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First Assessment of the Impacts of the COVID-19 Pandemic on Global Marine Recreational Fisheries

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This work is the result of an international research effort to determine the main impacts of the COVID-19 pandemic on marine recreational fishing. Changes were assessed on (1) access to fishing, derived from lockdowns and other mobility restrictions; (2) ecosystems, because of alterations in fishing intensity and human presence; (3) the blue economy, derived from alterations in the investments and expenses of the fishers; and (4) society, in relation to variations in fishers' health and well-being. For this, a consultation with experts from 16 countries was carried out, as well as an international online survey aimed at recreational fishers, that included specific questions designed to capture fishers' heterogeneity in relation to behavior, skills and know-how, and vital involvement. Fishers' participation in the online survey (5,998 recreational fishers in 15 countries) was promoted through a marketing campaign. The sensitivity of the fishers' clustering procedure, based on the captured heterogeneity, was evaluated by SIMPER analysis and by generalized linear models. Results from the expert consultation highlighted a worldwide reduction in marine recreational fishing activity. Lower human-driven pressures are expected to generate some benefits for marine ecosystems. However, experts also identified high negative impacts on the blue economy, as well as on fisher health and well-being because of the loss of recreational fishing opportunities. Most (98%) of the fishers who participated in the online survey were identified as *advanced*, showing a much higher degree of commitment to recreational fishing than *basic* fishers (2%). *Advanced* fishers were, in general, more pessimistic about the impacts of COVID-19, reporting higher reductions in physical activity and fish consumption, as well as poorer quality of night rest, foul mood, and raised more concerns about their health status. Controlled and safe access to marine recreational fisheries during pandemics would provide benefits to the health and well-being of people and reduce negative socioeconomic impacts, especially for vulnerable social groups.

Keywords: fishers' profiles, leisure activities, expert knowledge, fishery surveys, virus outbreak

INTRODUCTION

In late 2019, an outbreak caused by a novel coronavirus started in China (Graham and Baric, 2020; Hu et al., 2020; Maxmen, 2021). A global pandemic was declared in March 2020, as COVID-19, the disease caused by the coronavirus (World Health Organization, 2020b), escalated outside China (World Health Organization, 2020a). In mid-2021, when vaccination campaigns began to show positive effects on the control of the disease in several countries (Kaur and Gupta, 2020), the COVID-19 pandemic caused millions of deaths and hundreds of millions of infections (Dong et al., 2020).

To fight the pandemic, governments reacted with measures designed to contain the spread of the virus, especially through measures aimed to reduce social interactions, including lockdowns (Wilder-Smith and Freedman, 2020), travel restrictions (Chinazzi et al., 2020), and limiting people's access to non-essential activities (Storr et al., 2021). Humanity suffered a notable impact as a result of the pandemic, including losses of jobs and an abrupt disruption in global demand of goods and services (Barua, 2020; McKibbin and Fernando, 2020; Nicola et al., 2020). The pandemic further degraded the quality of life of the most vulnerable people, particularly those with mental health problems (Brooks et al., 2020), victims of domestic violence (Usher et al., 2020), children (Singh et al., 2020), or indigenous populations (Lane, 2020). As a result, an increase in economic inequality and worldwide poverty is expected, especially in developing countries (World Bank, 2020), and a peak in the suicide rate (Kawohl and Nordt, 2020).

On the other hand, global reduction of human activities has had some positive effects on the global environment, especially for air and water quality (Rutz et al., 2020), and noise reduction (Zambrano-Monserrate et al., 2020). Marine ecosystems for example experienced less impacts derived from commercial fishing due to disruptions in large markets such as the United States (White et al., 2021a) or the European Union (Prellezo and Carvahlo, 2020; Coll et al., 2021). In developing countries with large informal sectors, the lockdown and social

distancing measures have especially impacted small-scale fishers and communities (FAO, 2020). Therefore, marine ecosystems are showing positive effects derived from the reduction of human impacts, e.g., in the occurrences of flora and fauna in coastal areas (Soto et al., 2021), or in reef fish abundances (Edward et al., 2021).

Increasing human pressure on global ecosystems is likely to lead to outbreaks of viruses that remained hidden until now, leading to new pandemics in the future (Wilkinson et al., 2018; Schmeller et al., 2020; Platto et al., 2021). It is therefore urgent to know the effects of the current COVID-19 pandemic on the different socio-ecological systems, and especially on those human activities that positively affect the health and well-being of people. The lessons derived from these studies will help policy makers to develop contingency plans and adaptive strategies to deal with similar crises in the future.

In this sense, the COVID-19 pandemic has also had significant effects on people's recreation, with undesired consequences. For instance, access restrictions to outdoor activities practiced in blue areas due to lockdowns in Europe (Belgium, France, Germany, Ireland, Italy, Portugal, Spain, and United Kingdom) and other regions (Australia, New Zealand, and United States) limited protection against the negative effects of the pandemic on people's health and well-being (Astell-Burt and Feng, 2021; Guzman et al., 2021; Pouso et al., 2021). Recreational fishing is one of the most common human activities in the world's blue areas (Cisneros-Montemayor and Sumaila, 2010; Arlinghaus et al., 2014; Hyder et al., 2018), and its practice is beneficial to fishers' health and well-being (Snyder, 2007; Griffiths et al., 2016; Young et al., 2016). Considering that the recreational sector has suffered major socioeconomic impacts during the COVID-19 pandemic (Roy et al., 2021), an assessment of the impacts of the pandemic on marine recreational fisheries was needed.

In this manuscript we assessed the overall impacts of the COVID-19 pandemic on marine recreational fisheries by a consultation with experts involved in marine recreational fisheries in different countries (mainly scientists, managers, and representatives of recreational fishers' organizations). In addition, we developed an international online survey of recreational fishers, with a focus on the perceived intensity of the impacts depending on different groups of fishers. Our hypothesis is that the greater the fishers' involvement in the fishery, the greater the negative perception of the socio-ecological impacts of the COVID-19 pandemic on marine recreational fisheries.

MATERIALS AND METHODS

Study Design

An expert consultation about impacts of COVID-19 on marine recreational fisheries was performed from May 2020 to March 2021. A semi-structured questionnaire was distributed between international experts in marine recreational fisheries (mostly scientists, marine resource and spatial managers, and representatives of recreational fishers' associations) integrated in the Spanish Working Group on Marine Recreational Fisheries (GT PMR), composed by approximately 60 members, and the International Council for the Exploration of the Sea (ICES) Working Group on Recreational Fisheries Surveys (WGRFS), composed by approximately 50 members from Australia, Europe, New Zealand, and North and South America. Semi-structured questionnaires ensure that experts provide information on key topics, and allow them to expand on items that are more relevant to them (Bryman, 2016).

Experts were asked to identify their country of residence and institutional affiliation, and to: (1) report changes in access to marine recreational fishing during the COVID-19 crisis, e.g., because of mandatory or voluntary lockdowns, and to explain any COVID-19-related restriction in place, their duration, and the areas and activities affected; (2) provide their perception on expected changes in marine ecosystems due to the COVID-19 crisis, e.g., resulting from changes in fishing activities or in other human impacts; (3) provide their perception on expected impacts on the economy, e.g., derived from the reduction in expenses and investments of recreational fishers, if any (including tourism); and (4) provide their perception on the expected impacts of lockdowns or new habits due to social distancing on the social life, well-being and public health. Experts were asked to score how certain they were about their perceptions on ecological, economic, and social changes, on a scale from "1," which meant very low confidence, to "5," which meant very high confidence.

In addition, an online survey was conducted between April 2020 and January 2021 to collect perceptions of fishers on the different impacts of COVID-19 on marine recreational fisheries. A self-administrated, structured questionnaire was made available online in seven different languages, i.e., Dutch, English, French, Greek, Italian, Portuguese, and Spanish (English version is available in the **Supplementary Information, Annex I**). The language and layout of the questionnaire and quantitative economic questions were adapted to different socio-cultural contexts and ongoing surveys already in place. Thus, there were different versions for Portugal and Brazil, and for Spain and Spanish-speaking countries of South America. The links to the different questionnaires were disseminated through social media and the web portals of the scientific institutions of coauthors involved in this study following a snowball-style sampling approach (Goodman, 1961), starting with a core group of initial collaborators involved in the GT PMR and the WGRFS, and expanding through their contacts and social networks. A 3-month marketing campaign in Google Ads was also put into force to increase the scope of the survey. A small team of collaborators of the GT PMR and the WGRFS was responsible for the design of the questionnaire, the verification of the consistency of the translation, the collection and storage of the information, and the dissemination of the links among the fishers in each country/region. All questionnaires used in the study were anonymous and no personal information was collected.

Information on the different socio-ecological impacts of the COVID-19 pandemic affecting marine recreational fishing was gathered in section "Introduction" of the questionnaire. To prevent temporal trends in the responses, recall periods were less than 3 months (Pollock et al., 1994). Thus, fishers' perceptions of ecological changes on marine ecosystems derived from variations in recreational and commercial fishing efforts

on fish stocks because of the COVID-19 crisis were obtained first (question 1, **Supplementary Annex I**). Thereafter, social impacts derived from the COVID-19 crisis were assessed by analyzing the perceived degree of satisfaction of night sleep (Bobes et al., 2000) (question 2) and negative affect (question 3), which accounts for the affective state characterized by aversive emotional states driven by stress (Bolger et al., 1989). Also, we obtained information on consumption habits of fish (question 4), fresh fruits, and vegetables (question 5) to assess potential variations in nutritional value of fishers' diets (Öhrvik et al., 2012). Information of changes in employment (question 6), health (question 7), physical activity (question 8), and of expected changes in recreational fishing activity after the pandemic was also obtained (question 9). Finally, we assessed the overall economic impact derived from the loss of running costs during the lockdowns, excluding long-term investments such as annual insurance and licenses costs, or expenditures on boat maintenance and anchoring. We estimated this economic impact as the difference between the regular expenses incurred during the COVID-19 crisis (question 11), and the sum of the average monthly regular expenses incurred before the crisis (question 10), with investments not made because of the pandemic, e.g., during holidays (question 12).

Research on recreational fisheries must pay careful attention to human dimension aspects because recreational fishers exhibit an extraordinary diversity of behaviors and attitudes, which plays a fundamental role in understanding key socio-ecological dynamics, such as fishers' motivations for access (Fedler and Ditton, 1994), or the distribution of effort intensity and catches (Arlinghaus, 2006). Various approaches have been used to measure the heterogeneity of recreational fishers, and how different profiles of fishers show differences regarding preferences for, e.g., site (Salz and Loomis, 2005) or catch (Beardmore et al., 2011). Newcomers and infrequent recreational fishers tend to focus more on catches, while the more committed fishers value the fishing activity as a whole, tend to exhibit conservationist attitudes toward fish stocks, use increasingly sophisticated equipment and techniques, and show a growing dedication to the activity (Scott and Shafer, 2001).

In this study, we identified different profiles of recreational fishers through an assessment of their heterogeneity. Following Scott and Shafer (2001) we focused on three dimensions: (1) behavior, in particular orientation toward catches; (2) skills, i.e., fishing technique and fishers' ecological knowledge (Beaudreau and Levin, 2014); and (3) involvement, in the sense of how central recreational fishing is to their lifestyle in comparison with other activities (Kyle et al., 2007).

Fishers' behavior was assessed in the section "Materials and Methods" of the online questionnaire by asking about selectivity preferences toward target species (questions 2 and 3, **Supplementary Annex I**), the practice of catch and release (C&R) of live fish (question 4), preferences regarding fish and catch size (question 5), and frequency of consumption of the catches (question 6). Self-perceived involvement in the fishery was put into context in relation to the importance of fishing compared to other social activities and work (question 7). We also asked how often the respondents participate in fishing competitions (question 9) because it requires a certain degree of personal commitment. Finally, self-reported skills and fishers' know-how was obtained in question 8. In the analysis we considered anthropometric and socioeconomic variables included in the questionnaire as potential modifiers (section "Results" and **Supplementary Annex I**).

Data Processing and Statistical Analyses

Expert Consultation

Responses of the different consulted experts about changes in fishing access, marine ecosystems, economy, social life, well-being, and health were summarized for each country. Country summaries were updated and reviewed by the same group of experts and discrepancies were discussed until consensus was reached. Thereafter, to obtain overall estimations of impacts on access, ecosystems, economy, and societies, each of the experts' responses was categorized on the same scale (i.e., between "-1," meaning lower, or poorer, and "1," meaning more, or higher, while "0" meant no changes, or opposing trends). Subsequently, the mode of the different values available for countries with more than one expert was used to obtain a single set of observations for each country. Finally, responses were weighted proportionally to respondents' degree of certainty, i.e., the observations with a certainty score of "2" were doubled, the observations scored with "3" were tripled, and so on until the observations scored with "5" were quintupled.

Online Survey to Fishers

Hierarchical cluster analysis was done on the dissimilarity matrix of the fishers' responses to the seven questions designed to capture fishers' heterogeneity by using the *hclust* function of the software R version 4.0.2 (R Core Team, 2019). The Hopkins' statistic (H) was obtained first to assess the clustering tendency of the responses by testing the spatial randomness of the data (Lawson and Jurs, 1990). Silhouette width measure (S) was used to assess the degree of confidence of up to 20 different clustering assignments to select the optimal number of clusters. Finally, we selected "average" as the best linkage method (compared to "complete" and "Ward") by evaluating the different correlation coefficients between the cophenetic distances of the different dendrograms (height of the nodes) and the original distance matrix (Sneath and Sokal, 1973). The rescaled matrix of fishers' responses (with mean 0 and standard deviation 1) was used instead of raw data because it obtained better fits in the above-described metrics.

As a sensitivity analysis for the clustering procedure we assessed the single contribution of the seven questions designed to capture fishers' heterogeneity by a SIMPER procedure (Clarke, 1993), included in the *vegan* library of R (Oksanen et al., 2019), performing pairwise comparisons to estimate the average contributions of each question to the average overall Bray-Curtis dissimilarity. Furthermore, we assessed the contribution of each of the questions to support the identified clusters by generalized linear models (GLMs) in R. Fits of each of the seven questions as predictors of the clusters were obtained from unadjusted models, whereas a backward stepwise selection procedure was followed to fit adjusted models (i.e., from unadjusted to saturated models).

Unadjusted and adjusted GLMs were also used to assess the differences between identified clusters of fishers in relation to different perceived COVID-19 impacts, i.e., changes in fish abundances because of expected variations in recreational and commercial fishing effort; experienced health concerns; reported negative affect; perceived sleep quality; fish consumption habits; healthy food consumption habits (fruits and vegetables); developed physical activity; expected fishing activity after the crisis; economic perception (qualitative); and economic impact (quantitative).

The country of residence of the fishers, along with their anthropometric (age and Body Mass Index, BMI) and socioeconomic variables (gender, marital status, and academic and income levels[1]), were included in the models as potential predictors. Furthermore, the effect of social support was also included (people sharing the household), because it is considered a basic resource for coping with stress, modulating the response to stressors (Sarason et al., 1987).

The fit of different error structures and link functions was assessed in the different model selection procedures. The best models were selected based on the Akaike's information criterion (Akaike, 1973), goodness of fit (R^2), and appropriate residual structure. Models with highly dispersed and anomalous distributions of residuals were discarded.

RESULTS

Global Results of the Expert Consultation

We obtained 48 answers to the semi-structured questionnaires from different experts on marine recreational fisheries distributed in 16 countries of America and Europe (**Figure 1**). Most of the consulted experts were scientists (75% of total), followed by resource and spatial managers (13%), and by representatives of recreational fishers' associations (10%).

The different experts' responses about changes in recreational fishing access, expected ecological status of marine ecosystems, projected economic scenarios, and perceived people's health and well-being are summarized in the following sections ("Argentina" to "Uruguay"). In general, experts acknowledged a decrease in fishers' access to marine recreational fishing during roughly the first year of the COVID-19 pandemic, since the mean score was -0.63 $\pm$ 0.72 (SD) (in a scale between "-1," meaning lower, or poorer, and "1," meaning more, or higher, while "0" meant no changes, or opposing trends, see section "Expert Consultation"). Marine ecosystems are expected to experience limited benefits derived from some reductions of human impacts during the first year of the pandemic, as the mean experts' score was 0.32 $\pm$ 0.47. On the contrary, the economic scenario anticipated by the experts is very poor, with a mean score of -0.66 $\pm$ 0.48. Finally, experts also anticipated relevant impacts on social life, especially on fishers' health and well-being, with a mean score of -0.70 $\pm$ 0.48 (**Figure 2**).

[1]Four levels of monthly net household income were used, the lowest being less than € 1000 for developed countries, and less than € 600 for developing countries, while the highest was more than € 4000, and more than € 2000, respectively.

Country-Specific Results of the Expert Consultation

Argentina

Argentina decreed a strict and mandatory lockdown between late March 2020 (shortly after the first 100 cases of COVID-19 and the first deaths from this disease were verified in the country) and late April 2020. During that period, essential activities continued almost normally, while others, including tourism, recreation, and cultural services, faced an indefinite lockdown (Niembro and Calá, 2020). Thereafter, territorial less-severe measures (i.e., social distancing) were implemented, depending on the local epidemiological development. Some activities, including marine recreational fishing, began to be gradually allowed from mid to late May only for residents of some coastal cities, as mobility continued to be strongly restricted. In the absence of official statistics, consulted experts considered that compliance with social restrictions was high during the lockdowns, while in the following months marine recreational fishing was highly demanded in coastal cities (Aire Libre, 2020; Albanese, 2020).

The consulted expert did not expect relevant changes in marine ecosystems due to the reduction of the recreational fishing effort on the coast of Argentina after the lockdowns mainly because the effective prohibition extended only for a couple of months in most places (late March to late May 2020), and because it did not affect the austral summer season,[2] between January and February, when most tourists travel to coastal cities and practice recreational fishing. It is difficult to anticipate ecological effects derived from the summer season of 2021. In some cases, it seems reasonable to expect some ecological benefits at local level, compared to an average year before COVID-19. For example, the *Fiesta Nacional del Salmón de Mar*, an important annual fishing competition of Chubut (South of Argentina) was canceled due to the pandemic in 2020 and 2021. During this fishing competition, up to 900 individuals of reef fish are caught every year, mainly Argentinian sandperch *Pseudopercis semifasciata*, Patagonian grouper *Acanthistius patachonicus*, and Patagonian redfish *Sebastes oculatus*. Moreover, the overall operational level for commercial fishing and fishing-related activities in Argentina was estimated at approximately 70% of its normal capacity between April and September 2020 (Niembro and Calá, 2020).

In the absence of information on the economic importance of marine recreational fisheries in Argentina it is difficult to assess the economic impacts of the COVID-19 pandemic on this sector. However, suspension of important annual fishing competitions in the Buenos Aires province, with more than 13,000 participants (Dellacasa and Braccini, 2016), or the *Fiesta Nacional del Salmón de Mar*, whose attendees double the local population during the event, are economically relevant. The impact of the poor tourist season of the summer of 2021 on businesses related to recreational fishing could also be important.

Although some studies on the effects of the COVID-19 pandemic into mental health of different sectors have been already carried out in Argentina (e.g., Alomo et al., 2020; Johnson et al., 2020; Rogers et al., 2021), none of those studies

[2]Unless we indicate otherwise, we will refer in a generic sense to the seasons of the boreal hemisphere in the text.

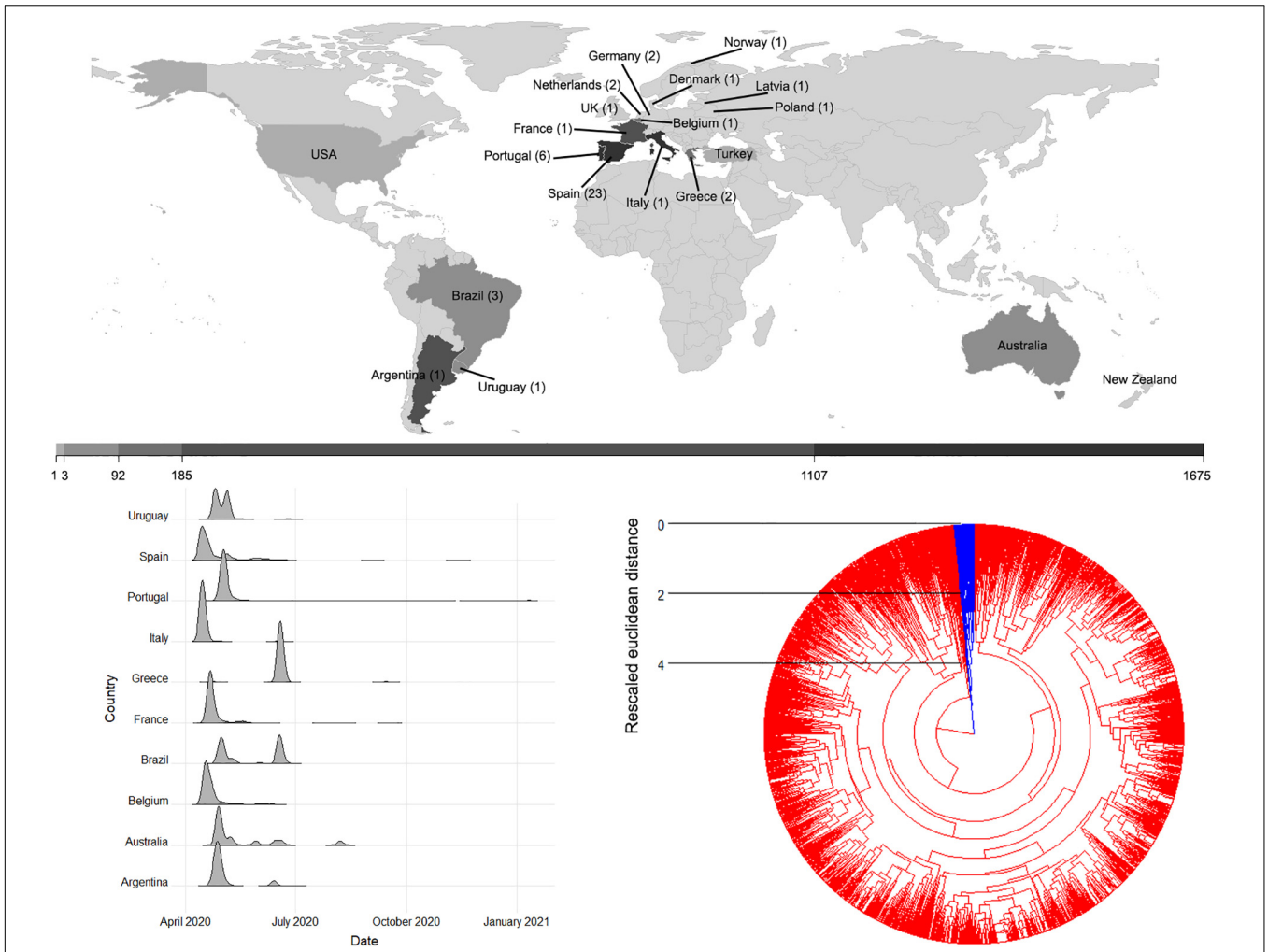

FIGURE 1 | Map showing the number of respondents by country, (although some responses were obtained from recreational fishers living in outermost regions, they are not included in the map. For example, the French Martinique, Guadeloupe, Guyane, and La Réunion, the Portuguese archipelagos of Madeira and Azores, or the Spanish Balearic and Canary Islands) both in the online survey of recreational fishers (the color refers to the number of responses) and in the expert consultation (in brackets the number of responses). Below in the *left* is the kernel density estimation of the temporal distribution of the responses to the online survey (we show countries with more than one answer). In the *bottom right* of the panel are the groupings of recreational fishers after a hierarchical clustering procedure on the Euclidean distance of the rescaled matrix of scores obtained in seven questions of the online survey designed to capture fishers' heterogeneity (see text in section "Study Design" and **Supplementary Appendix A** for details of the questions). In red Group 1, in blue Group 2.

dealt with the effects on recreational fishers. In part, this reflects the poor attention that in general has been given to this activity by the national and provincial fisheries agencies (Venerus and Cedrola, 2017).

Belgium

Fishers' compliance with a strict lockdown between March and May 2020 was high in Belgium. Thereafter, recreational fishing was gradually allowed, although limited in practice due to different partial restriction measures, including maximum number of people onboard recreational fishing boats, and temporal and spatial restrictions to people's movements. In Belgium, fishers do not need a license to practice marine recreational fishing, but they do need one to fish in freshwater. The number of freshwater licenses increased by 30% in 2020 compared to 2019. It is expected, therefore, some increase in fishing activity at sea after the strict lockdown period.

Some local effects derived from the reduction of recreational fishing effort cannot be ruled out due to the coastal nature of Belgian marine recreational fishing. The experts expect that the reduction in catches was probably around 40 tons between March and May 2020, affecting especially Atlantic cod *Gadus morhua*, whiting *Merlangius merlangus* and common dab *Limanda limanda*. However, the effects of the recreational fishing ban is likely to become concealed by reductions of up to 30% in commercial fishing activity in the Belgian part of the North Sea during the lockdown (Verleye et al., 2020a,b).

The direct economic loss during the first complete lockdown in Belgium (between March and May 2020), mostly related to an

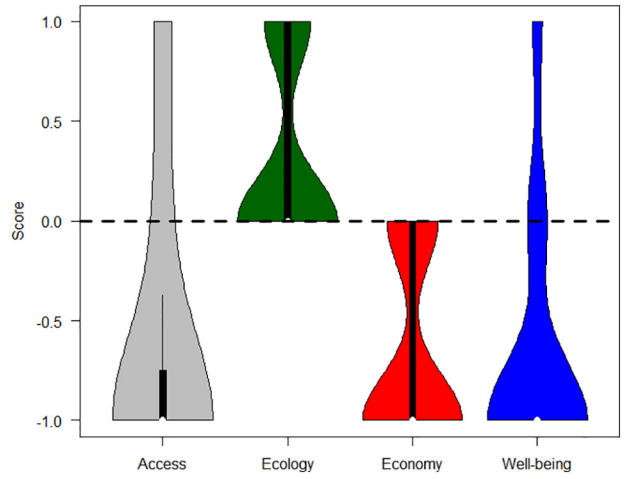

FIGURE 2 | Results of an expert consultation about changes due to COVID-19 in marine recreational fishing access, expected ecological status of marine ecosystems, projected economic scenarios, and perceived people's health and well-being. Mean values of the experts' coded answers scores are shown, which ranked between "–1," meaning lower, or poorer, and "1," meaning more, or higher, while "0" meant no changes, or opposing trends (identified with a dashed line). The top and bottom of the thick black lines correspond to the first and third quartiles of the data, the thin black lines extend to 1.5 times the interquartile range, and the median is indicated with a white dot. A two-side rotated kernel density estimation of each distribution is also shown.

average reduction of 84% in fishers' running costs, was estimated at a minimum of 0.6 million euros (Verleye et al., 2020b). Moreover, due to the gradual lift of social restrictions affecting recreational fishing and some expected reluctance to go back fishing by some people, total economic impact is likely to grow until the COVID-19 crisis ends.

In Belgium most recreational fishers regard that their hobby is of great importance to their lifestyle. Therefore, restrictions to fishing, and economic and social crisis derived from the pandemic (unemployment increased among recreational fishers by more than 25% during the first months of the pandemic) are probably behind the recent reduction of perceived well-being shown by Belgium recreational fishers (Verleye et al., 2020b).

Brazil

During the start of the COVID-19 crisis (March and April 2020), there were no mandatory restrictions regarding recreational fishing at the country level. However, while in some states such as São Paulo in the southeast, non-essential activities were not allowed and access to beaches, marinas and natural areas was denied, in other states only voluntary restrictions on social activities were in place, with uneven follow-up throughout the country. In the state of Espírito Santo, at the central coast, recreational fishers seemed to access the fishery almost normally, as reported in the expert consultation. However, in Bahia, a state in the northeast of Brazil with the longest coastline (about 1,000 km), consulted experts observed an 80% reduction in the access of recreational boats, while the average number of fishers onboard was reduced from six to two. In addition, experts acknowledge relevant decreases in numbers of shore anglers, especially at urban beaches of Bahia, but also at rocky shores and in mangroves. Normal activity has not yet reached there 1 year after the start of the pandemic.

In the absence of an official fisheries monitoring in Brazil (Reis-Filho et al., 2019, 2021), consulted experts collected perceptions of some fishers in the Bahia state (NE Brazil) who consistently reported that the decrease in human presence and derived pollution, including noise, following voluntary lockdowns favored closer proximity to the shore of different species, especially of the families Serranidae, Lutjanidae, and Scombridae. Some boat owners indicated that they were benefited by less port and marine traffic, and more fishing opportunities in traditional fishing spots, with up to 20% increases in fishery yields compared to pre-pandemic scenarios. On the other hand, experts noticed that in the last months of 2020, and because of lower levels of enforcement and control, instead practicing C&R, a growing number of fishers were retaining endangered species, like Atlantic goliath grouper (*Epinephelus itajara*) and billfishes (genus *Makaira, Kajikia*, and *Istiophorus*).

Tourism is very important for many Brazilian coastal communities and catches from different fisheries are sold to local restaurants to be consumed by tourists (Lopes et al., 2017). In some places where recreational fishers sell their catch to restaurants their revenue must have been reduced considerably. Furthermore, in places with serious social mobility restrictions, as in São Paulo, service providers who depend on recreational fishing as a source of income (e.g., charter boat owners and fishing guides) have been especially impacted. For this reason, the impact of the pandemic on reductions of national, and especially international tourism had an important effect on the recreational fisheries, and in local economies.

Interviews conducted by consulted experts with recreational fishers in Bahia, revealed that shortage of fishing gear, cancellation of fishing competitions, and closure of some charter fishing boats resulted in some disappointment among recreational fishers.

Denmark

During spring 2020 Denmark was locked down due to the COVID-19 outbreak. Non-essential activities were severely restricted, and the borders were also closed. Other less-severe lockdowns followed the gradual reopening after successive waves of the pandemic. Recreational fishing was allowed during the lockdowns and was even encouraged by the Danish Government (Miljøministeriet, 2021), with high media coverage about increased angling activity. Sales of mandatory licenses for recreational fishing increased by 24% compared with previous years, beginning to grow in April 2020, shortly after the first lockdown, and remaining higher than in previous years during the following months (Ministeriet for Fødevarer Landbrug og Fiskeri, 2021a). It is likely that younger, more urban, and less devoted fishers have accessed the fishery for the first time during the COVID-19 pandemic in Denmark (Gundelund and Skov, 2021).

Based on citizen science data, the only data available about angling activities during the lockdown, the increase in access to

the recreational fishery that was observed during spring 2020 did not result in more angling trips compared to previous years, but in more effort during labor days and evenings, instead of weekends and early in the day (Gundelund and Skov, 2021). For sea trout *Salmo trutta*, the most popular target species among Danish marine anglers, lower catch rates were observed, especially among the less experienced participants that entered the fishery during the spring lockdown in 2020. This may result in a lower biological impact on the species. On the other hand, the citizen science data also suggested that the anglers during the 2020 spring lock down tended to retain more fish than in previous years, which increase fish mortality in a way that may have counterbalanced the concurrent lower catch rates (Gundelund and Skov, 2021).

The lack of international fishing tourists during the border closures, resulted in some negative impacts on local economies, especially in the areas of Denmark where tourism is an important industry (Tress, 2002; Andersen et al., 2018). For example, this resulted in less rentals of summerhouses, lower activity in restaurants, or lower sales of fishing tackle. The charter boat industry was negatively affected during the lockdowns and periods with social distance restrictions. The sales of 1-week licenses, mainly purchased by foreign visitors, dropped by 40% in 2020 compared with previous years (Ministeriet for Fødevarer Landbrug og Fiskeri, 2021b). When the country borders reopened during the summer of 2020, international visitors purchased more licenses than during the same months in previous years. On the other hand, the increase in the sales of annual fishing licenses in 2020 with respect to previous years suggests the recruitment of new recreational fishers in Denmark. Newcomers must have needed to purchase their fishing equipment, with direct positive economic impact. It is unclear, however, if newcomers will remain in the fishery, or if they will abandon it after the international health crisis ends.

Social isolation can have dramatic effects, both on physical and mental health, especially in vulnerable groups of people. In this sense, there was an increase in the number of women seeking help because of sexist violence and abuse (Danner, 2021). Several demonstrations have been in place in Denmark against the governmental decision on the different lockdown (Euronews, 2021). However, it remains unclear if the reported increase in recreational fishing activities in Denmark influenced the collective well-being.

France

A strict and mandatory lockdown was implemented in mainland France from March to May 2020. Mobility of the population was restricted to essential activities. All sea-related leisure activities, including access to the beaches, sailing, or swimming, were forbidden by law at the national level. Therefore, recreational fishing was completely stopped during the first months of the pandemic. Fishers' compliance during this first lockdown was high, as well as in other recreational and cultural activities. The second lockdown took place from October to December 2020, including another ban for recreational fishing. Recreational fishing was resumed in 2021 in all France. The context was somewhat different in French overseas territories (with differences in dates and conditions of the lockdowns), however, access to recreational areas and activities was highly reduced in general.

The consulted expert collected perceptions of different fishers and the general perception is that local shellfish stocks (i.e., size and biomass of clams and cockles) benefited from the reduction of recreational fishing effort during the pandemic. This is relevant information considering that recreational shellfish gathering in mainland France is very popular (Herfaut et al., 2013). The first lockdown in 2020 did not affect the high season, during summer, but shellfish gathering is already relevant during spring. Therefore, it seems reasonable to expect some ecological benefits at the local level, compared to previous years. The effects of the recreational fishing ban are also difficult to predict but should be limited because of the short duration of the lockdowns, and because commercial fishing activities did not stop.

It is difficult to assess the economic impacts of the COVID-19 pandemic on the marine recreational fishing sector due to the current lack of data. However, the two lockdowns took place when the weather was not the most appropriate for recreational outdoor activities in mainland France. Weather and fishing practices are very different in outermost regions, where impacts could be even higher. French national economy has been negatively impacted during the pandemic, and negative consequences for the recreational fishing sector are also expected, even if those effects could have been limited with the reopening of the recreational fishing activities after the lockdowns.

In France, to date there was no specific survey to assess the effects of the COVID-19 pandemic on mental health and well-being for recreational fishers. After a strong initial coalition of social groups with very different political agendas stopped supporting government measures to contain the pandemic, social protests have been organized, illustrating the bad effects of social isolation for people during the lockdowns (Jørgensen et al., 2020). The recreational fishing ban could have increased the erosion of well-being in the French population because this activity is a source of relaxation and socialization. Sometimes, especially for people with low incomes, it could also be a relevant source of food or money. These social impacts could have been more important in French overseas territories, where subsistence fishing is more frequent (Failler et al., 2015, 2020).

Germany

Most (65%) of marine recreational fishers in Germany are domestic tourists (Strehlow et al., 2012). Following first severe COVID-19 restrictions to non-essential activities in March 2020, access of marine recreational fishers to the coast was highly reduced. Consequently, the restrictions due to COVID-19 had a strong impact on marine recreational fisheries. In general, compliance with these regulations was high among the German population and this was also the case for the recreational fishing community. The specific regulations were under the jurisdiction of the different federal states, leading to a variety of local and regional restrictions. During the first lockdown, between March and May 2020, coastal states imposed a travel ban for domestic tourists (residents were allowed to travel in their home state) restricting access to the Baltic and North Sea coastal states. In

addition, accommodation opportunities and marinas, as well as charter boat businesses and tackle shops were closed. Some municipalities even stopped selling daily fishing licenses (mainly sold to anglers targeting spring-spawning Atlantic herring *Clupea harengus* in the Baltic Sea). After June 2020, restrictions on marinas, charter boats, and domestic tourists were lifted. During subsequent lockdowns between November 2020 and May 2021, restrictions on tourism access to coastal areas were resumed, affecting fishers' access to the coast. Even though the consulted experts noted some increase in angling activities by residents (e.g., due to short-time work and more free time), it is unlikely that this compensated for the decrease in fishing effort by domestic tourists due to the travel restrictions. In this sense, available license data for one federal state on the Baltic Sea revealed a drop in the sales of sea angling licenses of up to 14% in 2020 compared to 2019. Moreover, trolling fishing effort in the 2020 Atlantic salmon *Salmo salar* season in the Baltic dropped by 50% compared to 2019, as stated in a recent survey developed by the consulted experts (MSW and HVS, unpublished data). On the other hand, the situation in freshwater recreational fisheries, that remained mostly unrestricted, was very different, with strong regional increases in fishing effort. It is expected that some marine recreational fishers (non-residents) have shifted from marine to freshwater fisheries.

Marine recreational fishing effort has been severely reduced in Germany in the spring and winter of 2020 and 2021, with less disturbances due to recreational boat traffic, beach walking and potentially lower recreational fishing mortality. However, the effect on marine ecosystems through reduced fishing mortality is limited because the strict lockdowns were relatively short. Nevertheless, lower fishing effort due to the travel restrictions in combination with lower catches per unit of effort resulted in an 80% reduction of fishing mortality in the 2020 Atlantic salmon trolling fishery in the Baltic Sea compared to 2019 (MSW and HVS, unpublished data). On the other hand, human disturbances caused by visitors and hikers may have increased during the lockdown, as people spent more time outdoors.

In general, the German economy has been impacted negatively due to the pandemic, affecting employment and household income, with potential negative consequences for the recreational fishing sector. Since domestic angling tourism makes up two thirds of the total marine recreational fishing effort in Germany, the COVID-19-related restrictions are expected to have a strong negative impact on fishers' expenditures in tackle shops, guided fishing tours, and boat rental and charter businesses, especially in coastal communities. On the other hand, some of these economic losses may be partially compensated, e.g., due to increased sales of tackle shops after the lockdowns, while others will not, e.g., canceled fishing trips, or guided and charter boat tours. However, it is possible to anticipate part of the economic impact at this time, since a 50% reduction of trolling boat fishing effort was observed in the 2020 Atlantic salmon fishing season in the Baltic. However, increased fishing effort in freshwater fisheries and potential subsequent increased expenditures for this sector may have compensated the reductions in expenditures for marine recreational fisheries as most of the recreational fishing effort in Germany is exerted in freshwater fisheries.

Although social impacts are difficult to anticipate, consulted experts speculate that since some of the marine recreational fishers started fishing in local freshwater facilities, expected health and well-being benefits derived from the practice of their activity could have partially remained. On the other hand, there are expected higher social impacts on fishers more specialized in marine recreational fishing. Moreover, some negative effects due to the restrictions regarding social distancing could be expected, since fishing competitions and team angling could not be performed, and neither meetings in fishing clubs nor fishing outings with people from different households. This might particularly impact on the social well-being of older people living alone.

Greece

In Greece, the COVID-19 crisis began in March 2020, when a complete lockdown was imposed in the country, and mobility of the population was restricted to essential activities. Shore and boat angling was not allowed until May 2020, while spearfishing until June 2020, affecting the 700,000 resident recreational fishers. In November 2020, the country was put into a second lockdown. Marine recreational fishers were again not allowed to fish, except between December 2020 and January 2021, until the end of March 2021. Recreational fishing was allowed again in April 2021 with some restrictions. International tourism was restricted for some months, but even when it was allowed again numbers decreased remarkably (up to 90% in some cases) compared to 2019, especially in northern Greece, where half of recreational fishers are foreigners (mainly from Bulgaria). Apart from very isolated areas where control and enforcement are difficult, compliance was high during the first lockdown, whereas it was reduced during the second lockdown, with some illegal fishing exposed by the press (e.g., Creta24, 2021; Kavalapost, 2021; Ypaithros, 2021).

The consulted experts expect some improvements in the conservation state of the Greek marine ecosystems and fisheries due to the reduction of human presence and lower fishing mortality. However, these benefits will not be of much importance because the fishing activity of commercial fleets has not greatly decreased. The highest impact on the fishing sector was found in the small-scale fisheries, as the fishes caught are sold at ports and not through the wholesale markets, and consumers could not easily reach the ports due to mobility restrictions. To compensate the commercial small-scale fishers the Government offered some economic support to the sector (Greek Government Decision 94/165904). The consumption of seafood by residents did not compensate for the lack of activity in the restauration, which largely depend on tourism.

The consulted experts anticipate that the recreational fishing industry faces an important reduction in sales and revenue, e.g., shops specialized in selling fishing tackle and baits, and boat services, including mechanical repairs and equipment sales and maintenance. Severe lockdowns led to reduction of production of different goods, difficulties in their distribution, and employment losses. In the mid-long term, the crisis might lead to business closures. On the other hand, although in the Northern provinces of Macedonia and Thrace fishing tourism is important, the economic impact of border closures is not expected to be high

because the expenses and investments of these tourists are not high in general.

Greeks are very sociable people and imposed measures for social distancing are affecting well-being across the country. Furthermore, recreational fishing is in many cases an activity sought to reduce stress in everyday life. Frustration derived from the imposition of social distancing measures, added to the prohibition of recreational fishing, triggered social protests throughout the country (e.g., Simera, 2021; Solaris, 2021). Economic crisis caused by the pandemic is expected to have more impact on the most vulnerable segments of recreational fishing. Coastal communities highly dependent on recreational fishing activities are expected to suffer from unemployment, poverty, and thereby social disruption. Although the pandemic affects all population segments, it is particularly detrimental to members of those social groups living in most vulnerable conditions, such as people living in poverty, older people, refugees, migrants, and other sensitive social groups that largely fish not for leisure purposes but for food. These vulnerable groups are highly engaged in recreational fishing and expected to be adversely affected by the pandemic.

Italy

In Italy, the first social confinement was between March and May 2020, and included a ban on recreational fishing. After this severe lockdown recreational fishing was allowed again in the country. Other regional lockdowns with restrictions to recreational fishing followed during 2020 and 2021, in a very dynamic scenario following the development of the pandemic in each region.

Although consulted Italian experts considered that the period in which recreational fishing effort was restricted or banned was too short to cause relevant ecological changes, the reduced fishing effort would have allowed some species to have more effective reproductive seasons, especially those that spawn in spring. Reduction in human disturbances, including pollution and noise, would also have favored some fish species to occur in coastal habitats where they are usually not found.

Some loss of expenses directly related to recreational fishing would be expected in Italy (e.g., travel, food, or baits), but on the other hand, consulted experts noted that some fishers invested in buying new fishing gear through online commerce during lockdown. The summer tourist season, including recreational fishing activities, was relatively normal, and it is also expected that more people will access the fishery after the pandemic because they value more contact with nature than before the lockdowns, with a consequent increase in their investments and running costs for recreational fishing.

In Italy a general decrease of well-being in almost all strata of the population is expected, in many cases because of the loss of contact with nature and reduced social contacts. Recreational fishers are especially sensitive to these aspects, because they practice their activities in blue areas, they fish with friends in many cases, and get involved in competitions and club activities. In addition, they face the consequences of having less opportunities to eat their catches. Health and well-being impacts derived from less seafood intake could be very important for semi-subsistence fishers, and for fishers with higher culinary motivations to access the fishery.

Latvia

No strict lockdown was applied in Latvia in the spring of 2020. On the contrary, the Government asked people to spend more time outdoors, while restrictions to indoor activities were imposed, e.g., in shops, bars and restaurants. As a result, more access to recreational fishing was observed, further driven by closures of schools and home office. Boat crews were restricted to two fishers, but compliance and enforcement of this rule was not high. Although popular competitions were cancelled, in spring of 2020 numbers of sea anglers targeting Atlantic herring, garfish *Belone belone*, and the invasive round goby *Neogobius melanostomus* were much higher than in previous years.

The consulted experts do not expect major changes in the marine ecosystem status of the Latvian Baltic Sea. Recreational fishing mortality is usually low compared to commercial fishing. Moreover, although commercial fishing effort was lower due to less demand during the COVID-19 crisis, due to reductions of the most important quotas in 2020, commercial fishers managed to meet their fishing opportunities, even with the fleet moored in the harbors for some months.

In Latvia most recreational fisheries are accessed by individual fishers, and there were no restrictions for that. However, some companies offer boat fishing trips, especially for fishers from Lithuania targeting Atlantic salmon and sea trout, and those were most probably impacted due to loss of tourism opportunities during the 2020 autumn season. Fishing tackle shops in big shopping malls were closed only on weekends, while small shops remained open.

In Latvia, the lockdown was quite mild in 2020, and therefore the impact of COVID-19 on social peace, well-being and public health could be lower compared to other countries. There was some debate about cancelling some restrictions for recreational fishing and lowering the prices of licenses to increase the time people spent outdoors, but they were not finally implemented.

The Netherlands

In the Netherlands there was a moderate lockdown starting in March 2020. Many people worked at home, while schools, bars, restaurants, camping facilities, and sport clubs, etc., were closed. On the other hand, outdoor activities keeping some social distance were allowed, including recreational fishing. Since keeping social distance was difficult, charter fishing boats were not allowed to operate, and competitions and popular fishing events were cancelled. There is no licensing or registration required for sea angling in the Netherlands. Therefore, it is difficult to quantify changes in access and effort. In recent years recreational angling has declined in the country (van der Hammen and Chen, 2020), however, since sales of mandatory freshwater licenses showed a steep increase, it is expected that shore angling also increased. Good weather, lack of alternative leisure activities, more free time, and children at home must have promoted access to recreational fishing. On the other hand, although this is a minoritarian option compared to shore angling, capacity restrictions (only two fishers allowed) to private boats

have probably limited their access. Moreover, parking lots close to the beaches were closed, so beaches were difficult to access for people living far from the coast. A second lockdown, starting in December 2020 through 2021 was stricter, as it included curfews, meeting capacity limitations, and shop closures, and worse weather conditions to spend time outdoors, all of which could have reduced interest in recreational fishing.

Although the increase in fishing effort could have been relevant in the case of shore anglers, the consulted experts do not expect significant effects on the marine ecosystems of the Netherlands, if compared to the strong reduction of the landings of the commercial fleet shown during the first months of the COVID-19 pandemic.

The worst economic impact has been borne by commercial charter boats based on the coasts of the Netherlands. However, tackle shops selling fishing gears, equipment, and baits, and angling associations selling fishing licenses took advantage of the increased recreational fishing demand in both marine and freshwater environments during the pandemic, especially during the first lockdown.

Consulted experts expect lower social impacts of COVID-19 in the Netherlands during the first lockdown compared to other countries because people could spend time outdoors, including recreational fishing. The results of the second, stricter lockdown must have been similar to those of other neighboring countries.

Norway

Marine recreational fisheries in Norway are exploited by both residents and tourists (Vølstad et al., 2020). Since March 2020, when the pandemic arrived in the country, main recreational fisheries regulations have not changed, except some changes in the export limit of fish for marine angling tourists. However, other measures had a direct impact on marine recreational fishing. These measures evolved, adapting to the different national and international health scenarios. The most negatively affected sector in the Norwegian marine recreational fisheries was the marine angling tourism sector, as this fishery is dominated by foreign anglers. From March 2020, access to Norway from other countries was restricted. During late spring and early summer these measures were relaxed for some time, but strict quarantine regulations were still in place, hampering the access of foreign tourists to the country. Quarantine was lifted for a time for some European countries but imposed again as infection numbers increased during autumn 2020. As a result of this scenario, the access of foreign marine angling tourists was dramatically reduced in 2020 compared to previous years. On the other hand, with increased unemployment rate and reduced holiday travel opportunities to other countries due to COVID-19 measures, residents had more time to spend fishing in Norway. Therefore, local access to the fishery was increased during the COVID-19 pandemic. There is no license required for sea angling, but a 23% increase in mandatory licenses to enter the European lobster *Homarus gammarus* fishery was observed in 2020, compared to 2019 (Directorate of Fisheries, 2021b). The sales of boats also increased substantially in 2020 compared to 2019 (Berglihn, 2020).

Although there are many other factors that impact marine ecosystems, sea angling tourism may have some impacts on local fish populations (Vølstad et al., 2011), and a decrease in their catches could, in theory, have had a positive effect. The mandatory catch reporting to the Norwegian Directorate of Fisheries showed that the overall catches of saithe *Pollachius virens*, Atlantic cod, Atlantic halibut *Hippoglossus hippoglossus*, Atlantic wolffish *Anarhichas lupus* and redfish *Sebastes* spp. in the marine angling tourism industry were reduced by ca. 75% in 2020 compared to 2019 (Directorate of Fisheries, 2021a). On the other hand, Norwegian residents seemed to have increased their fishing effort compared to previous years, which might have counterbalanced the decrease in tourist fishing mortality to some extent.

The COVID-19 measures had a substantial negative impact on the tourist fishing industry as many foreign visitors were never able to access the country. However, economic investments of residents in the fishery seemed to have increased, including the purchase of fishing tackle and new boats (Berglihn, 2020). For example, a market analysis conducted by Klarna (2020) showed that one of the largest online recreational fishing equipment stores in the European Nordic countries had an 87% increase in sales of recreational fishing gear in the period between March and September 2020, compared to the same period in 2019.

Norway has a low population density compared to many other countries, and there are several options of outdoor activities available to the local population. Indeed, fishing is one of the most popular leisure activities in Norway, with one third of the population fishing in the sea at least once a year (Vølstad et al., 2020). Even though there have been several lockdowns in Norway during 2020, many outdoor activities were not specially affected. In fact, while meeting friends indoors was restricted from time to time, people could meet outside, e.g., during fishing, keeping some social distance. Thus, recreational fishing may have been one of the activities which contributed to support social well-being during the COVID-19 pandemic.

Poland

People in Poland were in a mandatory complete lockdown from March to April 2020. Non-essential activities, including recreational fishing were prohibited by law.

The lower fishing mortality and reduced disturbances derived from the absence of recreational fishers may have been positive for local fish stocks during the lockdown in spring 2020, especially because it affected the prime fishing season for Atlantic salmon and sea trout in Poland. On the other hand, Polish anglers rapidly resumed their normal activity, so the closure has been relatively short.

The lockdown imposed during spring 2020 that affected the fishing season for Atlantic salmon and sea trout in the Baltic Sea had a high negative impact on fishing tourism. The lack of economic flow originated by the recreational fishers, including both private and commercial companies that provide fishing services is important to local economies, very dependent on tourism.

The consulted experts do not expect relevant impacts on social peace, well-being, and public health because of mandatory or

voluntary lockdowns, or new habits related to recreational fishing due to social distance.

Portugal

In Portugal, the first COVID-19 cases were reported in early March 2020, and the first peak in the number of cases was observed at the end of the same month. As part of the implemented lockdowns, Portugal banned all types of recreational fishing activities in the mainland and Atlantic archipelagos between March (April in the Azores Islands) and May 2020. Only essential activities such as working, buying food, etc., were allowed. Overall, many recreational fishers did not support the temporary fishing closure, and there are records of some noncompliance, especially by shore anglers and spear fishers in rural and remote areas where there is low enforcement. The available evidence collected by the experts suggests that compliance with the fishing ban was higher among boat anglers because they are easily controlled by the authorities, and boat anglers agreed that it would be difficult to keep social distance onboard.

During the COVID-19 crisis most recreational marine activities were severely reduced, and they were completely banned during the lockdown of spring 2020. Given commercial fleets continued fishing (commercial fishing was considered an essential activity), and recreational activities were only forbidden during a relatively short period, the consulted experts do not expect important reductions in overall fishing mortality. Nevertheless, some spear fishers reported increases in the abundance of crevice-dwelling fish species (e.g., European conger *Conger conger* or forkbeard *Phycis phycis*), and limpets *Patella aspera*, but not in the case of important recreational species like parrot fish *Sparisoma cretense*. Consulted boat and shore anglers did not report relevant changes compared to the previous year. On the other hand, a recovery would be expected for the white seabream *Diplodus sargus*. This is one of the most targeted species by local shore anglers and spear fishers at the SW coast of Portugal during the winter and early spring, when this fish aggregates to spawn and is more vulnerable and accessible to fishing (Veiga et al., 2010). Although there was a temporary closure for this fishery in place between February and March, the lockdown provided an extended closure. Moreover, reductions in the commercial landings of about 40% with respect to previous years (Instituto nacional de Estatística, 2021) may have resulted in greater benefits to marine ecosystems than those that result from the reductions of recreational fishing effort, especially during the winter-spring spawning season of many of the most important recreational and commercial coastal species. In addition, reduction of human use of intertidal ecosystems, e.g., digging for bait, that impacts on seagrass meadows, and of other recreational activities like sailing, swimming, or surfing, may also have had some positive effects on sensitive species, including seabirds. Furthermore, the decrease in tourism due to travel restrictions may have improved water quality by reducing urban wastewaters dumped into the sea. On the other hand, the increase of pandemic-related unemployment in the Azores is expected to increase commercial fishing effort on, e.g., limpets, common octopus *Octopus vulgaris*, and others. Poaching and non-compliance of limpet protection zones are also supposed to have increased, as happened in the past (Diogo et al., 2016).

In Portugal, bait sales, tackle shops, boat maintenance companies, and restaurant facilities at marinas suffered important economic losses during the complete lockdown. Another relevant negative economic impact to recreational fisheries is expected to affect touristic fisheries, especially to charter boats and head-boats involved in coastal and Big Game fishing, since this activity is heavily dependent on foreign tourists. In 2020, the pandemic had a major impact on the number of tourists visiting Portugal, and consequently on Big Game fishing tours, especially in the Algarve and the Atlantic islands of Madeira and Azores. For example, the international Big Game fishing competition of Madeira, which attracts many foreign visitors and participants, was canceled in 2020. As an indicator of tourism reduction, apartment's overnight stays showed a 67% decrease from January to November 2020, when compared to 2019 (Instituto nacional de Estatística, 2021). On the other hand, resident recreational fishers seem to have increased their number of fishing trips during the summer of 2020, which together with online purchase of fishing tackle, could help to revert some of the previous economic losses. Furthermore, some measures were implemented to stimulate local tourism to compensate for losses of foreign visitors, e.g., in the Azores, which could have a positive impact on the recreational fishing sector.

The rise in unemployment, limitations of social interactions and events, and changes of habits are increasing the stress, anxiety and social inequalities in the Portuguese society, especially in vulnerable and aged people (Silva Moreira et al., 2021). In this sense, in the Azores, and probably in some other areas of the country, some low-income residents that go fishing for food could have reduced their access to healthy food at low cost through the lockdown. Furthermore, new measures of social distancing are especially difficult for Portuguese people because they are used to close human contact. On the other hand, COVID-19 helped many people to adopt healthier habits, such as spending more time outdoors, either exercising, relaxing, or socializing. For recreational fishers in particular, experts consulted do not anticipate stronger impacts compared to other people because they were able to practice the activity soon after the ban was lifted. Although some fishers felt discriminated because other recreational activities were allowed during certain lockdown periods, such as surfing, among others, their return to fishing, each with their individual motivations, e.g., contact with nature, friends, and family, or to catch some fish, could have helped them to temper potential negative effects of the lockdown on their physical and psychological health, and well-being.

Spain

The Spanish population was confined in their homes between March and April 2020, after which the mandatory national lockdown was progressively withdrawn across the country. Essential activities such as some jobs, food shopping and health care continued under strict sanitary conditions, while other important activities like face-to-face education suffered severe restrictions. Non-essential activities were strictly forbidden, including recreational fishing. In general, recreational fishing

ban was respected by Spanish fishers. After this strict lockdown, marine recreational fishing was progressively authorized, with differences between autonomous regions, provinces, municipalities, and even between sanitary areas. However, throughout the following months of 2020 and early 2021 different restrictions to peoples' mobility were put into force, including travels, curfews, partial confinements, and border closures, which made full access to fishing difficult in practice, especially for foreign tourists and for residents of non-coastal areas. Access to the fishery can be assessed by the acquisition of compulsory fishing licenses in Spain. In some regions the volume of licenses increased during this period. For instance, in the Balearic Islands, consulted experts noted an increase in the licenses issued just after the main lockdown compared to previous years, especially for shore angling, which is the modality that requires less expenses in equipment and mobility. This could be explained to a certain degree by a renovated interest in outdoor activities, which may have developed during social distance. The increase could also be caused by a growing interest in catch consumption, which is an important fishers' motivation in Spain (Morales-Nin et al., 2015), and could feasibly have been reinforced by economic difficulties experienced by some people because of the pandemic.

Although commercial fisheries reduced their landings in the first months of the pandemic, with some differences between fleets segments, they never stopped fishing in Spain (Coll et al., 2021). Recreational fisheries were completely closed for a relatively short period during the 2020 spring. Therefore, in general, consulted experts do not expect major changes in marine ecosystems. On the other hand, the effects of the spring 2020 lockdown on Spanish fish stocks may have been somewhat positive due to reduced effort and fishing mortality. For example, in the Catalonian Mediterranean Sea, it was estimated that ca. 110,000 shore angling, 42,000 boat angling, and 10,000 spearfishing fishing trips have not been conducted. The overall reduction in recreational catches during this period could have contributed to protecting the reproductive period of some highly targeted species, especially Atlantic horse mackerel *Trachurus trachurus*, Atlantic mackerel *Scomber scomber*, annular seabream *Diplodus annularis*, comber *Serranus cabrilla*, Mediterranean rainbow wrasse *Coris julis*, surmullet *Mullus surmuletus,* and white seabream (Dedeu et al., 2019; ICATMAR, 2020). The reproduction of other important species in the Spanish Atlantic, such as the European seabass *Dicentrarchus labrax* in the North, or dusky grouper *Epinephelus marginatus* and rubberlip grunt *Plectorhinchus mediterraneus* in the South (Pita et al., 2020), may also have been favored. Reductions in local and foreign tourism contributed to lower pollution of coastal waters due to less discharge of urban wastewater. Also, lower human disturbances during the 2020 spring contributed to greater presence of some species, such as Atlantic bluefin tuna *Thunnus thynnus* and marine mammals, very close to the coastline. On the other hand, the post-social confinement phase could have contributed to a general increase in fishing effort due to increased demand for outdoor leisure activities, especially near the most populated areas due to mobility restrictions (e.g., Lloret, 2020). Thus, while human pressure in the best-preserved areas may have decreased in the months after the lockdown of spring 2020, pressure on the most degraded peri-urban areas would have increased.

The inclusion of recreational fishing as a non-essential activity during the first lockdown in Spain, and throughout subsequent restrictions of people's mobility, including tourism, have impacted the value chain that indirectly depends on this activity, affecting restaurants, hotels, guided fishing tours and charter boats, retail shops of fishing tackle, and fuel consumption. Although investments derived from recreational fishing may have been mostly unaffected, since they are related to multi-year expenses, short-term expenses have probably been affected to a greater extent. In this sense, running costs to cover travel expenses of the fishers tend to have a considerable weight within their total annual expenditure in Spain (García-de-la-Fuente et al., 2020). Based on seasonal average expenditure per fishing day of recreational fishers, consulted experts estimated a potential reduction of direct and indirect expenditures on transportation, meals, tackle and other related expenses, reaching five million euros in 2020, only in Catalonia (ICATMAR, 2020). Furthermore, services related to recreational tourism activities faced high loss of reserves and financial resources at an unprecedented scale, especially affecting the Mediterranean coast, and the Canary Islands, which are highly dependent on tourism. The economic activity related to the modalities that need higher investments, such as boat angling and spear fishing, have probably been affected the most. In fact, although there has been an increase in recreational nautical activity in some places, since the maintenance of recreational boats is expensive, especially in a context of global economic crisis, some of the consulted experts indicated that sales of second-hand boats increased during 2020. On the other hand, shore angling, which is a less expensive modality, could have seen an increase motivated by fishing for consumption resulting in reduced costs for food, particularly among the sectors of the population most affected by the health and economic crises. However, according to interviews carried out by the consulted experts with tackle shops managers, the sales related to the increase in the access to recreational fishing that followed the social lockdown did not cover the economic losses suffered during the spring 2020 fishing ban and the subsequent restrictions on mobility (online sales were not considered).

Recreational fishers were somewhat amenable to the first lockdown in the spring of 2020, but showed some frustration when some other outdoor recreational activities were progressively allowed, e.g., swimming in the sea, or surfing, while recreational fishing continued to be banned (FEPyC, 2020; Jara y Sedal, 2020). A period where contradictory regulations at the national, regional, and municipal levels were in place contributed to the confusion and frustration of the fishers. In Spain, close social contact and outdoor social activities are important, so the impact of social distancing on the well-being of the population is probably higher than in other countries. In fact, recreational fishing is mainly a social activity in Spain, where most fishers seek the company of friends or family when fishing (Pita et al., 2018a; ICATMAR, 2020). Although during the first phase of the crisis, with the ban on fishing, many social encounters were prevented, during the de-escalation phase, even with different restrictions on mobility, consulted experts agreed that an increase was

observed in the access to recreational fishing, probably promoted by the difficulty of accessing other leisure activities (cinemas, theaters, museums, bars, and restaurants were closed, or with very small capacity during the pandemic). The main reason indicated by the fishers interviewed by the experts was to obtain psychological benefits to cope with the lack of activity during the health crisis. The stress derived from the confinement situation and of the restrictions to access their preferred recreational activity, has probably most affected avid fishers, and those living in non-coastal regions. On the other hand, the COVID-19 pandemic has probably contributed to widening the social gap by mainly affecting vulnerable groups that obtained part of their food from fishing, or even illegally sell their catches, especially people with low incomes.

United Kingdom

Sea angling is the main form of marine recreational fishing in the United Kingdom. The number and duration of lockdowns, and the associated restrictions regarding sea angling varied between the different countries and were complex. For example, the first lockdown in United Kingdom meant that sea angling was not possible from the end of March until early May 2020. From May, Wales allowed sea angling within five miles of peoples' homes, but this was not possible in Scotland, Northern Ireland, or England until later. Fishing was a permitted activity for most of the summer across most of the United Kingdom, although some regions and cities had additional restrictions that prevented it. For example, there was a tiered approach based on the levels of COVID-19 that resulted in variation in restrictions. Depending on the location, this may have restricted sea angler's ability to travel to fish, engage in angling tourism, and participate in competitions. Subsequent lockdowns in the autumn and winter prevented angling for a time in England, but it was then allowed if undertaken locally with one other person. Access to charter and hire boats was also restricted for some periods.

There is limited evidence on the impact of COVID-19 on sea angling access, and derived ecological impacts across the United Kingdom, because there is no requirement to have a license to fish in the sea. The number of mandatory licenses sold for freshwater angling in England was higher in 2020 than previous years, suggesting that more individuals were angling. It is likely that sea angling has seen a similar increase, but this did not necessarily mean that there was more effort as some sea anglers were prevented from fishing. As angling was initially not allowed during the first lockdown in the 2020 spring, effort will have been lower, but this was at a time during the year where angling effort is usually low. As recreational fishing was one of the few allowable recreational activities toward the end of the first lockdown, it is likely that effort increased, especially as many people were working from home or were not able to work, so had more opportunity and free time to go angling.

Consulted experts expect that the impact of COVID-19 on the economy has been mixed. Online sales of fishing gear increased, but tackle shops were not able to open during lockdown or were only able to provide click and collect services, reducing local expenditure. Restrictions on access and travel are likely to have reduced the overall trip expenditure, as fishing has been more local. In addition, charter boats were only able to operate with reduced capacity if at all to maintain social distancing. This, along with limited government support, has impacted on the charter boat sector.

Consulted experts expect that reduced access to fishing could have a negative impact on physical health and well-being. Angling in the United Kingdom has been shown to be important as a source of physical activity, relaxation, and socializing. In addition, some people retain fish to eat, so it may also have reduced the benefits of fish consumption in the United Kingdom.

Uruguay

In Uruguay, a health emergency was declared due to COVID-19 in March 2020. Although there was no mandatory social lockdown, the Government asked the population to avoid crowds in public spaces, promoting voluntary social distancing. Recreational fishing was directly affected because ports were closed for recreational boats until May 2020, while fishing from docks and beaches decreased because of the voluntary social distancing measures, and the vigilance of the authorities to avoid overcrowding. During the voluntary social distancing period, most recreational fishers complied with the measures proposed by the government, and the experts consulted observed a reduction in recreational fishing effort of 25% compared to 2019. In May 2020 fishers began to gradually resume the activity, both from boats and from the coast.

Fishing effort exerted in the different recreational fisheries decreased in Uruguay due to social distancing and the closure of recreational ports. Consequently, it is expected that targeted and non-targeted species will benefit from the reduction of human disturbances and fishing mortality. Although consulted experts noted a 40% decrease in total recreational fisheries catches in 2020, compared to 2019, the period of reduction in activity was too short to produce benefits on ecosystems in the long term. The species that benefited the most from the reduction in catches were broadnose sevengill shark *Notorynchus cepedianus* and South American silver porgy *Diplodus argenteus*. On the other hand, commercial fishing fleets operated as usual, targeting some species that are also commonly caught in the marine recreational fisheries.

The COVID-19 pandemic has caused a deep economic crisis in Uruguay due to the closure of many companies. Tourism was one of the most affected economic activities due to the closure of borders. During the first 3 months since the start of the health emergency (i.e., from March to June 2020), investments and running costs related to recreational fishing decreased, due to the closure of ports and voluntary social distancing. After this period, recreational activity began to resume, but with little economic investment due to the economic crisis. The experts consulted found that imports of recreational fishing goods fell by 15% compared to the year before the pandemic.

Although the voluntary confinement and social distancing in Uruguay prevented infections and deaths during the first months of the COVID-19 pandemic, it has probably affected psychological health and well-being across the country, as reported by consulted experts. Restrictions to socialize and carry out leisure outdoor activities, including recreational fishing,

could have specifically contributed to some loss of social well-being.

Online Survey to Fishers

We obtained 5,998 answers in the different online questionnaires from recreational fishers from 15 countries of America (406 answers), Asia (2), Europe (5,573), and Oceania (17; **Figure 1**). Shore angling was the most popular modality (54% of the respondents reported using this platform and gear), followed by boat angling (45%), shore spearfishing (29%), boat spearfishing (21%), shell fishing (7%), and recreational fishing operating with nets and commercial-like gears (1%; **Table 1**).

Most fishers were men (98%), with an overall mean age of 44.52 ± 12.82 years, and a mean BMI of 26.61 ± 3.94, which is equivalent to moderate overweight (CDC, 2021). On average, fishers lived in a household with 2.95 ± 1.28 members and showed an intermediate income level[3]. More than half of the fishers finished secondary school education (59%), followed by those that obtained a university degree (22%), and those who only finished primary school (19%). Most fishers were married or lived with a partner (74%), followed by singles (19%), divorced, or separated persons (6%), and widowers (1%; **Table 1**).

The answers of the respondents (4,788 after excluding incomplete cases) to the seven questions designed to capture fishers' heterogeneity suggested the existence of some clusters in the data (H = 0.238), with an optimal number of two clusters (S = 0.465). Most fishers were included in Group 1 (98% of total; **Figure 1**), with similar ratios in all countries, except in Australia, Denmark, New Zealand, Turkey, United Kingdom, and United States, where all fishers were included in the main cluster. All access platforms and fishing gears showed higher allocation of fishers to Group 1, with similar ratios. Fishers operating with nets and commercial-like gear were all included in Group 1.

Age and BMI of fishers in Group 1 was lower than in Group 2, while fishers of Group 2 showed lower socioeconomic status, with lower income and education levels. Thus, up to 27% of fishers in Group 2 only completed primary school (only 13% in Group 1), while only 12% obtained a university degree (up to 23% in Group 1). Furthermore, the ratio of widowers and divorcees or separated was higher among Group 2 fishers. Finally, while family size was similar between the two clusters, the relative proportion of women included in Group 2 (9% of fishers in Group 2) was higher than in Group 1 (2%; **Table 1**).

The SIMPER analysis showed some variability in the contribution of the different questions used to define the clusters. Consumption preferences of the catch, followed by centrality to lifestyle of recreational fishing, and catch preferences contributed most to differences between clusters. Attendance at fishing competitions, self-reported fishing skills and know-how, and number of target species showed a medium contribution, while C&R practices showed the least contribution (**Table 2**).

[3]Between € 1000 and € 2000 of monthly net income for the households of fishers in developed countries, and between € 600 and € 1000 in the case of developing countries.

TABLE 1 | Description of the participants in the online survey distributed to marine recreational fishers, including details of each cluster of fishers (incomplete cases were excluded; BMI stands for Body Mass Index).

Fishers' characteristics		All	Group 1	Group 2
Gear and platform (*N*)				
	Shore angling	3,223	2,177	36
	Boat angling	2,711	2,279	34
	Shore spearfishing	1,756	1,546	26
	Boat spearfishing	1,252	1,139	19
	Nets	31	31	0
	Shell fishing	423	360	4
Country (*N*)				
	Argentina	254	248	3
	Australia	16	16	0
	Belgium	150	149	1
	Brazil	57	56	1
	Denmark	1	1	0
	France	932	921	11
	Greece	100	97	2
	Italy	1,194	1,157	22
	New Zealand	1	1	0
	Portugal	1675	493	6
	Spain	1,520	1,481	25
	Turkey	2	2	0
	United Kingdom	1	1	0
	Uruguay	92	89	2
	United States	3	3	0
Age (years)				
	Mean	44.52 ± 12.82	43.79 ± 12.60	47.93 ± 14.76
Gender (*N*)				
	Men	5,850	4,602	64
	Women	107	84	6
Civil status (*N*)				
	Divorced or separated	376	281	7
	Married/living with a partner	4,421	3,501	44
	Single	1,148	900	20
	Widower	49	33	2
Household members (*N*)				
	Mean	2.95 ± 1.28	2.96 ± 1.28	3.0 ± 1.57
Education (*N*)				
	Primary	1,155	620	20
	Secondary	3,504	3,007	44
	University	1,316	1,085	9
Income (level)				
	Mean	2.38 ± 0.81	2.45 ± 0.80	2.25 ± 0.93
BMI				
	Mean	26.61 ± 3.94	26.59 ± 3.95	27.24 ± 5.0

The two clusters showed significant differences regarding the scores given by the fishers to the seven questions designed to capture fishers' heterogeneity, both separately in the unadjusted models, as well as the final adjusted model (**Table 3**). The

TABLE 2 | Output of a SIMPER procedure showing the average contribution to the groupings of each of the seven questions designed to capture fishers' heterogeneity of the online survey participants (see text and **Supplementary Appendix A** for further details of the questions).

Attribute	Contribution
Consumption preferences	0.0997795
Centrality to lifestyle	0.0817971
Catch preferences	0.0806974
Competition's attendance	0.0582528
Skills and know how	0.0485037
Target species	0.0468437
Catch and release	0.0445635

TABLE 3 | Outputs of the binomial generalized linear model (GLM) fitted to the two groups of fishers.

Outcome	Predictor	Coefficient	*P* value	Goodness of fit (R^2)	AIC
Group	Catch and release	−1.1167	0.0085	0.0103	752
Group	Catch preferences	−2.0360	< 0.0001	0.3907	464
Group	Competition's attendance	1.2338	< 0.0001	0.0541	719
Group	Consumption preferences	−2.1094	< 0.0001	0.4816	396
Group	Centrality to lifestyle	−2.0878	< 0.0001	0.4218	441
Group	Skills and know how	−1.6425	< 0.0001	0.1166	672
Group	Target species	1.0799	0.0576	0.0049	756
Group	Catch and release	−1.1768	0.0167	0.8355	140
	Catch preferences	−1.6194	< 0.0001		
	Competition's attendance	1.4757	< 0.0001		
	Consumption preferences	−2.1502	< 0.0001		
	Centrality to lifestyle	−1.9035	< 0.0001		
	Skills and know how	−1.2408	0.0272		
	Target species	1.1656	0.0364		

*We show the estimated model coefficients (compared to Group 1) and p-values for the predictors (seven questions designed to capture fishers' heterogeneity, see text and **Supplementary Appendix A** for further details of the questions) of unadjusted, and of final adjusted models. The error structure (family), values of Akaike's information criterion (AIC), and goodness of fit (R^2), are also provided.*

adjusted model (R^2 = 0.836) showed that fishers in Group 1 consumed more of their catches ($p < 0.001$), fishing was more important for their lifestyle ($p < 0.001$), showed a preference to catch (few) larger fish than (many) little fish ($p < 0.001$), attended less fishing competitions ($p < 0.001$), considered their fishing skills and know-how to be greater ($p = 0.027$), practiced C&R more ($p = 0.017$), and were more selective in terms of their target species ($p = 0.036$; **Figure 3**). From now on we will call the fishers of Group 1 *advanced*, and those of group 2 *basic*, in reference to the theoretically expected progress made during recreational activity careers (Bryan, 1977; Scott and Shafer, 2001).

Impacts of COVID-19 on the Ecosystems

We found evidence in both unadjusted and final adjusted models that fishers of the two clusters differed in their perception of the expected changes in ecosystems due to variations in the recreational and commercial fishing effort because of the COVID-19 pandemic (**Supplementary Table 1**). *Advanced* fishers did not expect increases in fish abundances because of potential reductions in recreational fishing effort during the pandemic, while the positioning of *basic* fishers was neutral ($p = 0.012$, final adjusted GLM, $R^2 = 0.036$; **Supplementary Figure 1**). In contrast, *advanced* fishers did expect important increases in fish abundances after (even low) reductions in commercial fishing effort, while *basic* fishers did not ($p < 0.001$, $R^2 = 0.034$; **Supplementary Figure 2** and **Figure 4**).

In addition to some differences between countries, fishers that were older ($p = 0.001$), and with higher education level ($p = 0.047$ and $p < 0.001$, comparing secondary and university studies with primary school, respectively) were more skeptical of the benefits to the ecosystems derived from reductions in recreational fishing effort during the pandemic. However, the same group of fishers expected greater benefits to fish stocks from reduced commercial fishing effort ($p = 0.028$ in the case of age, and $p = 0.006$ comparing university with primary education; **Supplementary Table 1** and **Supplementary Figures 1, 2**).

Impacts of COVID-19 on Fishers' Well-Being

Concern about self-perceived health conditions related to the COVID-19 pandemic was very high among *advanced* fishers, while much lower for *basic* fishers ($p < 0.001$ in the final adjusted GLM, $R^2 = 0.094$). In addition to some differences between countries, concerns about health increased with age ($p = 0.001$) and BMI of the fishers ($p = 0.011$), while decreased with economic status ($p < 0.001$; **Supplementary Table 1**, **Figure 4**, and **Supplementary Figure 3**).

The perceived negative affect of *advanced* fishers was very high because of the COVID-19 pandemic, while it remained stable for *basic* fishers ($p < 0.001$, $R^2 = 0.038$). Some differences between countries were found in relation to the emotional stability of fishers, while overall fishers' mood improved with age ($p < 0.001$), and economic status ($p = 0.018$; **Supplementary Table 1**, **Figure 4**, and **Supplementary Figure 4**).

Quality of night sleep was poorer during the COVID-19 crises for *advanced* fishers, whereas it remained unchanged for *basic* fishers ($p < 0.001$, $R^2 = 0.032$). We also found differences between countries in terms of the reported quality of sleep. Moreover, satisfaction with night rest improved with age ($p < 0.001$) and economic status ($p = 0.018$), decreased with family size ($p = 0.036$), it was better for men than for women ($p < 0.001$), and for married and single than for divorced persons ($p = 0.007$ and $p = 0.022$, respectively; **Supplementary Table 1**, **Figure 4**, and **Supplementary Figure 5**).

Fishers reported in general much lower fish intake than before the COVID-19 crises, either because they fished less, or because they bought less fish (**Figure 4**). *Advanced* fishers showed the greater reduction in fish consumption habits ($p < 0.001$, $R^2 = 0.031$). Fish consumption varied among fishers

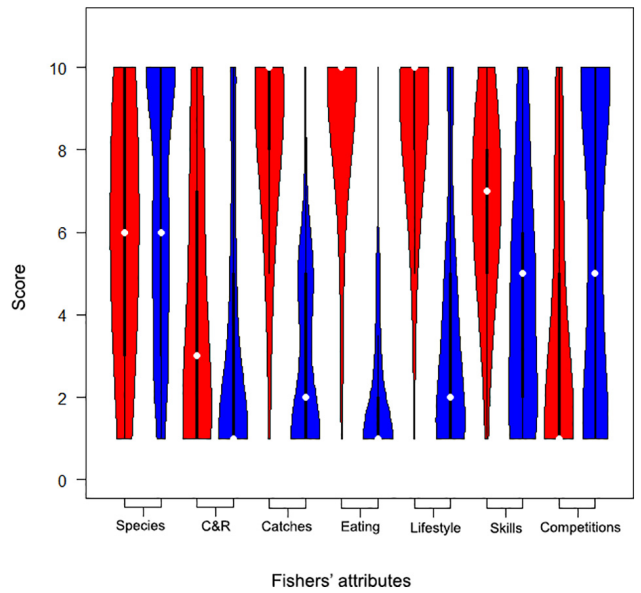

FIGURE 3 | Scores by a cluster of fishers (in red Group 1 *-advanced-*, in blue Group 2 *-basic-*) obtained in seven questions designed to capture fishers' heterogeneity during the online survey. It is shown the mean value of fishers' scores when asked about the number of target species ("species"), scored between "1," meaning one species, and "10," meaning no preferences; catch and release of live fish practices ("C&R"), scored between "1," meaning no fish are released, and "10," meaning all fish are released; catch preferences ("Catches"), scored between "1," meaning a preference for (many) little fish, and "10," meaning a preference for (few) large fish; consumption preferences ("eating"), scored between "1," meaning that the caught fish is not consumed, and "10," meaning that all catches are consumed; centrality to lifestyle of recreational fishing ("lifestyle"), scored between "1," meaning not at all important, and "10," meaning very important; fishing skills and know-how ("skills"), scored between "1," meaning poor, and "10," meaning high; and attendance to competitions ("competitions"), scored between "1," meaning never attending, and "10," meaning participating in all competitions (see text in section "Study Design," and **Supplementary Appendix A** for further details of the questions). The top and bottom of the thick black lines correspond to the first and third quartiles of the data, the thin black lines extend to 1.5 times the interquartile range, and the median is indicated with a white dot. A two-side rotated kernel density estimation of each distribution is also shown.

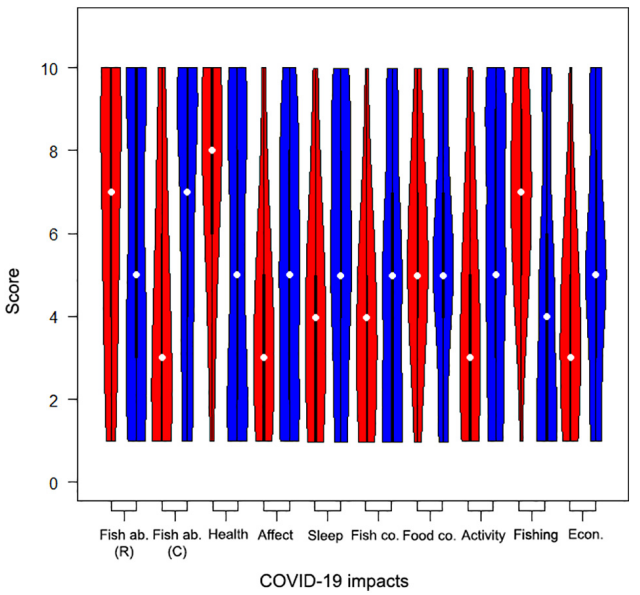

FIGURE 4 | Results of the online survey about impacts of COVID-19 in marine recreational fisheries by cluster of fishers (in red *advanced* fishers, in blue *basic* fishers). It is shown the mean value of fishers' scores, between "1," meaning strongly agree, and "10," meaning strongly disagree, when asked about expected increases in fish abundances ("fish ab.") because reductions in recreational fishing access ("R"); and when asked if they expect little changes in fish abundances because commercial fishing effort was not significantly reduced ("C"). It is also shown their perceived health condition ("health"), scored between "1," meaning not worried, and "10," meaning very concerned; their perceived negative affect ("affect"), scored between "1," meaning sadder, restless, irritated, or disgusted, and "10," meaning less sad, restless, irritated, or disgusted; their perceived quality of night sleep ("sleep"), scored between "1," meaning much worse, and "10," meaning much better; their fish consumption ("fish co."), scored between "1," meaning lower, and "10," meaning higher; their overall healthy food habits ("food co."), scored between "1," meaning less intake of fresh fruit and vegetables, and "10," meaning more fresh fruits and vegetables in diet; their physical activity ("activity"), scored between "1," meaning much less exercise, and "10," meaning much more exercise; their planned fishing activity ("fishing"), scored between "1," meaning expected reductions in fishing access, and "10," meaning expecting more time fishing; and their perception on the economic ("econ.") situation, scored between "1," meaning expecting very negative trends, and "10," meaning expecting very positive trends. The top and bottom of the thick black lines correspond to the first and third quartiles of the data, the thin black lines extend to 1.5 times the interquartile range, and the median is indicated with a white dot. A two-side rotated kernel density estimation of each distribution is also shown.

living in the different countries and increased with fishers' age ($p < 0.001$) and economic status ($p = 0.009$; **Supplementary Table 1** and **Supplementary Figure 6**). On the contrary, overall healthy diet habits remained unchanged (**Figure 4**), without differences between the two clusters of fishers ($p = 0.715$ in the unadjusted GLM). However, we found some differences between countries, age, and BMI, with healthier food consumed by older fishers ($p < 0.001$), and unhealthier food consumed by people with higher BMI ($p = 0.002$; **Supplementary Table 1** and **Supplementary Figure 7**).

Advanced fishers reported a step decrease in physical activity during the pandemic, while exercise habits of *basic* fishers did not vary ($p < 0.001$, $R^2 = 0.049$; **Figure 4**). Fishers reported different levels of activity in each country, while in general, exercise moderately increased with age ($p = 0.001$) and income ($p = 0.008$), and strongly decreased with BMI ($p = < 0.001$; **Supplementary Table 1** and **Supplementary Figure 8**). Moreover, *advanced* fishers anticipated strong increases in their recreational fishing effort, while *basic* fishers expected to go fishing a little less in the future ($p < 0.001$, $R^2 = 0.062$; **Figure 4**). There were some differences between countries and education levels regarding expected recreational fishing effort after the pandemic. Also, older fishers ($p < 0.001$) with bigger families ($p = 0.007$) believed that they will reduce time devoted to fishing in the future, while people with higher BMI expect to go fishing more often ($p = 0.001$; **Supplementary Table 1** and **Supplementary Figure 9**).

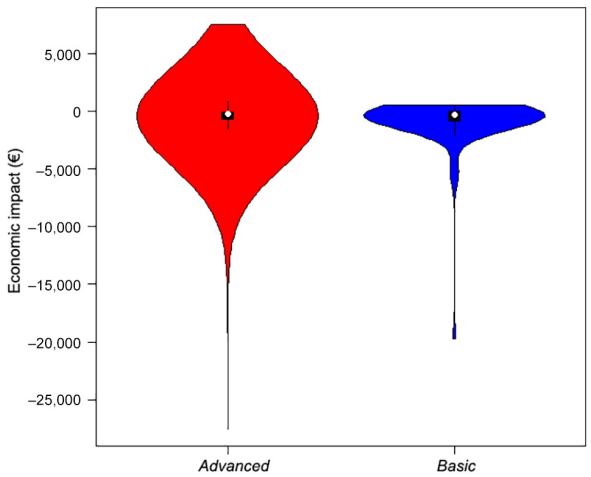

FIGURE 5 | Economic impact of COVID-19 on each recreational fisher obtained in an online survey. It is shown the mean reported change in expenses (Euros·fisher^{-1}) by cluster of fishers. The top and bottom of the thick black lines correspond to the first and third quartiles of the data, the thin black lines extend to 1.5 times the interquartile range, and the median is indicated with a white dot. A two-side rotated kernel density estimation of each distribution is also shown.

Economic Impacts of COVID-19

Advanced fishers were very pessimistic about overall economic perspectives after the COVID-19 pandemic. In contrast, *basic* fishers did not expect economic changes in either direction ($p < 0.001$, $R^2 = 0.051$; **Figure 4**). Fishers' perception of the economic scenarios because of the pandemic differed between countries and improved with age ($p = 0.011$) and economic situation ($p < 0.001$), while worsened with family size ($p = 0.004$; **Supplementary Table 1** and **Supplementary Figure 10**).

Mean overall economic impact derived from the loss of investments and running costs during the first months of the pandemic was estimated at 504.74 ± 1244.05 €·fisher.[1] However, up to 17% of respondents did not show changes in their expenses related to recreational fishing, while 4% of fishers increased them (all of them *advanced* fishers). Reported economic reductions were somewhat higher for *basic* fishers ($p = 0.029$, $R^2 = 0.037$), as none of them showed increases in their expenses, unlike *advanced* fishers (**Figure 5**). In addition to differences between countries, negative economic growth was more relevant for fishers with higher incomes ($p < 0.001$; **Supplementary Table 1** and **Supplementary Figure 11**).

DISCUSSION

The experts consulted in this study concluded that marine recreational fishing access was reduced during the first year of the COVID-19 pandemic, especially during temporal lockdowns imposed in most countries. According to this, recreational fishers reported in the online survey that they reduced their physical activity and fish consumption, especially in the case of *advanced* fishers, for whom recreational fishing is central for their lifestyle, and the consumption of the catch is very important. The restrictions affecting recreational fishing access intensified the important negative effects of the pandemic on the perceived health and well-being of recreational fishers. Thus, *advanced* fishers experienced a poorer night rest, and consequently showed higher concerns about their health status, and worsened mood. Furthermore, both the consulted experts and *advanced* fishers agreed that the economic impact derived from the limitations imposed on recreational fishing was highly relevant, with average economic losses derived from the decrease in expenses of the fishers during the first months of the pandemic of 505 €·fisher.[1] On the other hand, both experts consulted, and surveyed fishers expected some benefits for marine ecosystems derived from reductions of human impacts during the COVID-19 pandemic. In general, they agreed that the reductions on commercial fishing effort were more beneficial to fish stocks and marine ecosystems than reduced recreational fishing effort.

Global Importance

Results of the survey to recreational fishers and of the expert consultation showed that it is expected that global fish stocks could benefit from the reduction of the impacts of commercial fisheries during the COVID-19 pandemic, in line with what was found in recent studies (e.g., Kemp et al., 2020; Coll et al., 2021; Ferrer et al., 2021; White et al., 2021a). Whether reductions of recreational fishing effort will accrue similar benefits is less clear for recreational fishers, especially in the case of older and more educated fishers. However, as already pointed out by Cooke et al. (2021) in global freshwater recreational fisheries, consulted experts identified some benefits derived from reduced marine recreational fishing pressure, especially on highly vulnerable target species like Argentinian sandperch or broadnose sevengill shark in America, and Atlantic cod, Atlantic halibut, Atlantic salmon, Atlantic wolffish, dusky grouper, European seabass, redfish, rubberlip grunt, saithe, or white seabream in Europe. Furthermore, the experts indicated that overall reductions in human disturbances, including pollution and noise, led to an increase in the abundance of infrequent species near the coast, which resulted in an increase in recreational fishing opportunities (see e.g., Edward et al., 2021). However, experts also noted that recreational human pressure on marine ecosystems near large population hubs was increased after lockdowns, when people were allowed to practice outdoor activities, including fishing, while activities in closed spaces and travels were restricted, or banned. The greater free time of people due to rising unemployment may also have contributed to increased human pressure on these areas. Consequently, human impacts escalated in the already most ecologically degraded areas, as it was found in different marine ecosystems (China et al., 2021; Gundelund and Skov, 2021). Furthermore, some of the experts consulted in this study confirmed that more recreational fishing licenses were issued in many countries during the COVID-19 pandemic, which suggests an increase in the number of fishers. Although restrictions affecting access and mobility of recreational fishers prevented increases in the overall fishing effort, newcomers may have caused greater fishing mortality, because these fishers tend to retain more fish (Gundelund and Skov, 2021). We also showed

a similar pattern in our results, with *advanced* fishers practicing more C&R. In consequence, the consulted experts showed some concerns regarding higher retention rates of fish species with key ecological roles, like billfishes and groupers.

The overall reduction in the access to recreational fisheries has also had a significant economic impact, as recognized by the experts consulted and by the fishers in the surveys. This was particularly the case for those fishers with greater economic power, who reduced their expenses to a greater extent. As a rough estimate, taking into account the loss of investments and running costs indicated by the fishers (505€ on average), and the numbers of marine recreational fishers operating worldwide estimated by Cisneros-Montemayor and Sumaila (2010), the economic impact of the first year of the COVID-19 pandemic on global marine recreational fisheries would be around 29 billion €, approximately half of the annual investments generated by recreational fishers globally.[4]

In addition to the economic impacts derived from the reduced activity of recreational fishers in many countries during the COVID-19 pandemic, the consulted experts highlighted important indirect effects on fishers' health and well-being. Experts anticipated a greater importance of these types of impacts in countries where social relevance of fishing is deeply rooted (see Cohen and Lemay, 2007; Rosenquist et al., 2011), such as in southern European countries (Pita et al., 2018b, 2020), and lower impacts in those countries that imposed fewer restrictions on outdoor leisure activities, including recreational fishing, such as Latvia, the Netherlands, Norway, or Uruguay. As a result of restrictions affecting access to the fishery, recreational fishers in general, and especially *advanced* fishers, showed lower physical activity and lower fish consumption. Recent studies on the impacts of the COVID-19 pandemic on different recreational activities also showed results like those found in our study; e.g., Howarth et al. (2021) noted that fish consumption was lower among recreational fishers during the pandemic, while Curtis et al. (2021) concluded that the physical activity of the population decreased. Consequently, it is not surprising that the fishers surveyed in this study reported poor night rest, worse mood, and concerns about their health condition, especially in the case of *advanced* fishers.

Many of the consulted experts highlighted the unequal distribution of the socioeconomic impacts derived from the loss of access to recreational fishing, affecting more seriously coastal populations highly dependent on tourism, and vulnerable people dependent on fishing for food (Nieman et al., 2021). Therefore, unemployed, or poor persons, refugees, immigrants, ethnic minority groups, and other sensitive social groups would be the most impacted (Lee and Miller, 2020). In fact, we showed that fishers' concerns of the economic situation due to the pandemic improved with economic status, while a comfortable economic situation mitigated the main negative impacts on their health and well-being.

[4]Cisneros-Montemayor and Sumaila (2010) estimated that globally there are about 58 million marine recreational fishers that in 2003 generated 39.7 billion USD in expenditures, which is equivalent to 64 billion € in current money. In our estimate we did not take into account multiplier effects of fishers' expenses on the economies, especially in touristic areas.

Limitations of the Study

The consultation of experts in marine recreational fishing had a good coverage in Europe but it was limited in other areas, most probably because of the early involvement of the Spanish working group, and of the higher proportion of Europeans in the ICES WGRFS. Similarly, although the online survey of fishers had a greater geographic coverage than the expert consultation, including all continents (except Africa), a higher number of responses were also obtained from Europe and South America. The limited information gathered for North America and Oceania is more important than for Africa and Asia, where marine recreational fishing is relatively less prominent (Potts et al., 2019). However, despite limitations regarding coverage, our results provide a reasonable diagnosis of the COVID-19 pandemic impacts on global marine recreational fishing.

We obtained a convenience, non-random sample by using a self-administrated questionnaire in the online survey distributed to marine recreational fishers. Despite efforts to promote the existence of the online survey, including an international marketing campaign, many fishers either did not know about the survey or did not respond for some reason. Therefore, this sample may not be representative of the world population of marine recreational fishers or even of individual surveyed countries (Fisher, 1996; Venes, 2017). Spear fishers are probably overrepresented in the sample, likely due to the high number of responses obtained in countries of southern Europe, where this fishing modality has a greater relative importance than in other areas (Pita et al., 2017).

It is not possible to determine whether the ratio between groupings obtained in our survey, i.e., *advanced* (with up to 98% of fishers) versus *basic* (2%), could be globally escalated. Taking into account the four "personas" identified by Bryan's (1977) seminal work on typologies of trout anglers, our *advanced* fishers would include Bryan's "technique specialists" and "technique setting specialists," while our *basic* fishers would include Bryan's "occasional" and "generalists." Considering that we identified only two groups of fishers, it could be argued that our sampling may not have fully captured the heterogeneity of global marine recreational fishers. However, the groupings found by other studies with marine fishers are relatively similar to those identified by us. Thus, Beardmore et al. (2013), e.g., found two main groups of German anglers: a majority group (ca. 60% of total anglers) consisting of anglers with equivalent characteristics to our *advanced* fishers, and a much smaller one (ca. 30%) integrated by *basic*-like anglers. Furthermore, the questions that we used to group the fishers showed, in general, a similar performance than the ones used by Beardmore et al. (2013). In both studies centrality to lifestyle and catch preferences were very important to predict the typologies of fishers; skills and know-how were of moderate importance, while C&R practice was less relevant. Conversely, consumption preferences were the most important attribute for our groupings, while it was of much less importance in the case of German anglers. A greater variability in our sample in relation to the consumption of catches by fishers could explain the differences, which suggests that our sample is reasonably heterogeneous, at least in relation to this dimension. Nevertheless, in the absence of specific

studies on large populations of marine recreational fishers, it is not possible to determine to what extent our sample reflected the heterogeneity of worldwide marine recreational fishers. In this sense, due to the different characteristics of recreational fisheries in industrialized countries (Arlinghaus et al., 2014), a greater representation of countries in Northern Europe and North America, as well as the most developed countries in Oceania, would perhaps result in changes in the groupings identified in our study. However, although we acknowledge these limitations, we did not make inferences or extrapolations to the overall population. Instead, we exclusively use the results to make comparisons between the two groups of fishers identified: *advanced* versus *basic*.

Recall and declaration biases (Pollock et al., 1994) could also have affected both the experts consulted and the fishers surveyed. However, since our recall period was limited to the previous months (3 months in the online survey) it is not expected that the responses are affected by substantial recall bias. It cannot be ruled out that some of the experts and fishers surveyed have answered some questions idiosyncratically according to their convenience, or to accommodate to their preconceptions. We hope that the size of the sample, that includes a high degree of redundancy in the case of expert consultations, may have contributed to limiting this bias.

Governing Marine Recreational Fishing in Future Pandemics

Policy makers are generally not aware of the enormous diversity of attitudes of recreational fishers (Johnston et al., 2010; Knoche and Lupi, 2016; Magee et al., 2018), and how they influence their interaction with other components of socio-ecological systems (Fenichel et al., 2013; Hunt et al., 2019; Matsumura et al., 2019). Although this study showed the importance of recreational fishing for the health and well-being of all practitioners involved, we demonstrated that the COVID-19 pandemic had a greater impact on *advanced* fishers.

During the COVID-19 socioeconomic crises, policy makers sometimes were not able to clearly define which activities should be considered essential during lockdowns, with important differences within and among countries (Storr et al., 2021). We highlighted important spatiotemporal differences regarding the possibility of practicing marine recreational fishing, varying according to the development of the pandemic between countries, and even regions within countries. Thus, while in most countries recreational outdoor activities, including marine recreational fishing, were not allowed for some periods, in some countries (e.g., Denmark, Latvia, the Netherlands, Norway, or Uruguay in our study), or the United States (Paradis et al., 2021), governments encouraged outdoor activities keeping social distances.

Social restrictions imposed in many countries led to an increase in the global demand of the population for the outdoors (Ding et al., 2020), and the more *advanced* recreational fishers particularly suffered from a lack of access to blue areas, especially for those living in urban areas (Rice et al., 2020; Venter et al., 2020; Herman and Drozda, 2021; White et al., 2021b). As a result of the frustration of fishers with restriction measures imposed to recreational fishing access there were some protests, e.g., in France, or Greece, at a time of great uncertainty.

Individual outdoor leisure activities facilitate social distancing and indirectly mitigate the spread of COVID-19 (Güzel et al., 2020), especially when practiced in natural areas (Venter et al., 2020). In this work, as also found by other authors (e.g., Howarth et al., 2021), we show that the practice of marine recreational fishing improves the perceived health and well-being of the population during a pandemic. Allowing access of marine recreational fishers would significantly contribute to reducing important socioeconomic impacts, especially on the most vulnerable population groups. Following Freeman and Eykelbosh (2020) distance between recreational fishers should be maximized to minimize interactions, e.g., limiting access to popular fishing spots, restricting the number of fishers on boats, or enabling temporal access restrictions to different groups of people to avoid overcrowding.

As we also demonstrated in this study, the benefits derived from lower human disturbances, among other impacts, on marine ecosystems should not be overlooked (see also Cooke et al., 2020). However, the main human impacts on global marine ecosystems are far from being reduced (Ripple et al., 2017). It is unlikely that the health of the world's marine ecosystems will show sustained improvement once the COVID-19 pandemic has been brought under control (see Corlett et al., 2020; Soga et al., 2021). Therefore, as suggested by other authors (e.g., China et al., 2021), in the event of a new pandemic in which recreational activities are not restricted in natural areas, it would be advisable to limit peoples' impacts in the more degraded peri-urban areas, favoring the dispersion of the population in larger areas to limit the excessive concentration of their impacts.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because most of questionnaires are property of different agencies and institutes. They could be asked individually to get the data. Requests to access the datasets should be directed to PP, pablo.pita@usc.es.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2021.735741/full#supplementary-material

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