishers' incomes, within a sustainable use of fishery resources. The bio-econometric model is translated into a web application accessible from all portable devices and computer. 20 fishery operators (13 from Italy and 7 from Croatia) participated to the project pilot activity by entering daily data regarding economic and biological aspects from December 2017 to June 2022. In term of catches, these data highlight the importance of sardine for the harbours located in the North Adriatic Sea, whereas anchovy is more relevant for the ports based in the central Adriatic Sea. Instead, revenues are generally higher for anchovy, except for the harbours of Chioggia, Cesenatico and Porto Garibaldi. Moreover, these data underlines seasonal patterns by species in most of the considered harbours, both for catches and revenues, as well as a decrease for both the catches and revenues in the month of August due to the fishing ban. Lastly, restrictions due to the COVID19 does not seem to have influenced the fishing activity on these species: 2020 and 2021 catches and revenues are similar to those registered in the previous years.

The ICT system foresees the production of weekly or monthly forecasts about the future prices and size of anchovy and sardine. This option will be very useful in future developments of this project, as possible tool to promote the economic sustainability of the fishery enterprise and support the recovery of these stocks.

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1. Introduction

Small pelagics, particularly anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*), are the most important species for the Adriatic fishery sector. These species account for the highest landings in this basin, fished mainly by pelagic trawlers in Italian waters and purse seiners in the Eastern side of the Adriatic Sea (FAO, 2020). In the last decades, these stocks registered a high fishing pressure and a strong decrease in biomass (GFCM, 2021). Consequently, a number of regulations (e.g. Rec. GFCM/37/2013/1, Rec. GFCM/38/2014/1, Rec. GFCM/39/2015/1, Rec. GFCM/40/2016/3, Rec. GFCM/42/2018/8, Rec. GFCM/44/2021/20) have been developed with the aim of restoring these stocks and sustain the fishing activity. However, in the last decade, the small pelagic fishing sector underwent to a strong crisis; specifically in Italy the number of boats exploiting these species drastically decreased, as well as some harbours historically ports of landing for anchovy and sardine disappeared. Nevertheless, the state of these stocks does not seem improving.

The management of fishery resources, i.e. anchovy and sardine in this case, is a complex task. Evaluations are carried out considering information from the fishing activity, research surveys and biological features; however, several other aspects should be considered. Among these, economic aspects should be taken into account in order to produce management options able to support the fishery enterprises, as well as to develop management regulations economically sustainable for the fishery companies.

In order to close this gap, the ITACA project is introduced in this context by promoting the use of a bio-econometric model aimed at reducing catches and increasing fishers' incomes, within a sustainable use of fishery resources. The bio-econometric model is constituted by two sections: i) the economic module, which is able to produce forecasts about the landed quantity requested by the different harbours and the respective mean prices, and ii) the biological model, able to make previsions of the size of these species at a given time and area, coupling biological information with environmental data, e.g. sea surface temperature (SST) and chlorophyll. The ultimate objective of this project is to create a network between the Italian and Croatian fishery operators with shared market strategies able to jointly individuate the day or the period more profitable to go fishing and sell a certain quantity of anchovy and sardine.

2. Present status of the small pelagics, anchovy and sardine, stocks in the Adriatic Sea

The last public stock assessment of anchovy and sardine was carried out in 2022, using data up to 2021. The stock of anchovy results being in overexploitation, that is the fishing mortality exceeds the reference value F_{MSY} (the expected F to give maximum sustainable yield in the long term), with biomass above the reference points (B_{pa}, which is the biomass limit above which the stock is considered to have full reproductive capacity, and B_{lim}, which is the biomass limit below which a stock is considered to have reduced reproductive capacity) (Figures 2.1 and 2.2; GFCM, 2022). Indeed, the stock of sardine is overexploited and in overexploitation, thus the fishing mortality exceeds F_{MSY} and the biomass is below the reference points (Figure 2.3; GFCM, 2022).

Based on the input data and considering all the analysis carried out within the stock assessment procedure, two different stock assessment models have been selected for the two target species: the FLSAM methodology (Kell et al., 2007; Nielsen and Berg, 2014) for the anchovy stock and the a4a approach (Jardim et al., 2015) for sardine. All the details are contained in the Report of the Working Group on Stock Assessment of Small Pelagic Species (WGSASP) session on the assessment of European anchovy and sardine in the Adriatic Sea (GFCM, 2022).

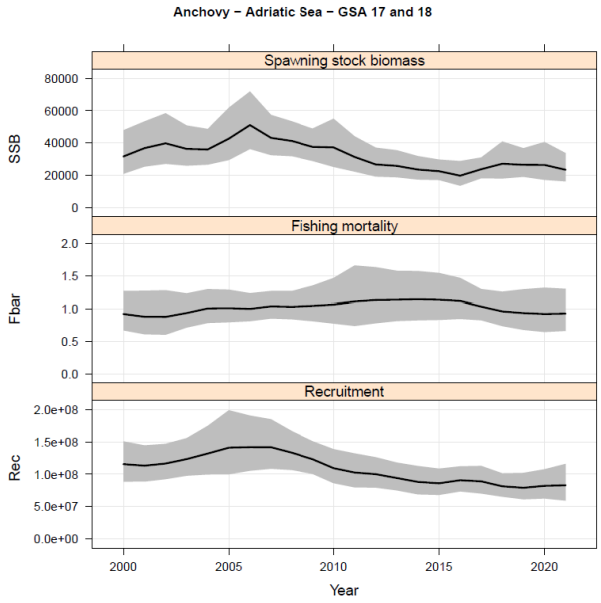

Figure 2. 1 Result of the stock assessment of anchovy in the Adriatic Sea. Source: GFCM anchovy stock assessment form (GFCM, 2022).

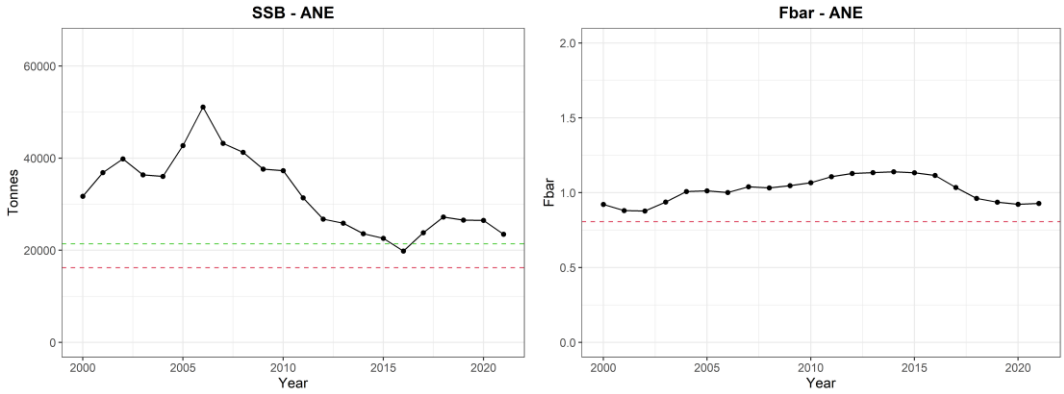

Figure 2. 2 The left panel shows the estimated spawning stock biomass (SSB, black line) together with the respective reference points (B_{pa}, green line; B_{lim}, red line), whereas the right panel shows the estimated fishing mortality (F_{bar}, black line) together with the respective reference points (F_{MSY}, red line) for the stock assessment of anchovy (Engraulis encrasicolus) in the Adriatic Sea. Source: GFCM anchovy stock assessment form (GFCM, 2022).

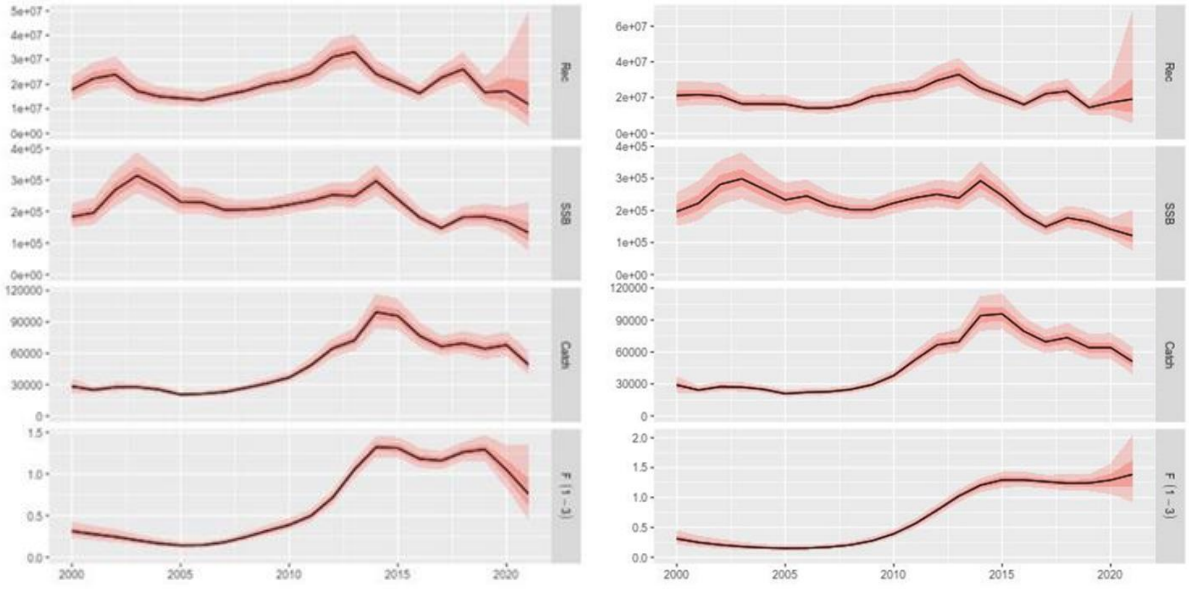

Figure 2. 3 Results of the stock assessment of sardine (Sardina pilchardus) in the Adriatic Sea. Two settings of the FLSAM model have been carried out, giving similar results. Source: GFCM sardine stock assessment form (GFCM, 2022).

3. Assessment of the ICT system environmental efficacy

3.1. Introduction to the ICT system

The ITACA project was aimed at developing an ICT system for the small pelagic fishery operators and, in particular, a software interface for the utilization of the science-based econometric model developed within this project. The science-based econometric model acts as a sales price formation mechanism, which allows, elaborating historical biological and economic data, to predict on a daily/weekly/monthly basis the most probable selling price of small pelagic products in the market according to the amount of landings of the same products. The prediction of the selling price represents a great advantage for the small pelagic fisheries sector and the fishery operators that could, in that way, plan the quantity of landings in order to maintain the market price at an economic sustainable level (avoiding phenomena of excessive price reduction deriving from the availability of a large quantity of small pelagic products) and at the same time, preserving the status of small pelagic stocks (avoiding overexploitation).

The ICT system has been developed as a web application accessible from all portable devices and computers (Fig. 3.1.1). It includes the two sections of the science-based econometric model, i) the economic module and the ii) biological module, and a tool able to summarize all the data included by harbours (Fig. 3.1.1).

Figure 3.1. 1 Homepage of the ITACA web application, available at https://itaca-webapp.mostaz.app/; account activation has to be requested. The yellow box corresponds to the economic module, whereas the green box coincides with the biological module; the blue box summarizes the data included in the web application.

The ITACA consortium was able to create a network among the most important Italian and Croatian harbours landing small pelagic species. Specifically, 20 (13 from Italy and 7

from Croatia) fishery operators participated at the project pilot activity by entering daily data regarding economic and biological aspects. The economic information includes daily catch, mean price and income divided by species and harbours (Figs. 3.1.2 and 3.1.3); the biological data includes daily mean weight lumped by species and harbours, specifying also the fishing ground (Fig. 3.1.4).

Figure 3.1. 2 Summary of the economic input data included in the web application for a given harbour, i.e. Ancona, and species, i.e. anchovy. Purple line represents daily catches in Kg and green line the daily mean price (€/Kg).

Figure 3.1. 3 Summary of the economic input data included in the web application for a given harbour, i.e. Ancona, and species, i.e. anchovy. Purple line represents the daily income in € and green line the daily mean price (€/Kg).

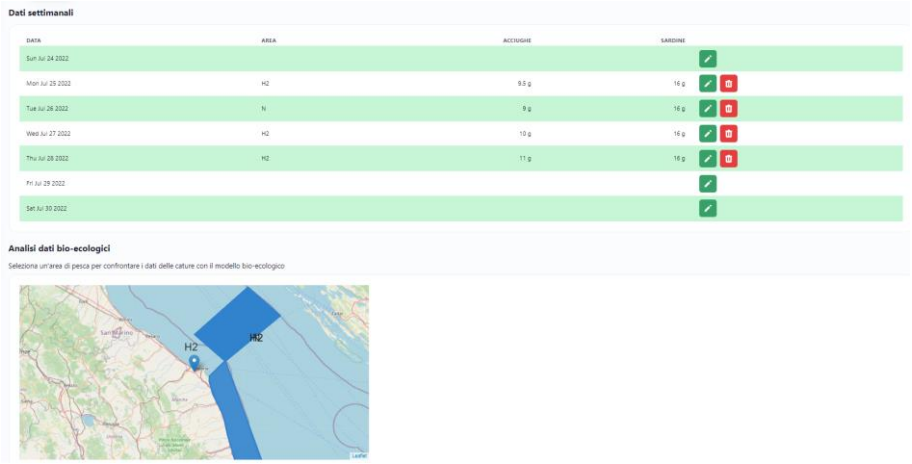

Figure 3.1. 4 Summary of the biological input data included in the web application for a given harbour and species. Table reports the date (DATA), the fishing ground (AREA), the mean weight in grams for anchovy (ACCIUGHE) and sardine (SARDINE).

3.2. Summary of the data included in the ITACA ITC system

The ITACA ITC system includes data by harbour, i.e. catches, mean daily price and income, from December 2017 to June 2022 harbour. Each fishing operator involved in the project pertains to a giving port.

To give a general overview of the data collected within the ITACA web application, input data have been aggregated by species, year, harbour and type, i.e. catch or income. Generally, catches are higher for sardine, with the highest value registered for Chioggia harbour in 2019 (4,196 tonnes) (Fig. 3.2.1); the highest value of anchovy has been registered in Pila Mare harbour in 2021 (3,533 tonnes). Chioggia accounts for the highest quantities of sardine landings, followed by Cesenatico, Pila Mare, Ancona, Pila and San Benedetto del Tronto (Fig. 3.2.1, right side). Sardine catches show a fluctuating trend for Chioggia, Cesenatico and Porto Garibaldi, whereas they describe a decreasing trend for Pila Mare, Ancona and Pila; sardine landings from San Benedetto del Tronto describe a quite stable trend over the years. Also, sardine depicts a declining trend in landings from North to South Italy, whereas the role of Croatia cannot be properly evaluated due to the few data available for this country (see details in the next section). This is also the

case of Apulia region, for which very few data were reported (see details in the next section).

Anchovy catches describe more fluctuating trends compared to those of sardine, with the exception of Pila Mare, which shows an increasing trend over the years reaching the highest value of 3,533 tonnes in 2021, Pila and Ancona, for which catches seem rather stable over the years (Fig. 3.2.1, left side). In the most recent years, Chioggia has resulted the second most important harbour for anchovy landings followed by Ancona, Pila, Cesenatico, San Benedetto del Tronto and Porto Garibaldi. Also for this species, the role of Croatia and Apulia region cannot be properly evaluated due to the very few data collected for these areas (see details in the next section).

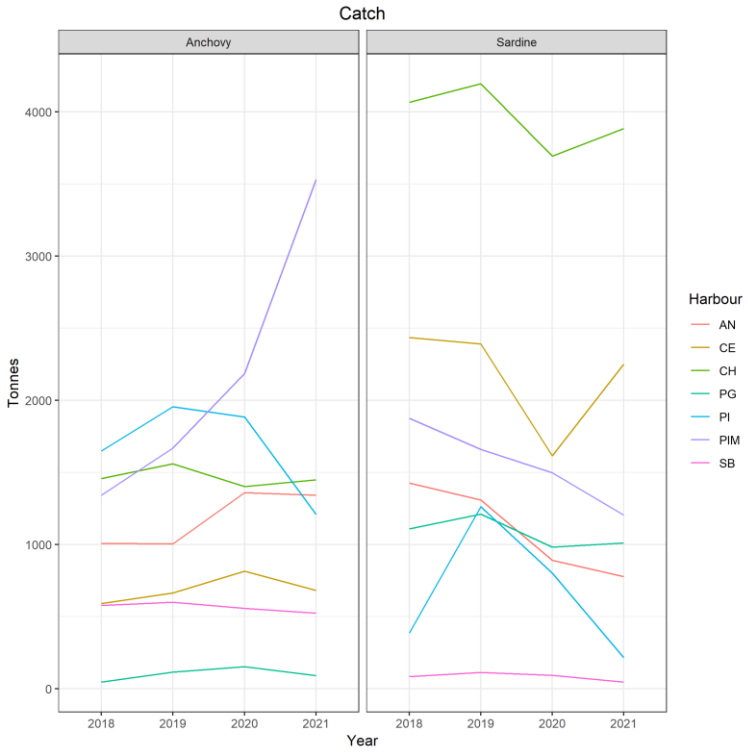

Figure 3.2. 1 Catches in tonnes of anchovy (left side) and sardine (right side) by year and harbours (AN Ancona, CE Cesenatico, CH Chioggia, PG Porto Garibaldi, PI Pila, PIM Pila Mare, SB San Benedetto del Tronto). Years 2017 and 2022 and harbours belonging to Croatia and Apulia region are not shown, since for these years and harbours only few data have been entered in the ITACA ICT system.

Revenues are generally higher for anchovy; this is true for all the examined harbours with the exception of Chioggia, Cesenatico and Porto Garibaldi, which show higher profits from the sales of sardines (Fig. 3.2.2). Moreover, revenues from sardine sales appears rather stable over the years, except for Cesenatico, Pila and Pila Mare; whereas revenues from anchovy trades seem more fluctuating, with similar trends for Ancona, Cesenatico and Pila. In the most recent years, Pila Mare is the harbour that reached the highest revenues from anchovy catches (3,162,017 €), followed by Ancona, Chioggia, Pila, San Benedetto del Tronto, Cesenatico and Porto Garibaldi (Fig. 3.2.2, left side). Instead, Chioggia registers the highest profits from sardine catches (2,753,006 € in 2019, 2,713,119 € in 2021), followed by Cesenatico, Porto Garibaldi, Ancona, Pila Mare, Pila and San Benedetto del Tronto (Fig. 3.2.2, right side). Also in this case, the situation for Croatia and Apulia region cannot be evaluated considering the few data available.

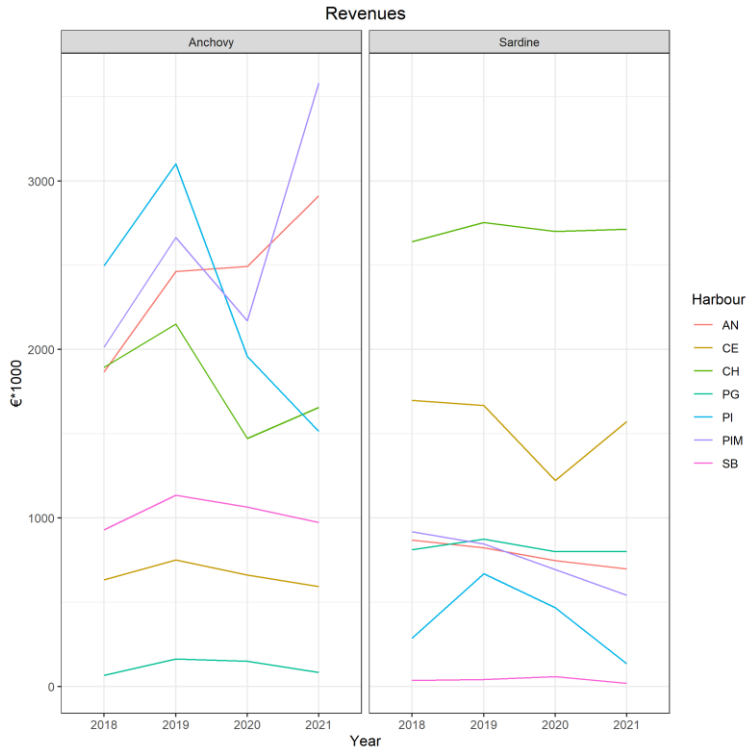

*Figure 3.2. 2 Revenues in €*1000 of anchovy (left side) and sardine (right side) by year and harbour (AN Ancona, CE Cesenatico, CH Chioggia, PG Porto Garibaldi, PI Pila, PIM Pila Mare, SB San Benedetto del Tronto). Years 2017 and 2022 and harbours belonging to Croatia and Apulia region are not shown, since for these years and harbours only few data have been entered in the ITACA ITC system.*

3.3. Analysis of the data collected within the ICT system by harbours

Monthly data by harbours and species are summarized in the following figures (Figs. 3.3.1 – 3.3.9).

Chioggia harbour shows a preference for sardine, which accounts for higher catches compared to anchovy landings (Fig. 3.3.1, panel A). Trends are similar among the years with a decay in August, month in which a fishing ban is foreseen, and at the end of the year; specifically, sardines show peaks in June and September, whereas anchovy presents a rather stable trend with peaks in wintertime. Regarding revenues, sardine generally accounts for higher profits compared to anchovy; however, during winter

months (November – December) revenues coming from anchovy landings can be higher than those deriving from sardine landings (Fig. 3.3.1 – panel B).

The fishing activity exerted in the Pila harbour is particularly concentrated on sardine, whereas anchovy constitutes a negligible part of the catch (Fig. 3.3.2 – panel A). Catches show similar trends among the years, with very low values in August and December. On the contrary, anchovy landings produce higher profits than those from sardine, with a mean revenue of 200,000€ per month and a peak of 600,000 € in November 2019. Revenues from sardine catches appear quite stable over the years and months, with values around less than 100,000 € per month (Fig. 3.3.2 – panel B).

Catches from the harbour of Pila Mare show different trends by year (Fig. 3.3.3, panel A). In 2018, sardine generally accounts for higher landings compared to anchovy, with a peak in May, June, September and November, whereas anchovy is characterised by higher amounts of catches in the winter months (December – March). In 2019, anchovy and sardine show similar trends, whereas in 2020 anchovy landings are prevalent from January to July, while sardine constitutes the majority of the catches from September to November. In 2021 and 2022, anchovy landings represent the majority of the catches, with a peak of sardine landings in October 2021. Anchovy catches produce higher profits than sardine landings, as shown for all the examined years (Fig. 3.3.3, panel B).

Porto Garibaldi landings are mainly dedicated to sardine, whereas anchovy is caught only in the winter months with very low values (Fig. 3.3.4, panel A); revenues derive mainly by sardine catches with similar seasonal trends among the years (Fig. 3.3.4, panel B). Similarly, the harbour of Cesenatico shows a preference for sardine, which accounts for higher landings along all the examined months and years, with values approaching to zero for August, due to the fishing ban (Fig. 3.3.5, panel A). Regarding revenues, sardine allows higher profits compared to anchovy landings, even if the latter are not negligible (Fig. 3.3.5, panel B).

Catches of sardine and anchovy in the Ancona harbour are fluctuating all over the years and months, with a significant peak of sardine catches in August 2019 (Fig. 3.3.6, panel A). Revenues are generally higher for anchovy, and this is true for all the examined years (Fig. 3.3.6, panel B).

Anchovy is the most important small pelagic species landed in the San Benedetto del Tronto harbour, whereas sardine accounts for negligible values except for the winter

months (from November to March) (Fig. 3.3.7, panel A). The importance of anchovy catches is also underlined in the revenue plots: they show important values from anchovy sales and a very small incomes from sardine catches (Fig. 3.3.7, panel B).

Very few information is available for the harbours belonging to the Apulia region and Croatia; specifically, data for Apulia region are available from October 2021 to May 2022, whereas data for Croatia are available only for October and November 2021 and February and March 2022 (Figs. 3.3.8 and 3.3.9). Anchovy results the most important species for both catch and revenues for the Apulia region, whereas sardine seems to be the main species for Croatia.

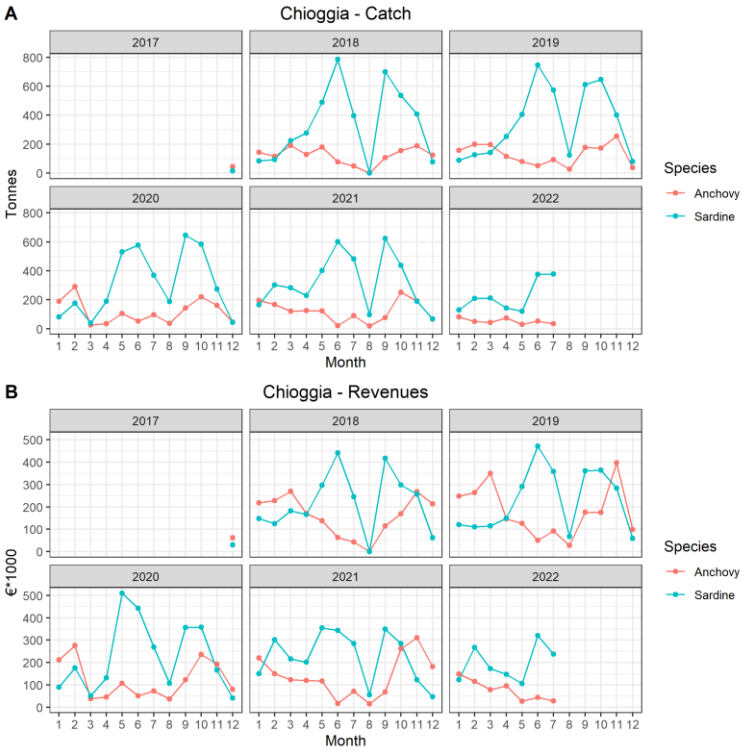

*Figure 3.3. 1 Catches and revenues data included in the ITACA webapp for the Chioggia harbour. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

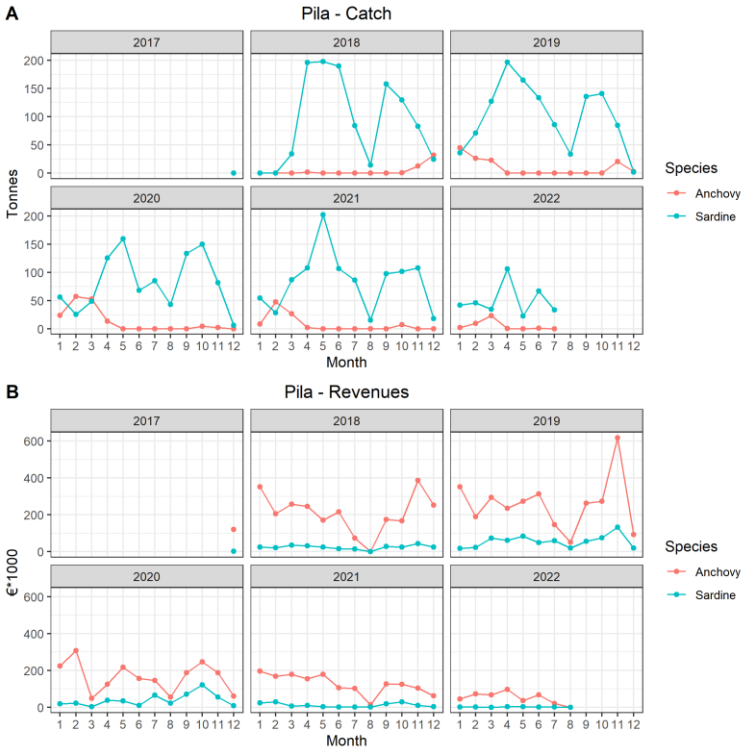

*Figure 3.3. 2 Catches and revenues data included in the ITACA webapp for the Pila harbour. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

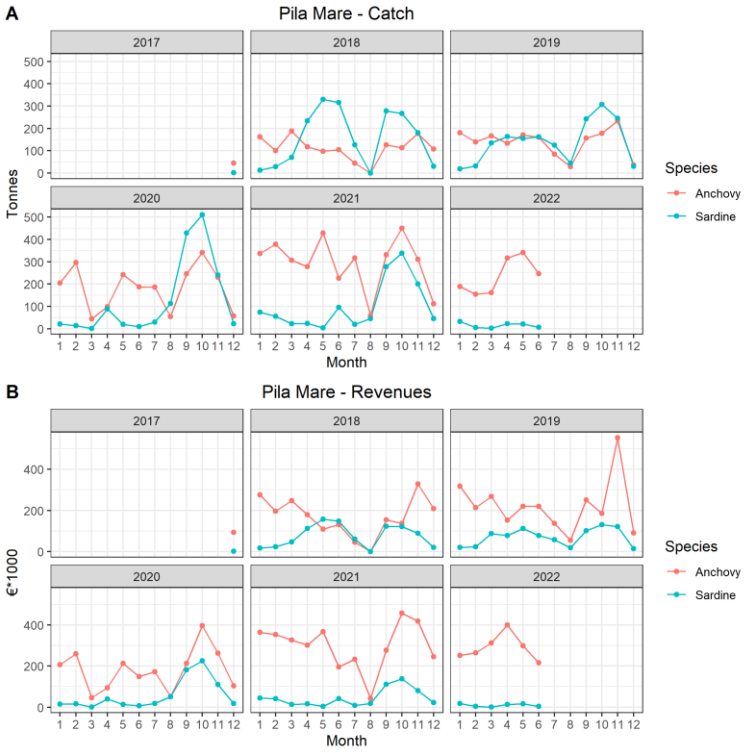

*Figure 3.3. 3 Catches and revenues data included in the ITACA webapp for the Pila Mare harbour. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

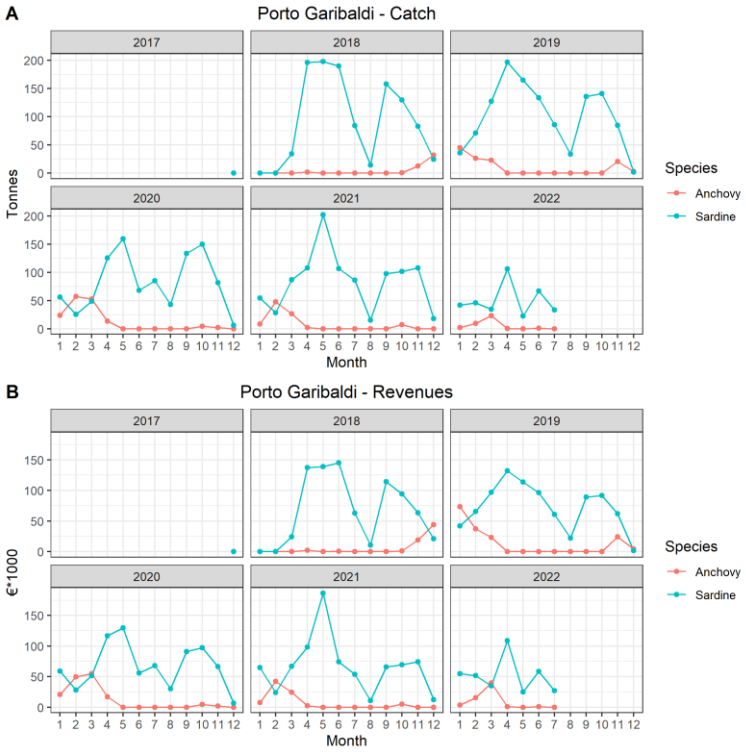

*Figure 3.3. 4 Catches and revenues data included in the ITACA webapp for the Porto Garibaldi harbour. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

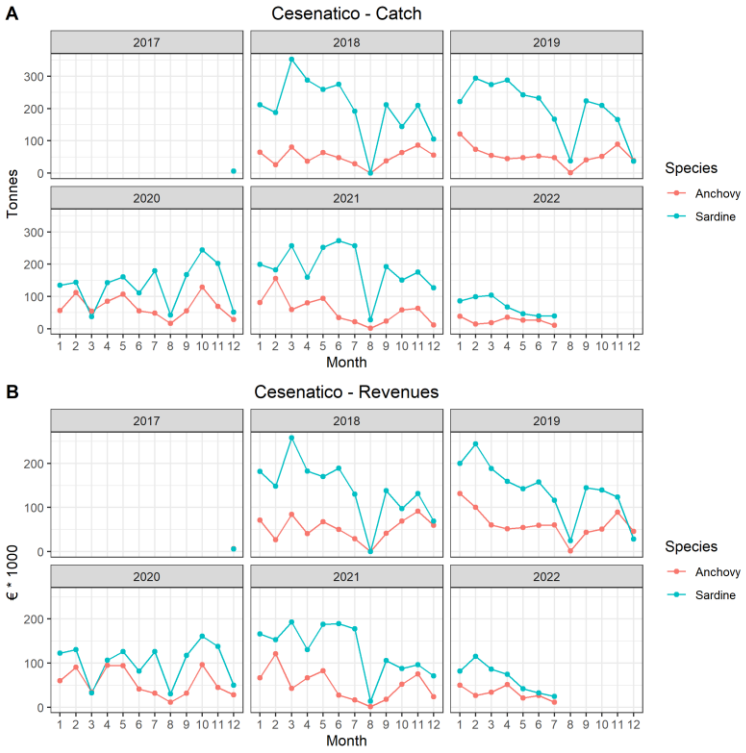

*Figure 3.3. 5 Catches and revenues data included in the ITACA webapp for Cesenatico harbour. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

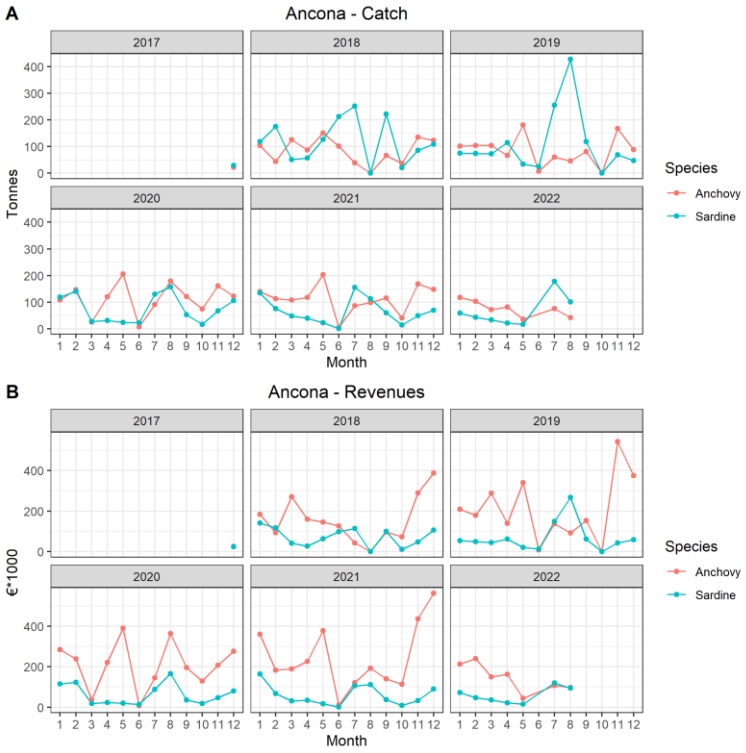

*Figure 3.3. 6 Catches and revenues data included in the ITACA webapp for Ancona harbour. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

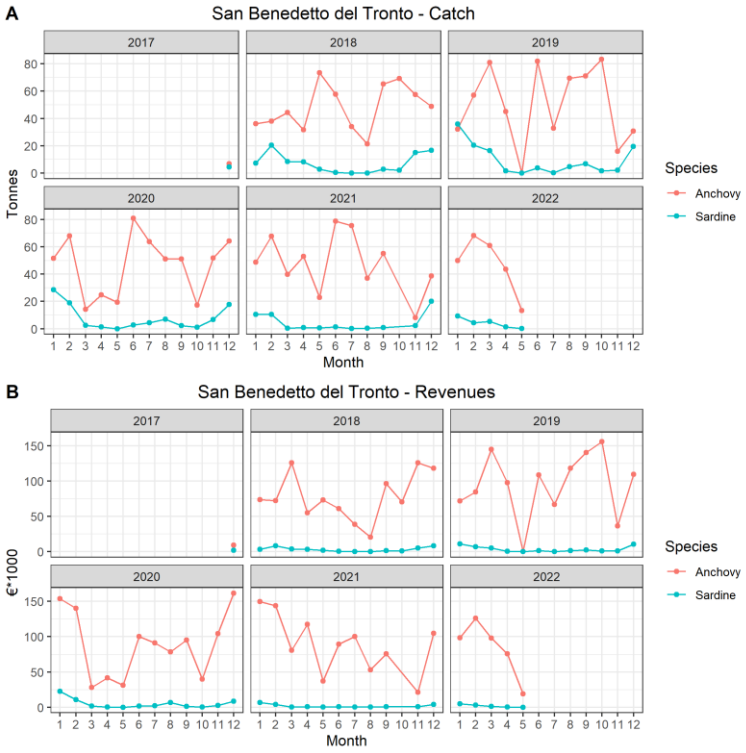

*Figure 3.3. 7 Catches and revenues data included in the ITACA webapp for San Benedetto del Tronto harbour. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

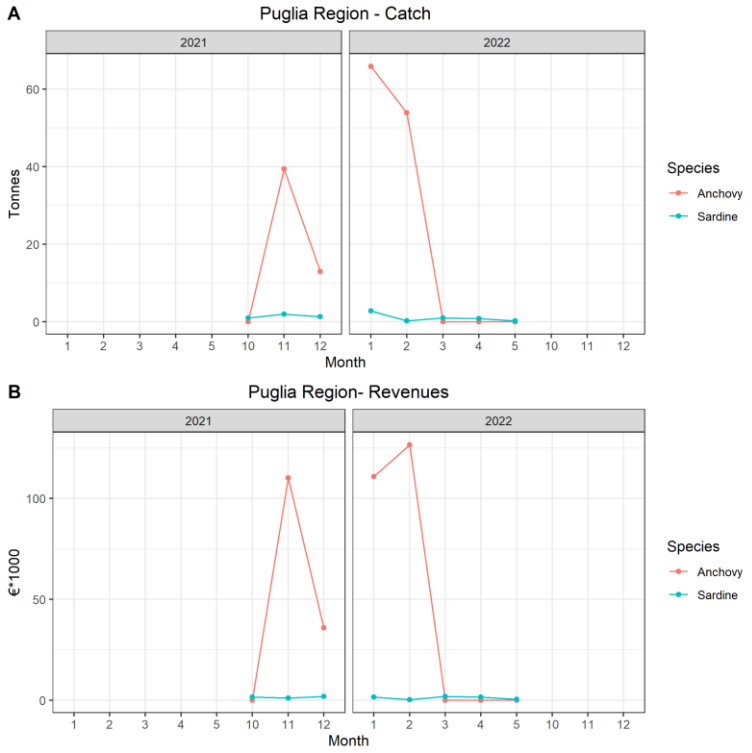

*Figure 3.3. 8 Catches and revenues data included in the ITACA webapp for the harbour belonging to Apulia region. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

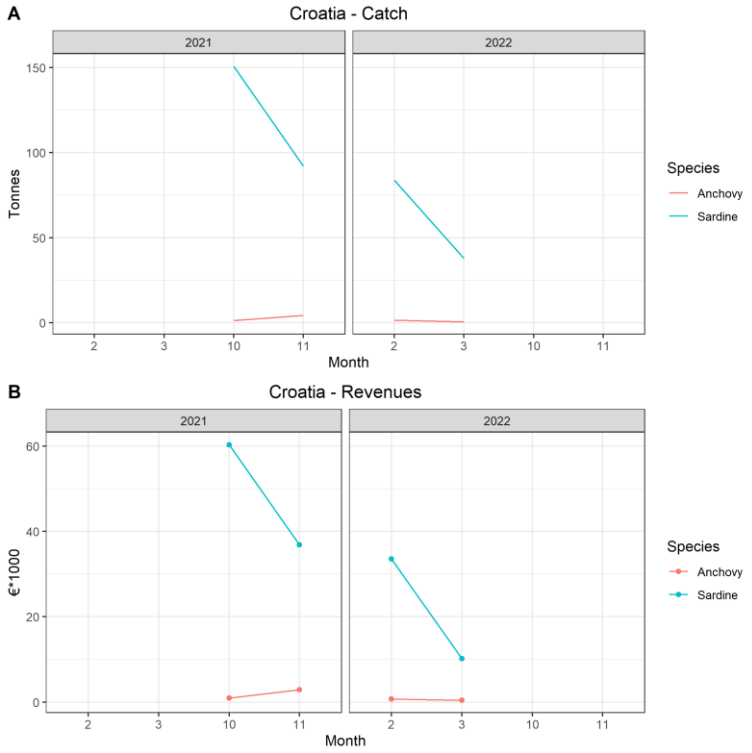

*Figure 3.3. 9 Catches and revenues data included in the ITACA webapp for the Croatian harbours. Panel A shows the catch data in tonnes and panel B presents the revenues data (€*1000) divided by year, month and species (anchovy in red and sardine in blue).*

Monthly data by harbour guides to some common considerations. This data underlines seasonal patterns by species in most of the considered harbours, both for catches and revenues. As described by the aggregated data (Section 3.2), sardine is the favourite species for the ports located in the North Adriatic Sea: Chioggia, Porto Garibaldi and Cesenatico land mainly sardines, which produce higher revenues compared to those obtained by the anchovy sales. On the contrary, anchovy is the most important species for the harbours located in the central Adriatic Sea, i.e. San Benedetto del Tronto, which show relevant amounts of anchovy landings, but negligible values for sardine. In this area, revenues are mainly produced by the anchovy sales. The harbours of Pila and Pila Mare present similar catches of anchovy and sardine, but profits are derived mainly by anchovy

landings. Ancona harbour results being the harbour with a higher mix of catches and revenues from the two species.

All the harbours underlined a decrease of the fishing activity in August, mainly due to the fishing ban occurring for trawlers in this month. However, since 2017, the fishing vessels exploiting anchovy and sardine stocks in the Adriatic Sea have to respect two fishery closures, one in spring/summertime for anchovy and one in autumn/wintertime for sardine (Rec. GFCM/40/2016/3). In most cases, the fishing ban for anchovy overlaps the one in August for the trawlers. Also, revenues seem to follow catches' trend, with profits approaching to zero in August.

Lastly, the monthly and yearly data allow to make some considerations about the effect of the COVID-19 pandemic on the fishing activity exerted on the small pelagic stock in the Adriatic Sea. Restrictions due to the COVID19 does not seem to have influenced the fishing activity on these species: 2020 and 2021 catches and revenues are similar to those registered in the previous years. This is also confirmed by the literature (e.g. Coro et al., 2022).

4. Evaluation of the usefulness of the model previsions developed within the ITACA project

The ICT system developed by the ITACA project aimed at promoting the collaboration between the Italian and Croatian small pelagic fishery enterprises operating in the Adriatic Sea and at facilitating the development of shared commercial strategies to enhance the profits of the fishing operators while reducing the exploitation on these resources.

The web application facilitates the collection of daily biological and economic data, as well as their of analysis. Also, it foresees the production of weekly or monthly forecasts about the future prices of anchovy and sardine. Consequently, thanks to such forecast, fishing operators will be able to know when landing and selling these species will be more advantageous, with the ultimate aim of decreasing catches when not profitable and thus reducing the fishing pressure on these stocks. Unfortunately, this option has not been tested up to now; considering the limited time dedicated to the pilot action due to the COVID-19 pandemic and some delays in the project development, fishery operators were not able to test the forecasts produced by the ICT

system. However, during the last months of the project implementations, all the partners and fishery operators involved in ITACA signed a Memorandum of Understanding (MoU) for continuing some project activities for at least the next three years. The utilization of the web application, as well as the possibility to extend the use of this platform to other fishery operators are included in this follow-up.

Also, a comparison between the pressures made by fisheries on Adriatic small pelagic stocks in absence of any mechanism of fishing management (ex-ante status) and the reduction of human impacts thanks to the co-management of resources oriented by the utilisation of model's provisions coming from ITACA webapp has not been properly developed. Since the predictions have not been tested, also the influence of this model on the management of the small pelagic species could not be examined. However, the data collected within the ITACA project mainly depicts seasonal dynamics both for catches and for revenues of the small pelagic species, also influenced by the harbours' location: ports situated in the North Adriatic Sea show a preference for sardine. The influence of Croatia and Apulia region was not properly analysed since very few data has been collected for these locations. However, European data shows the importance of Croatian sardine landings in the Adriatic basin (GFCM, 2021), thus the dynamics of this country cannot be neglected. On the contrary, small pelagic landings from Apulia region slightly affect the market dynamics of these species in the Adriatic basin; this is also shown in the Italian national statistics, in which anchovy and sardine from GSA 18 (South Adriatic Sea) represent respectively ~30% and ~3% of the Italian small pelagic total landings coming from the Adriatic Sea, whereas revenues for GSA 18 represents, both for anchovy and sardine, ~1% of the Italian small pelagic total income from the Adriatic Sea (DCF, 2021).

Considering the stock assessments produced annually, the status of these stocks appears in a quite stable situation: in the last five years, anchovy and sardine stocks result overexploited and in overexploitation, i.e. the biomass is below the reference points and the fishing pressure is above the reference value (see Section 2). The management actions put in place in the last years do not seem to have strongly enhanced the situation of these stocks; however, the last stock assessments have reported an improving situation for the biomass of anchovy, whereas sardine biomass is still in an alarming status (GFCM, 2022). However, the stock assessment of sardine will be deeply investigated in the next meetings, since uncertainties in input data have produced difficulties in the setting of the stock assessment model (GFCM, 2022).

Notwithstanding these aspects, the ITACA project and its ICT system have paved the ground for promising improvements, with a potential number of benefits in the next future. For the very first time, the ITACA project have been able to create a network of fishery operators from Italy and Croatia sharing their experiences on the small pelagic sector. Moreover, the ICT system is one of the first tools available for storing and sharing data, with further possibilities of developing common commercial management strategies. This point will be a key aspect for the future management of small pelagic species in the Adriatic Sea, as also underlined by all the partners and fishery operators adopting the MoU. Fishery operators have also expressed the intention of taking advantage of this consortium for participating to future cross-border cooperation projects and joint initiatives in the field of economic and environmental sustainability of small pelagic fishing in the Adriatic Sea.

Therefore, the ITACA project and the tools developed within this project represent promising opportunities to face the future management of the small pelagic stocks not only in the Adriatic Sea but also in similar complex contexts where climate changes are influencing biological and fishing dynamics urging the management of fishery resources to take into account a wider number of variables, e.g. environmental aspects, socio-economic elements.

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Recommendation GFCM/37/2013/1 on a multiannual management plan for fisheries exploiting small pelagic stocks in geographical subarea 17 (northern Adriatic Sea) and on transitional conservation measures for fisheries exploiting small pelagic stocks in geographical subarea 18 (southern Adriatic Sea)

Recommendation GFCM/38/2014/1 on precautionary and emergency measures for 2015 on small pelagic stocks in geographical subarea 17 and amending Recommendation GFCM/37/2013/1

Recommendation GFCM/39/2015/1 establishing further precautionary and emergency measures in 2016 for small pelagic stocks in the Adriatic Sea (geographical subareas 17 and 18)

Recommendation GFCM/40/2016/3 establishing further emergency measures in 2017 and 2018 for small pelagic stocks in the Adriatic Sea (geographical subareas 17 and 18)

Recommendation GFCM/42/2018/8 on further emergency measures in 2019-2021 for small pelagic stocks in the Adriatic Sea (geographical subareas 17 and 18)

Recommendation GFCM/44/2021/20 on a multiannual management plan for the sustainable exploitation of small pelagic stocks in the Adriatic Sea (geographical subareas 17 and 18)