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Lockdown: How the COVID-19 Pandemic Affected the Fishing Activities in the Adriatic Sea (Central Mediterranean Sea)

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The coronavirus disease 2019 (COVID-19) has brought a global socio-economic crisis to almost all sectors including the fishery. To limit the infection, governments adopted several containment measures. In Italy, Croatia, and Slovenia, a lockdown period was imposed from March to May 2020, during which many activities, including restaurants had to close or limit their business. All of this caused a strong reduction in seafood requests and consequently, a decrease in fishing activities. The aim of this study is to investigate the effects of the COVID-19 in the Northern and Central Adriatic fleet, by comparing the fishing activities in three periods (before, during, and after the lockdown) of 2019 and 2020. The use of the Automatic Identification System (AIS) data allowed us to highlight the redistribution of the fishing grounds of the trawlers, mainly located near the coasts during the 2020 lockdown period, as well as a reduction of about 50% of fishing effort. This reduction resulted higher for the Chioggia trawlers (−80%) and, in terms of fishing effort decrease, the large bottom otter trawl was the fishing segment mainly affected by the COVID-19 event. Moreover, by analysing the landings of the Chioggia fleet and the Venice lagoon fleets, it was possible to point out a strong reduction both in landings and profits ranging from −30%, for the small-scale fishery operating at sea, to −85%, for the small bottom otter trawl.

Keywords: pandemic, fishing activities, trawling, small-scale fishery, AIS data, Northern and Central Adriatic Sea, Mediterranean Sea

INTRODUCTION

The coronavirus disease 2019 (COVID-19) emerged in China in December 2019 (Wang et al., 2020). On January 30, 2020 the World Health Organization (WHO) declared the outbreak of COVID-19 a Public Health Emergency of International Concern (PHEIC), and on March 11, 2020 announced the global pandemic[1]. COVID-19 caused a huge number of severe infections and deaths all over the world and, up to now, it is still claiming victims. The other side of the coin was a global socio-economic crisis in almost all the sectors including fishery (Ahmad et al., 2020; Depellegrin et al., 2020; FAO, 2020; Fernandes, 2020; Laing, 2020). To limit

[1]https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen.

the infection, the European governments, among the first, adopted several containment measures. In Italy, a lockdown period was imposed from March 11, 2020 until May 17, 2020 (GU, 2020a,b), during which people had to stay at home, leaving the house only for necessary reasons, and many business activities, including restaurants had to close or limit their activities. In almost the same period Croatia (Jakovljević et al., 2020) and Slovenia (Dentes De Carvalho Gaspar et al., 2020) also adopted similar measures.

During the lockdown period, many people lost their jobs or were put in layoffs causing a general rethinking of food consumption, for instance with a strong reduction of the more expensive food, such as some kind of seafood (ILO, 2021). Consumers used to prefer not only cheaper products but also long-life ones (FAO, 2020). Indeed, the suggestion to limit the movement only for necessary activities as well as the fear of this not well-known and dangerous virus has made people to reduce shopping. Another issue was related to the travel ban to and from foreign countries, which caused a block of seafood exportation and total closure of the tourism sector (Dentes De Carvalho Gaspar et al., 2020). Moreover, to reduce the economic losses of the fishery sectors, the government has funded daily allowance for the fishers who did not work at all, and clearly, this opportunity made many fishers to stop their activities (Dentes De Carvalho Gaspar et al., 2020). All of this affected the fishery sector, and a strong reduction in seafood requests caused a decrease in the fishing activities and consequently also the related ones, such as fish markets and harbours. This was a worldwide situation, affecting countries, regions, and fishing segments in different ways (Dentes De Carvalho Gaspar et al., 2020; White et al., 2021).

The Northern and Central Adriatic Sea (GSA17), enclosed among Italy, Croatia, and Slovenia, is well-known to be an intensively exploited basin (Barausse et al., 2009; Pranovi et al., 2015; Fortibuoni et al., 2017; Russo et al., 2020) where a powerful fleet, composed of small-scale and industrial vessels, operates. For these reasons, this area and fleet represent an interesting case study to assess the COVID-19 effects on the fishery sector.

The importance to use vessel tracking tools, such as the Automatic Identification System (AIS), in the scientific field to monitor and assess the fishing activities, was already pointed out in previous works (e.g., Natale et al., 2015; de Souza et al., 2016; Vespe et al., 2016; Ferrà et al., 2018; Russo et al., 2020). The AIS system, introduced by the International Maritime Organisation (IMO) and designed for security purposes (e.g., navigational aid to avoid vessel collisions), provides vessel positions with high temporal frequency (from 2 seconds to few minutes) and information such as length overall (LOA), speed, and vessel name. Since the coverage of the AIS signals in the Adriatic Sea is very high (Russo et al., 2020), the use of AIS data for the assessment of the fishing activities and behaviours of fishers during this unexpected period turned out to be very useful.

The aim of this study was to assess the effects of the pandemic on the Adriatic fleet by comparing the fishing activities of 2019 and 2020, on a basis of different factors such as fishing effort, landings, and profits, as well as considering the before, during, and after lockdown periods. A focus on the Italian Northern Adriatic Sea was performed, and the fishing activities of the Chioggia fleet, considering both industrial and small-scale fisheries, as well as of the artisanal fleet operating in the Venice lagoon have been investigated.

MATERIALS AND METHODS

Study Area and Fishing Fleets

The main study area was the Northern and Central Adriatic Sea (FAO Major Fishing Area 37.2.1; FAO Geographical Sub-Area [GSA] 17), located in the Central Mediterranean Sea. Moreover, a focus on the fishing grounds of the Chioggia trawlers and the Venice lagoon was also performed (**Figure 1**).

For its high level of productivity, mainly due to the presence of river estuaries, the Northern and Central Adriatic Sea (GSA17) is recognised to be intensively exploited by multi-gear and multi-specific fisheries (Barausse et al., 2009; Pranovi et al., 2015; Fortibuoni et al., 2017; Russo et al., 2020).

The GSA17 fleet is composed of industrial and small-scale fishing segments, flying the flag of Italy, Croatia, and Slovenia. The industrial one can be classified in demersal gears, that are bottom otter trawls (OTB, classified in large [LOTB, LOA >18 m] and small [SOTB, LOA <18 m]) and *rapido* trawl (RAP), a kind of beam trawl typical of the Italian Adriatic fleet and characterised by a serrated rigid mouth used to catch mainly flatfish and pectinids (Pranovi et al., 2015), and pelagic gears, which are midwater pair trawl (PTM, typical of the Italian fleet and called also *volante*) and purse seines (PS). The Small-Scale Fishery (SSF) is characterised by fishing vessels with an LOA under 12 m and limited tonnage (Lleonart and Maynou, 2003) that use passive gears, namely as gillnets, longlines, and traps. The use of the different gears, targeting both demersal and pelagic species, is strongly dependent on the season (Lucchetti et al., 2020).

GSA17

To assess the fishing activities in the GSA17 more than 450 trawlers (SOTB, LOTB, RAP, and PTM), composed of Italian (∼91%), Croatian (∼8%), and Slovenian (∼1%) vessels were considered.

Chioggia

The Chioggia port is located on the Italian side of the Northern Adriatic Sea and specifically in the southern part of the Venice lagoon. Chioggia hosts one of the biggest Italian fishing fleets and one of the most important fish markets in the Adriatic Sea. The investigated fleet was composed of trawlers and SSF.

Venice Lagoon

The Venice lagoon, a wide transitional system of about 550 km^2, is the largest in the Mediterranean Sea (Libralato et al., 2004; Facca et al., 2011). It hosts an artisanal fishing activity, with a long tradition, which mainly uses traps, gillnets, and fyke nets for targeting molluscs, crustaceans, and fishes, belonging to both resident and migratory species (Granzotto et al., 2001).

Dataset

Different datasets, depending on the analysed fishing segments, were used for the analysis of the fishing activities.

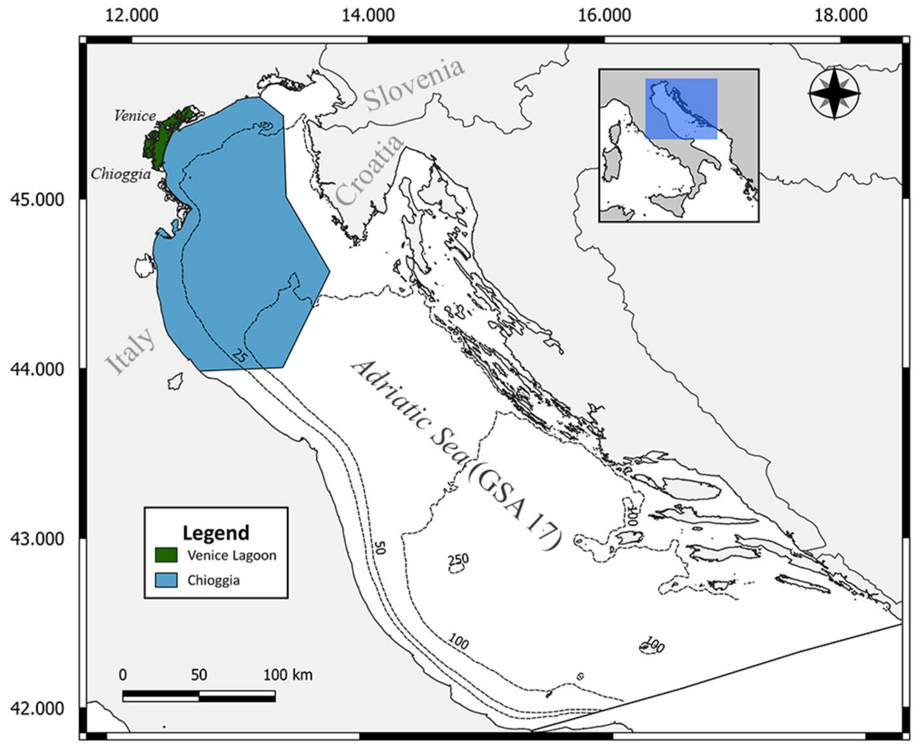

FIGURE 1 | Map of the investigated areas. The two-coloured polygons represent the fishing grounds of Chioggia (light blue) and Venice (green).

Automatic Identification System Data in the GSA17

The terrestrial Automatic Information System (AIS) raw data of the first semester 2019 and 2020 were provided by the Italian Coast Guard (ITC and Traffic Monitoring Department—Rome) and consist of about 72 and 56 million positions released respectively in the first semester 2019 and 2020 by Italian, Croatian and Slovenian vessels. These data supply several information essential for the analysis and the spatialisation of the fishing activities. Dynamic information (e.g., ship positions, time, and speed) were used to discriminate the vessels activities (fishing, navigation, departure, or return in port) and reconstruct the trajectories, while static ones [i.e., Maritime Mobile Service Identity (MMSI), name of the ship and the International Radio Call Sign (IRCS)] were used for the identification of vessels. Technical information (e.g., LOA, primary gear, and secondary gear) was obtained from the European Fishing Fleet's Register[2]. Since, up today, the AIS system is mandatory for fishing vessels with a LOA over 15 m, the AIS data were used to investigate only the fishing activities of trawlers. In particular, they were used to estimate and spatialise the Fishing Effort (FE), that is a percentage of swept area (Russo et al., 2020), and extract the fishing days and the number of active vessels.

[2]https://webgate.ec.europa.eu/fleet-europa/index_en.

Landings of Chioggia

Daily landings data were collected from the Chioggia Fish Market[3] and were referred to 83 target species caught by 73 trawlers and SSF. Furthermore, the monthly market price (euro/kg)[4] of each species was associated with the landing data to estimate the profit of the whole fleet of Chioggia.

Landings of the Venice Lagoon

Monthly data reported by statistics from the main fishers' association in the Venice lagoon, namely landings, fishing days, number of vessels, and profit were used to analyze the SSF in the lagoon.

Data Analysis

The AIS data were processed by using PostgreSQL[5], an open-source object-relational database, and its spatial extension PostGIS[6]. The analysis of the AIS data, relative to the trawling fleet of the GSA17, was performed following the procedure reported in Russo et al. (2020). Briefly, the dataset was cleaned by removing duplicate records and erroneous positions. Then, the trajectories of each fishing vessel were reconstructed by linearly interpolating the AIS data from the departure to the return port. A trajectory was therefore defined as a sequence of segments,

[3]www.clodia.it.
[4]http://www.sstchioggia.it/.
[5]http://www.postgresql.org.
[6]http://postgis.net.

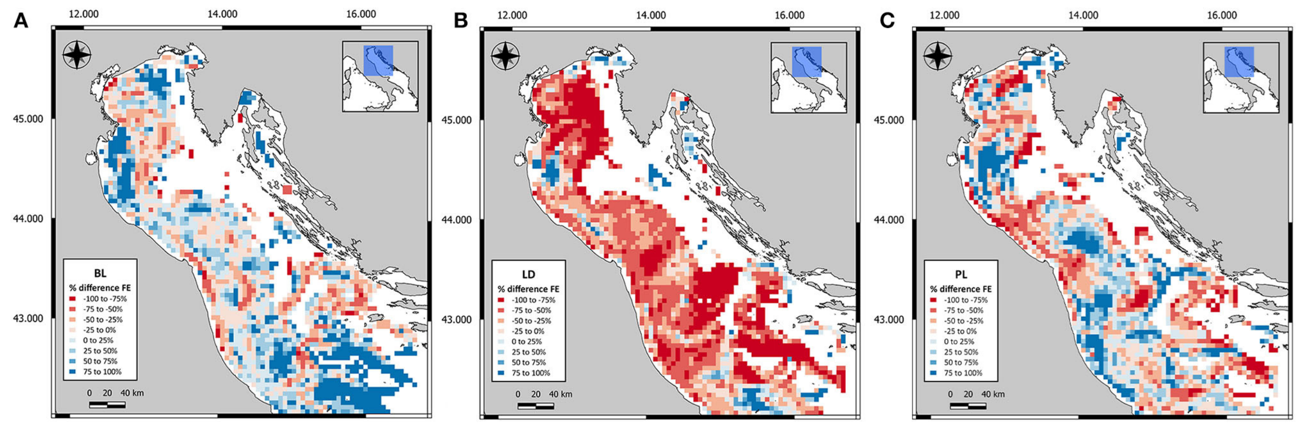

FIGURE 2 | Difference in terms of fishing effort distribution (%) between 2019 and 2020 for the trawling fleet of the GSA17, during the three periods [BL: before lockdown **(A)**, LD: lockdown **(B)**, and PL: post-lockdown **(C)**].

and each segment was associated with an activity performed by the vessel. We distinguished five activities: *in port*, *exiting from port*, *entering to port*, *fishing*, and *navigation*. The *in port*, *exiting from port,* and *entering to port* situations were deduced from the position of the extremes of the segment with respect to the port area. In case none of the previous situations occurred, the *fishing* or *navigation* activities were established based on the specific fishing speed range, previously defined for each fishing gear. To compute the fishing effort, the area under study was partitioned into a square grid of 1 km x 1 km cell size. The fishing effort for a cell during a fixed period of time was defined as the ratio between the area of the cell "swept" by vessels while fishing during the given time period and the total area of the cell itself. The swept area for a vessel in a cell was estimated as the product of the length of the fishing portion of the trajectory inside the cell, and the width of the net, fixed at 20 m for each gear. For computational reasons, the data for cells of 1 km × 1 km, pre-computed and stored in a data warehouse, were aggregated to 5 km × 5 km to compare the fishing effort between 2019 and 2020.

To assess the fishing activities before, during, and after the lockdown, three periods (Before Lockdown [BL]: from January 1th to March 10th; Lockdown [LD]: from March 11th to May 16th; Post-Lockdown [PL]: from May 7th to June 30th) were selected for the 2 years. The fishing effort, the number of active vessels, and the fishing days were extrapolated for each period.

The fishing segments of the trajectories of each trawler of Chioggia were annotated with the corresponding landings. Specifically, the daily landing data of the Chioggia fish market were associated with a trajectory of the vessel having the specified MMSI code. To accomplish this task, for each landing, we selected the vessel trip with the most recent arrival in the port (before 4 p.m. of the landing date). Arrivals after 4 p.m. were associated with the landing of the next day. The quantity of landings of each vessel was uniformly distributed along the corresponding fishing segments. Hence, for each trip, the quantity of landings associated with the fishing segment was proportional to the length of the segment itself (Adibi et al., 2020; Russo, 2020). As for the fishing effort, we summed up the landings according to the regular grid of 1 km × 1 km cell size. Also for the comparison of the landing, the cells of 1 km × 1 km were aggregated to 5 km × 5 km.

The spatialised fishing effort of the whole trawling fleet, and the landings of the Chioggia trawling fleet, relative to the three selected periods, were used for the comparison between 2019 and 2020. The percentage differences between the 2 years were calculated for each cell and mapped by using the open-source Geographic Information System QGIS[7]. Three maps, one for each period (BL, LD, and PL), were produced both for fishing effort (GSA17) and landings (Chioggia).

The percentage difference of the number of active vessels and the days at sea was calculated for all the fishing fleets (i.e., trawlers and SSF), while the percentage difference of the profits was calculated only for vessels from Chioggia and from the Venice lagoon, according to the following equation:

$$\%\ difference = \frac{2020\ value - 2019\ value}{2019\ value}\ x\ 100$$

Statistical Analysis

To test the significance of the obtained results, a statistical analysis was performed. First, data were tested for normality by using the Shapiro-Wilk W test. Even if the data resulted not normally distributed and considering that the robustness of a statistical test is influenced by the size of the data (Blair and Higgins, 1980; Ghasemi and Zahediasl, 2012), the two-sample Student's t-test was used, being the datasets formed by more than 300 values, for the landings, and more than 1,500 values for the fishing effort. The two tests were used for comparing the spatialised fishing activities, in terms of fishing effort and landings, recorded in 2019 and 2020. All analyses have been performed by using the free software R [8].

[7]https://www.qgis.org/en/site/.
[8]www.r-project.org.

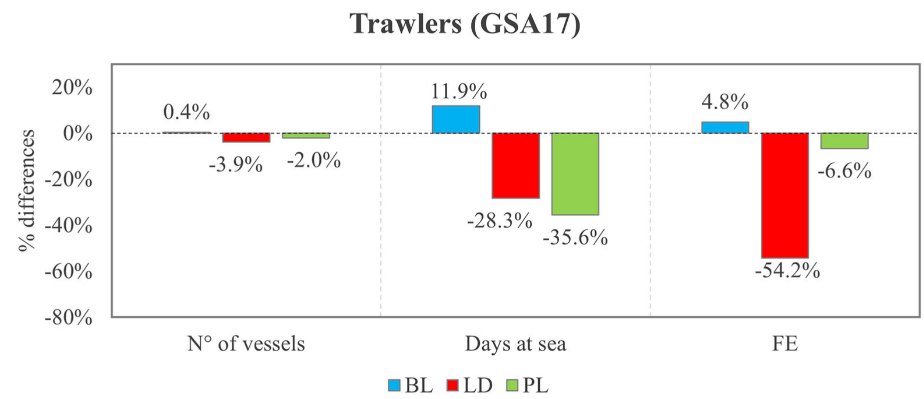

FIGURE 3 | Percentage differences between 2019 and 2020 during the three periods (BL: before lockdown, LD: lockdown, and PL: post-lockdown) considering the number of vessels, the days at sea and the fishing effort (FE) of the GSA17 trawling fleet.

RESULTS

GSA17

Figure 2 shows the high-resolution maps (5 km × 5 km) of the Fishing Effort (FE) differences, expressed as a percentage on the annual basis, between 2019 and 2020, estimated for the periods before, during, and post lockdown (BL, LD, and PL, respectively).

In BL, the fishing activities distribution showed no significant variations, with a small increase of the FE (4.8%) in 2020, and a good overlapping of the exploited fishing grounds (**Figure 2A**). On the contrary, during the LD a reduction of more than 50% of the FE has been recorded (see also **Figure 3**), with a fishing grounds spatial distribution completely different (**Figure 2B**). Specifically, in 2020 the northernmost area, that is the fishing ground of the Chioggia fleet, as well as the central area and the Croatia fishing grounds, in the central-southeast area, resulted totally not exploited (red cells). On the contrary, small areas (blue cells), mainly located near the coasts, resulted exploited only in 2020. Finally, in PL the FE resulted quite similar in the two years (−6.6% in 2020; see also **Figure 3**) but in this case, some differences were highlighted in the fishing grounds distribution (**Figure 2C**). All this was confirmed by the statistical analysis showing no significant differences in terms of FE, between 2019 and 2020, for the BL and PL periods (t-test, p-value: BL=0.3313 and PL = 0.5249), while a statistically significant difference resulted in the comparison during the LD (t-test, p-value: LD = <2.2e − 16).

A reduction of −28% and −36% of the number of days at sea was recorded in 2020 in LD and PL, respectively, while it was positive (12%) in BL (**Figure 3**). On the contrary, no clear differences were observed in the number of active vessels.

The analysis at the fishing gear level confirmed the general pattern recorded for the whole trawling fleet, with the main reductions in terms of days at sea and fishing effort recorded in LD (**Table 1**). The *rapido* trawl (RAP) was the segment most affected in LD, with a reduction of about −10% of active vessels, −61% days at sea, and −67% of FE (**Table 1**). In PL, a recovery of the fishing activities was recorded for all the segments, and a positive trend was observed for the number of active vessels of LOTB (2%) and the days at sea of PTM (6%) (**Table 1**).

TABLE 1 | Percentage differences disaggregated per fishing gears (LOTB, SOTB, RAP, and PTM), between 2019 and 2020 during the three periods (BL: before lockdown, LD: lockdown, and PL: post-lockdown) considering the number of vessels, the days at sea, and the fishing effort (FE).

N° of Vessels	**BL**	**LD**	**PL**
LOTB	3%	-3%	2%
SOTB	-1%	-5%	-10%
RAP	-7%	-10%	-3%
PTM	1%	-1%	-2%
Days at Sea	**BL**	**LD**	**PL**
LOTB	5%	-46%	0%
SOTB	7%	-43%	-7%
RAP	-8%	-61%	-17%
PTM	-1%	-47%	6%
Fishing Effort	**BL**	**LD**	**PL**
LOTB	8%	-52%	-6%
SOTB	13%	-49%	-13%
RAP	-3%	-67%	-17%
PTM	-2%	-49%	-8%

Chioggia Trawling Fleet

The focus on the Chioggia trawling fleet highlighted a general negative balance for all the variables and for all the three periods (**Figure 4**). In the 2020 BL, during which there was a small reduction of the number of active trawlers (−7%), the main decrease was recorded for profits (−20%), even if in the presence of a small increase of the days at sea (4%). During the LD, the number of active vessels was reduced by −22%, and a strong decrease of all the indicators was observed (fishing effort −80%, profits −73%, and landing −48%). Then, as observed also for the whole GSA17 trawling fleet, a partial recovery of the fishing activities was observed after the lockdown (PL).

The comparison between the 2019 and 2020, in terms of the spatial distribution of landings, expressed as percentage

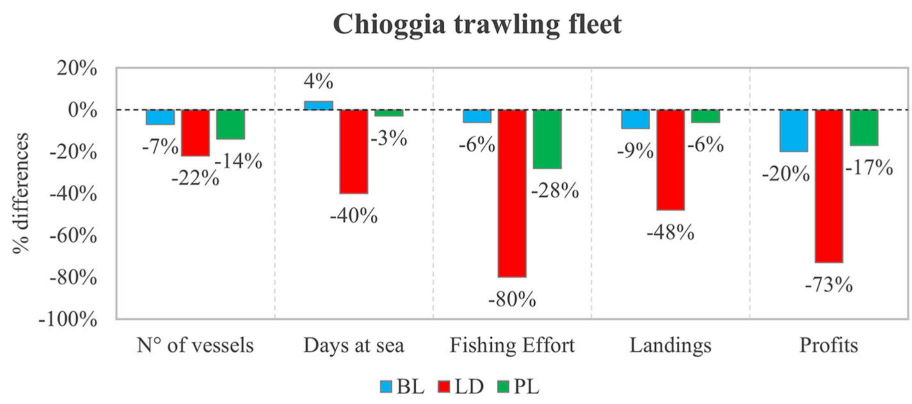

FIGURE 4 | Percentage differences between 2019 and 2020 during the three periods (BL: before lockdown, LD: lockdown, and PL: post-lockdown) considering the number of active vessels, the days at sea, the fishing effort (FE), landings, and profits of the Chioggia trawling fleet.

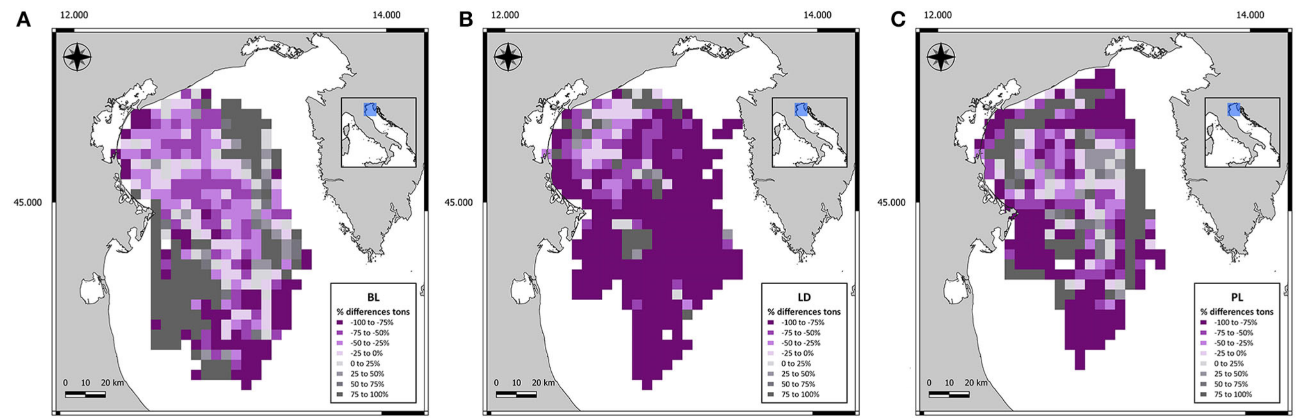

FIGURE 5 | Comparison of the quantity of landings recorded in 2019 and 2020 (expressed as percentage) during the three periods [BL: before lockdown **(A)**, LD: lockdown **(B)**, and PL: post-lockdown **(C)**].

difference of tonnes, showed significant differences in the LD ($p = <2.2e{-}16$), with only a small portion of the area, close to the Veneto coast, where the landings distribution resulted similar in the 2 years (**Figure 5B**). On the contrary, in BL and PL, the spatial distribution of the landings resulted similar (**Figures 5A,C**), and no significant differences were observed (BL $p = 0.411$ and PL $p = 0.840$).

Figure 6 shows FE, landings, and profits of Chioggia fleet disaggregated per fishing segments (LOTB, SOTB, RAP, and PTM). In BL, the fishing effort recorded in 2019 and 2020 was quite similar (**Figure 6A**), with the major difference recorded for SOTB (−17%). On the contrary, in LD the fishing effort recorded in 2020 was lower compared to 2019, ranging from −66% for PTM to −92% for LOTB. In PL, the fishing activities have started to recover and the reduction of fishing effort was about −30% for LOTB, SOTB, and RAP, while for PTM an increase of 1% was recorded.

Concerning the landings (**Figure 6B**), a general negative trend was observed for each fishing segment in 2020, except the PTM that showed almost no differences in the BL and PL period (5% and −2%, respectively). The major reduction, during all the periods, was observed for SOTB (−84% in LD), while the lower was observed for PTM (−36% in LD). A similar trend was observed for LOTB and RAP, recording a reduction in landings of about −20% in BL and PL and about −70% in LD.

In line with the landings pattern, profits of each fishing gear resulted always negative in 2020 compared with 2019 (**Figure 6C**), and, regardless of the period, SOTB was the segment showing the most negative balance. However, differently from the landing results, also the PTM profits showed negative values in 2020, in all the three periods. Also, in this case, LOTB and RAP showed a similar trend and a reduction in line with the one recorded for the landings.

Small-Scale Fishery

SSF–Chioggia

In 2020, the Small-Scale Fishery (SSF) showed an increase in the fishing activities, in terms of number of vessels (11%), days at sea (81%), landings (48%), and profits (38%), during the BL

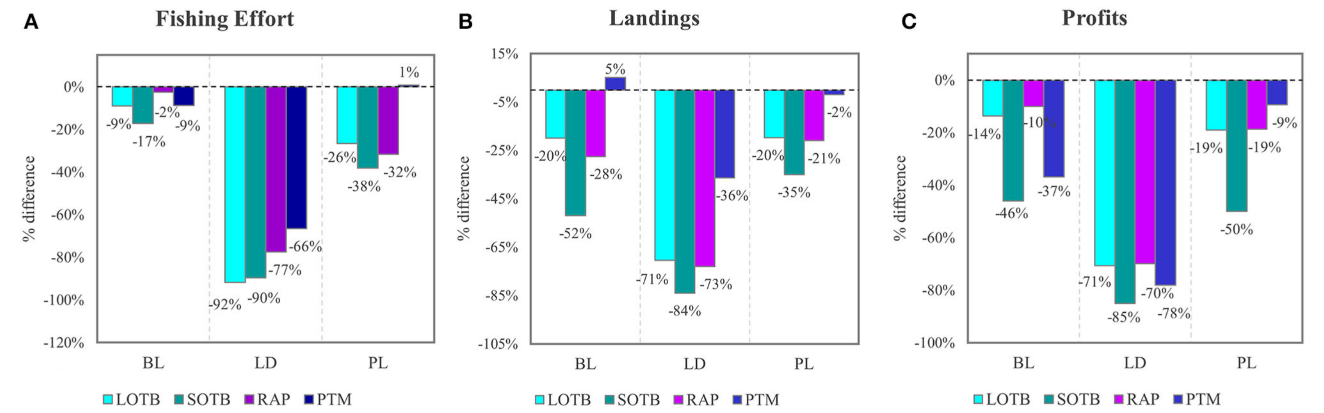

FIGURE 6 | Difference of fishing effort **(A)**, landings **(B)**, and profits **(C)** expressed as percentage (%), considering the three periods (BL: before lockdown, LD: lockdown, and PL: post-lockdown) and disaggregated per fishing segments (LOTB, SOTB, RAP, and PTM).

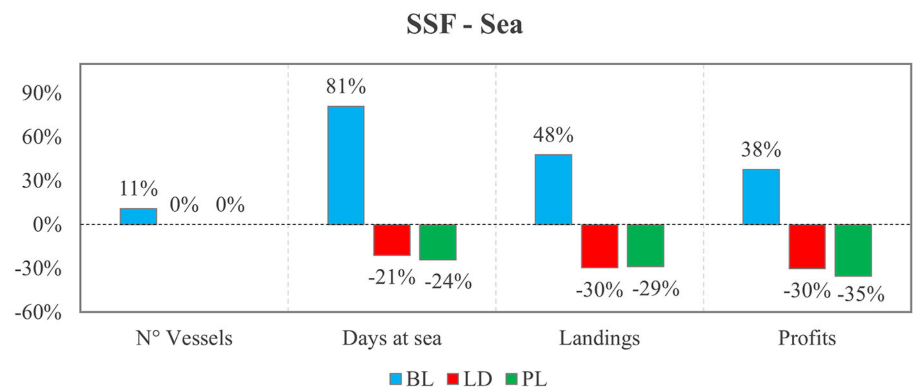

FIGURE 7 | Percentage differences between 2019 and 2020 during the three periods (BL: before lockdown, LD: lockdown, and PL: post-lockdown) considering the number of active vessels, the days at sea, landings, and profits of the Chioggia SSF fleet.

period. Differently, in LD and PL, a negative balance of about −20% for the number of days at sea and about −30% both for landings and profits, was recorded (**Figure 7**). However, while in LD, the same reduction was observed for landings and profits, in PL, the reduction of the latter was higher (PL: landings = −29%; profits = −35%). No difference was observed for the number of vessels.

SSF–Venice Lagoon

The analysis performed on the SSF operating in the Venice lagoon showed a similar pattern to that operating at sea, with positive values recorded in BL and a negative trend both in LD and PL (**Figure 8**). Specifically, the number of vessels showed an increase in the BL period (21%) and a decrease in LD (−6%) and PL (−19%). The number of landings resulted stable in BL (1%) and markedly negative in LD (−59%) and PL (−76%). The same trend was observed for the profits in LD (−57%) and PL (−65%), while a considerable increase was recorded in BL (150%).

DISCUSSIONS

The COVID-19 pandemic emergency was, and still represents, an unpredictable and never experienced condition that deeply changed all our consolidated behaviours, lifestyles, and social processes. It has caused a deep worldwide crisis, in several productive sectors, including the fishery. Even if the COVID-19 does not have direct effects on the fishery activities (FAO, 2020), since there were no restrictions for fishers, it has produced deep and long-lasting impacts on the fishery sector in many different ways. The closure of restaurants, due to the lockdown measures, on one side, and the financial and the economic crisis, combined with the preference to long-life foods by a large part of the population to reduce movements as much as possible, determined a strong decline of seafood requests. Both wholesale and retail fish markets remained unused and totally deserted for about 2 months.

In response to the demand decrease, the fishing activities strongly declined, with the reduction of the fishing effort, landings, and profits. The assessment of all these effects represents the first step for understanding a completely unknown

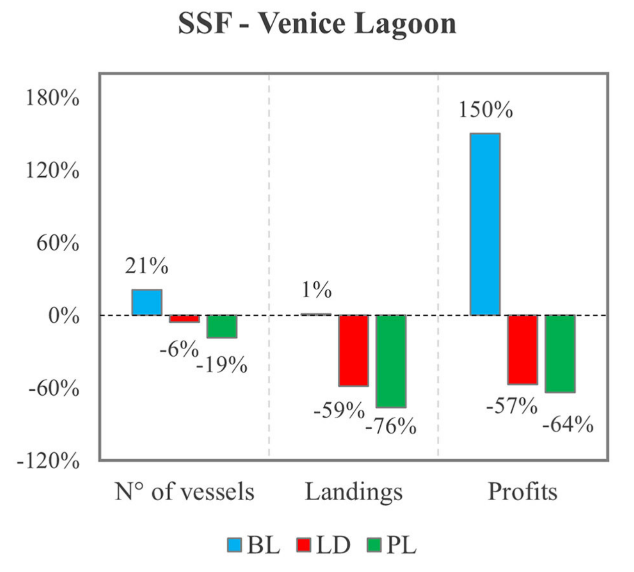

FIGURE 8 | Percentage differences between 2019 and 2020 during the three periods (BL: before lockdown, LD: lockdown, and PL: post-lockdown) considering the number of active vessels, landings, and profits of the Venice lagoon SSF fleet.

phenomenon, possibly identifying vulnerabilities and new strategies to cope with it.

In this study, the effects of the lockdown put in place by the national governments of the three countries overlooking the GSA17 (namely Italy, Slovenia, and Croatia) have been assessed by investigating different fishing segments, belonging to both industrial and artisanal fisheries, considering the period before, during, and post lockdown.

Generally, the before lockdown period analysis showed a slight increase of the trawling activities at the GSA17 level in 2020, reflecting in a higher number of active vessels, days at sea, and, more in general, of the fishing effort. Moreover, the high-resolution maps of the difference of the fishing effort between 2019 and 2020 highlighted a similar distribution of the fishing grounds in the period before the lockdown, confirming the already pointed out non-random behaviour of the fishers in the Northern and Central Adriatic Sea (Russo et al., 2020). Even the analysis of the data disaggregated per fishing gears highlighted the increase of the fishing activities for all the trawling segments, with the exclusion of the *rapido* trawl. On the contrary, data from the Chioggia port underlined, for all the fishing segments, a slight decrease of the fishing effort, with the SOTB showing a larger reduction (−17%). Moreover, a higher decrease, in terms of both landings and profits, has been detected, and in particular for SOTB, a reduction of about −52% of landings and −46% of profits was observed. This reduction was not totally explainable with the fishing effort reduction, suggesting the influence of other factors, such as the overexploitation of the resources, as suggested also by Russo et al. (2020), or a different spatial distribution of the target species area, may be related to environmental factors.

On the contrary, the small-scale fishery, operating both at sea, near Chioggia, and in the Venice lagoon, in the first period of 2020, showed a positive balance both in terms of landings and profits, in comparison with 2019. All of this could be related to a different spatial distribution of the target species and/or to higher prices due to the scarcity of the landings by trawling.

The situation completely changed in March, with the lockdown measures put in place by all the GSA17 countries. The fishing activities dramatically decreased (Depellegrin et al., 2020; Veneto Agricoltura, 2020), and the fishing effort of trawling vessels collapsed, on average, of about −50%, with a redistribution of the fishing grounds, being in 2020 mainly located near the coasts and in the proximity of the origin harbours. This behaviour could be due to the possibility to reduce time at sea, limiting the fuel consumption and the related costs. The reduction of the fishing activities was higher for the Chioggia trawling fleet, for which, as reported also by Depellegrin et al. (2020), a reduction of about 80% of fishing effort was recorded. The contraction of the fishing activities directly affected both landings (−48%) and profits (−73%). However, the fishing segments reacted in a different way to the lockdown, being the SOTB the most impacted in both landings and profits, whereas the PTM showed the lowest reduction, at least in terms of landings. Indeed, as reported also by STECF (2020), this fishing segment during the first period of the lockdown has suffered due to the fish market closure and the impossibility to export the product to foreign countries. But in April, the demand for small pelagic fishes, targeted by this gear, suddenly raised accompanied by a sharp decrease in the market price, producing a negative balance in profits (−78%).

Less critical was the situation of the small-scale fishery (SSF) operating at sea, recording a decrease of about 30% in landings and profits, probably because usually fishers of SSF used to sell seafood directly to consumers or local fish markets (STECF, 2020). For the SSF operating in the Venice lagoon, the reduction in landings reached 60%, which may be related to the fact that those fishers used to sell in the wholesale market (the same issue of the trawlers) and to the restaurants deeply affected by the crushing of tourism-related activities in Venice. Possible ecological effects of this could be assessed on a wider temporal scale. A good portion of the species targeted by SSF in the lagoon belongs to the marine migrant functional group, exploiting nursery habitats as juveniles, for trophic purposes, or during migrations between marine and freshwater habitats (Franzoi et al., 2010; Scapin et al., 2019), and so possible positive effects could be visible in the following seasons outside the lagoon environment itself.

The analysis of the fishery activities during the period immediately after the lockdown, from May 17th to June 30th offers the opportunity to analyse the recovery capability of each fishing segment, since in this period fish markets and restaurants gradually resumed their business.

The trawl fishery operating in the GSA17 showed a quick upturn, at least in terms of fishing effort, reflecting in a partial recovery of both landings and profits, even if the 2020/2019 comparison remained negative, for the Chioggia fleets. The small-scale fishery was revealed to be less resilient, and for this more vulnerable, with no recovery at all in the case of the lagoon activities, mostly related to the fact that the tourism in Venice showed no recovery in that period.

It is worth noting that even if the main differences highlighted in this study were related to the lockdown measures, however, other factors, both environmental and managerial, could also have contributed to this situation. Indeed, as highlighted for Chioggia, a reduction in fishing activities was also observed during the period before the lockdown, and therefore not related to the pandemic.

From an environmental perspective, the positive side of the lockdown was the reduction of the fishing pressure to the marine ecosystem, as 45% of the Northern and Central Adriatic Sea was intensively exploited (Russo et al., 2020). For instance, in the JRC report (Dentes De Carvalho Gaspar et al., 2020), it was highlighted how the Slovenia fishery has benefited from the reduction of the Italian and Croatian fishing activities. Indeed, an increase in the quantity of Slovenian landings in the period March–May 2020 was observed, as well as a rise in the seafood price, due to the possibility to sell seafood directly to customers. However, even if the near-term effects of the lockdown on the marine environment could be positive, there is an uncertainty of the long-term ones (Coll, 2020).

Further analyses would be required, monitoring both the stocks and the landings, for highlighting possible positive effects, for instance in terms of enhanced recruitment, due to increased reproductive outputs.

CONCLUSIONS

In conclusion, this study analysed how an external factor, that is the COVID-19 pandemic, affected fishery in the Adriatic Sea, a very important sector that is at the base of several socio-economic businesses, and therefore needs to be well-managed to guarantee an effective support for fishers and also to protect the marine ecosystem. In this study, SSF was detected as the most vulnerable fishing sector, in relation to the short-term socio-economic effects induced by the lockdown. For instance, a modification of the fishing behaviour during the lockdown was detected, providing valuable evidence about the social aspects of this sector. Moreover, the possibility to use AIS data, coupled with landing data, provided essential information about the effects on the species caught and the relative revenues. However, future studies should also consider the long-term effects of the pandemic situation, which is still ongoing, both in terms of fish stock recovery and fishing sector decline.

The pandemic effects on the fishery have underlined the importance of the fish market and of the preferences of customers to determine the exploitation choices. Of course, this highlighted the need to act in different directions and levels to implement new fishing management strategies to reach a more sustainable fishery.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not available because the raw AIS data are protected by confidentiality.

AUTHOR CONTRIBUTIONS

FP and ER have developed the initial idea. ER and GT collected the data. ER and CS performed the analyses. ER, FP, and MAM interpreted the results. ER, FP, and AR wrote the first draft of the manuscript. All the authors have contributed to the manuscript revision and have read and approved the submitted version.

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