First Central Mediterranean Scientific Field Study on Recreational Fishing Targeting the Ecosystem Approach to Sustainability

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The Maltese Islands have a very active recreational fishing community which may affect the coastal marine ecosystem. Despite this, studies to scientifically document the effects of this activity have been lacking prior to works between July 2012 and June 2017 presented here as a case study. This project, with the aim of collecting long-term data on the characteristics, trends, catches and impacts to fish populations of the recreational shore sport fishery at the national level also involved a pilot study on hobby shore angling. Two thousand five hundred and eighty nine roving-access creel surveys conducted during 132 sport fishing events and 159 catches from hobby fishers were documented with the methodology used also applicable to shore fishing taking place in the Mediterranean and elsewhere. Ninety species belonging to twenty-nine families were documented with the most common being the Sparidae and Labridae. Catch per unit effort was higher for sport fishers with hobby fishers targeting larger fish. Results from this case study go to augment the limited and necessary knowledge on this fishing sector in the Mediterranean. Findings also indicate that recreational fisheries need to be taken into account when considering conservation measures for national, regional and global fisheries management.

Keywords: conservation, Mediterranean Sea, recreational fishing, sport fishing, sustainability, monitoring, fishery management for conservation

INTRODUCTION

As more reports state that overfishing is mostly found in the Mediterranean, it is essential to consider sustainable management of any fishing activity in the region through research required to guide and monitor its effectiveness (FAO, 2008; Vella, 2009). In fact, under the Common Fisheries Policy, Mediterranean countries are obliged to restore all stocks' sustainability rates by 2020. Until recently, recreational fishing (RF) in the EU and Mediterranean has been considered as small and marginal with no impacts on the marine ecosystem. However, as this activity has increased through the years it has become clear that it requires critical consideration toward targeting its sustainable management (Font and Lloret, 2014) to avoid impacts on marine biodiversity, ecosystem services, and full-time traditional artisanal fishing (Prato et al., 2016).

In the Mediterranean, RF plays important economic, social and cultural role and is a flourishing activity in coastal areas (Font et al., 2012) where it generates a pressure on the service sector in places where it is exercised (Franquesa et al., 2004). It is largely the domain of small-scale

concerns operating in coastal areas (Morales-Nin et al., 2005) and involves 10% of the total fisheries production in the area. It principally involves hook and line angling (McPhee et al., 2002; Arlinghaus and Cooke, 2009) where specific methods are used by anglers to pursue selected species or else catch any available species through various means (Griffiths, 2012). RF may also involve activities offshore which focus mostly on deep water resources and big game fishing, typically carried out by fishers who can afford to purchase costly high-quality gear (Thrush et al., 1998; Font et al., 2012) which *de facto* increases fishing efficiency (Lloret et al., 2016). These include electronic equipment, such as GPS, depth sounders, fish finders and sensitive fine tipped graphite rods and invisible fluorocarbon lines.

Despite this, a sound information base and adequate management plan for RF are still lacking (Font et al., 2018). Acquiring sound estimates of vital factors from RF is still challenging but critical for stock assessment and management of ecosystems (Griffiths et al., 2010). Available data on Mediterranean RF catches, caught by hook and line angling or spearfishing show that effects are not to be ignored (Chavoin and Boudouresque, 2004; Cadiou et al., 2009). The removal of biomass in many areas is considerable, especially when one relates it with artisanal fishing, thus confirming the seriousness of the impact on marine resources caused by RF (Font and Lloret, 2014). In Europe an estimated 8.7 million (1.6%) engage in marine recreational fishing (MRF) activities totaling an estimated 77.7 million fishing days annually (Hyder et al., 2018), where besides contributing economically, other benefits such as "relaxation, exercise and experience of nature" (DG MARE, 2017) are gained. The effects of RF therefore merit further investigation to ensure its compatibility with sustainable exploitation of living aquatic resources (European Commission, 2006). Since 2002, there has been an increase in research on European fisheries and their management, since the assessment of recreational catches of some species including bass, cod, salmon, bluefin tuna, eels, and sharks, becoming a requirement through legislation (CEFAS, 2011; Ferter et al., 2013).

USA and Australia are well ahead of Europe when it comes to the collection and use of RF records (EAA, 2016). However, a number of species have been listed for inclusion in data collection for the Mediterranean. They are all highly migratory species falling under ICCAT's mandate: Eels and elasmobranchs (European Commission, 2016). In Europe, some MRF management measures have been employed and should affect future catches. These include prohibition of RF for European eel (*Anguilla anguilla*), bag limits with seasonal variations for cod (*Gadus morhua*) (European Council, 2017a) and only catch-and-release fishing allowed for sea bass (*Dicentrarchus labrax*) by RF in the North Sea and Atlantic (European Council, 2017b). The latter was subsequently changed to allow one specimen of *D. labrax* to be retained per fisher per day (European Council, 2018). Fishing and landing of several shark species has also been prohibited (European Council, 2019) while the European Union habitats directive protects wild Atlantic salmon (*Salmo salar*) and its major spawning sites.

The recreational angling community also holds a wealth of historical data. However, this has seldom been used for monitoring, scientific research and management purposes, mainly because data are provided in diverse formats and are generally not easily accessible (Dedual et al., 2013). Hence, improved data accessibility and better understanding of the different perspectives among all stakeholders including fishery scientists, managers and the recreational fishery sector are also required for RF management (Dedual et al., 2013; Morales-Nin et al., 2015) since these may provide different views on the RF industry (Hasler et al., 2011). Over 6 million Europeans are members of their local fishing clubs and/or a national angling association (Brainerd, 2011). A number of common fishing behaviors exist amongst anglers participating in fishing competitions. These include motives, attitudes and preferences irrespective of the location they are fishing (Wilde et al., 1998). Recreational fishers are often considered to be sensitive to the environment in which they fish and the need to manage aquatic resources they depend on (Gaudin and Young, 2007; FAO, 2012). Thus, while some of the fish caught by anglers are kept for their own consumption (Rudd et al., 2002; Cooke and Cowx, 2004), substantial fish are released shortly after capture. This may be due to the fish caught being different from that targeted (smaller, size, undesirable species etc.) or catch-and-release is practiced by the angler (Cooke and Suski, 2005). Legal sizes [Regulation (EC) No 1967 2006], daily bag limits, minimum hook sizes and support of catch-and-release fishing (Cooke and Schramm, 2007; Alós et al., 2009) have steadily become significant tools to manage RF. Although some fish may perish post-release, there is a great reduction in fishing mortality compared to the mortality associated with planned fish retention (Cooke and Schramm, 2007). However, survival rates and successful reproduction of released fish must be managed to ensure that mandatory or voluntary practices are effective (Bartholomew and Bohnsack, 2005).

Legislation Regulation for Recreational and Sport Fishing

Although many Mediterranean countries have MRF regulations, these vary by country and region (Franquesa et al., 2004). Very few Mediterranean countries have a mandatory system of licenses in place and often not all methods are covered (ICES, 2017). To date the European Commission has introduced some universal advice and some recommendations for sustainability regulation and the collection of data in the Baltic sea and North Sea for salmon and bluefin tuna (European Commission, 2001) managed by international commissions, such as ICCAT. In most European countries, there are only approximate figures of participating recreational fishers, their overall catches, and expenditure, while in others, no information is available (Herfaut et al., 2013).

In the Canary Islands, a fishing license is required. When carrying out RF from the shore or from boats, only a fishing rod or handline with a maximum of 3 hooks per line is permitted with boats also allowed to carry out trolling and use squid-jigs. Both natural bait and lures are permitted while electronic fish attractants are forbidden (Jiménez-Alvarado et al., 2019). In Portugal, a license is also required where a daily bag limit of

10 kg per angler is specified during shore fishing (Presidência do Conselho de Ministros e Ministérios da Defesa Nacional, 2006). The legislation also includes minimum legal sizes (MLS) for both commercial and RF which aims to permit the survival of sufficient juveniles to reach spawning size (Stergiou et al., 2009). Previous legislation (Decree law 246/2000) had already defined allowable RF gears and prohibited selling or displaying of catches for sale (Pawson et al., 2007). Restrictions in Portugal were however implemented with minimal scientific data on the effects of this type of fishing activity on marine stocks and no studies on the demography and figures of the recreational marine fishing population (Veiga et al., 2013). Similarly, Spain presents the most restrictive policies (Franquesa et al., 2004; Gordoa et al., 2019) where a number of regulations regarding classes, tackle and equipment, off-season periods and areas, authorized species and daily bag limits (Decreto, 347/2011) are in force. Sport fishing licenses are only required to participate in official fishing contests (Gordoa et al., 2019). In the Balearic Islands, legislation limits both fishing effort, specifies daily bag limits and stipulates minimum landing sizes and closed seasons for certain species (Morales-Nin et al., 2015). In France, RF is subject to only limited regulation. There is no licensing system or registry of marine recreational fishers (Franquesa et al., 2004; Herfaut et al., 2013). At the other end of the spectrum, Italy is lacking in policies related to RF (Franquesa et al., 2004). Permits are not required for sport or RF activities. Fishing is however subject to a list of permitted gear types, time and area restrictions with sale of catch prohibited (President of the Italian Republic, 1968, 2012; Pawson et al., 2008) and respect of fish minimum sizes required. In addition, for anglers to engage in sportfishing competitions, it is obligatory for them to be enrolled with the national sport fishing federation with reporting of catch data also required (FAO, 2016). Commercial fishing gear is prohibited for use by recreational fishers and only fishing lines are permitted (Pawson et al., 2008), In Albania a license is required only if the individual recreational fisher intends to use a boat while in Greek waters, fishing from the shore does not require a license but is prohibited at night and sale of fish caught is prohibited (Pawson et al., 2008). MRF fishing by sea angling, vertical lines and trolling in Cyprus are exempted from a fishing license. Other categories of MRF including boats with nets (>400 m) and longlines (limited to 100 hooks) and traps, scuba divers, spear fishing, and fishing with nets from the shore all require a license with stipulated daily catch limits for selected species (FAO, 2005; Ulman et al., 2014). Marine recreational fisheries in Turkey also does not require a compulsory license, but a document is given to anglers who wish to certify their activities (Ünal and Göncüoglu, 2012). Tourists are only allowed to practice boat-based and shore-based fishing, with the former requiring a fishing tourism certificate. Policies include prohibition of sale, prohibition of catch of certain species, daily bag limits, length, and weight limits and restriction of gear types (Unal et al., 2010). In Syria and Egypt, an individual RF license is required while in Lebanon, Morocco, and Tunisia, a license is required for recreational underwater fishing (Cacaud, 2005). On the other hand, RF in Algeria is unregulated (Babali et al., 2018). No information was available for Libya.

Case Study: Recreational Fishing in the Maltese Islands

The Maltese Islands are an archipelago located in the Central Mediterranean and the smallest EU member state in terms of territory, population, and economy (Harwood, 2019). The Maltese fishing fleet is predominantly small-scale with 94% of vessels under 10 m in length (NSO, 2018). They employ various modes of artisanal fishing methodologies with seasonal changes in species targeted (Vella and Vella, in press). Very few vessels operate in larger scale or in open seas (Vella, 1999). Maltese small-scale fishers are one of the smallest fisheries in Europe. They face important challenges due to competition with other maritime activities and decline in fishing space (Vella and Vella, 2019) owing to other maritime activities co-occurring in Maltese shallow waters. These include tourism related activities such as pleasure cruises, aquaculture for gilthead bream, sea bass and tuna penning, bunkering activities and yacht marinas. With 2,977 vessels (NSO, 2018), the Maltese fishing fleet accounts for 1.1% of the fishing fleet in the EU (Eurostat, 2017a) with landings of just under 2,000 tons annually (NSO, 2017), equivalent to only 0.1% of the total EU catch (Eurostat, 2017b). The main exploited species include horse mackerel (*Trachurus* sp.), dolphinfish (*Coryphaena hippurus*), swordfish (*Xiphias gladius*), bluefin tuna (*Thunnus thynnus*), and demersal species. The dolphinfish on its own, comprises 11% of the total commercial catch (NSO, 2017) and is of primary economic importance in Malta especially for the Maltese artisanal fishery (Vella, 1999). Although the economic contribution to the national Gross Domestic Product (GDP) at about 0.1% is negligible, the Maltese fishing industry provides important social and cultural influences (FAO, 2015).

Category C vessels (MFC), licensed for RF, comprise 68% of the total fishing fleet (NSO, 2018). Professional fishing operations such as "the use of towed nets, surrounding nets, purse seines, boat dredges, mechanized dredges, gillnets, trammel nets and combined bottom-set nets and longlines for highly migratory species are prohibited" (Government of Malta, 2013). Minor gears including set bottom longlines, traps, trolling lines and jigging (European Commission, 2006) are permitted. The National Maritime Register also registers vessels employed in RF. A fishing license is not required, and only sport fishing gear is permitted (Gaudin and Young, 2007; FAO, 2015). Since 2014, permit applications for boat owners practicing MRF for bluefin tuna have opened annually. The permit is open between June and October. The recreational quota was 1 ton in 2014 increasing to 2 tons in 2015 (Source: ICCAT), equivalent to around 2% of the national total allowable quota (TAC).

MRF in the Maltese islands is an important activity involving both hobby fishing and sport fishing. Hobby fishing is fishing for leisure. Sport fishing is very competitive. Fishers enroll with a sport fishing club and participate in shore fishing competitions organized on a regular basis by their club. Sale of fish caught during RF activities is prohibited (European Commission, 2006; Pawson et al., 2007) with the exception that fish caught from sporting competitions may be sold so long as "*the profits from their sale are used for charitable purposes*" (European Commission, 2006). Since no fishing licenses are required, an absence of data regarding the total

figure of recreational shore anglers exists, making data collection challenging. Recently, a recreational fisheries board was set up with the aim of introducing possible management measures such as the reduction of fishing effort (Government of Malta, 2013).

The first shore sport fishing club was set up in 1995 and it is only recently that this sport has picked up. A few years ago, three other sport fishing clubs were instituted, each holding its own leagues and competitions. All clubs are affiliated with the National Federation of Sports Angling Malta (NFSAM) while EFSA-Malta, a branch of the European Federation of Sports Anglers is also present. Catch and release is required during all competitions and use of keep nets (nets for keeping live fish which are hung near the angler and extend partly into the sea) is specified by club competition regulations (KSFA, 2012; Denci Club, 2014; NFSAM, 2018).

With the exception of bluefin tuna catches, national surveys addressing MRF in the Maltese islands are inexistent. Regulation and control over the catches by recreational fishers are absent. Recently, two studies have attempted to estimate RF catches in the Maltese Islands using specific accessible means. A study by Giovos et al. (2018) attempted to identify boat based recreational fisheries in the Mediterranean, including Malta using social media, while Khalfallah et al. (2017) reconstructed the catches for Malta, including recreational fisheries through extensive research of published data. However, both studies fell short of providing an accurate data set and should be considered with caution. In the former, Giovos et al. (2018) used videos from social media, however, most anglers do not upload their catches on social media. Other factors including fishing effort, total catch, date and location cannot be accurately documented from videos. Khalfallah et al. (2017) reconstructed catches based solely on a pilot study taking place in 2005 and ignored non MFC vessels and shore-based anglers. Monitoring of this type of fishery is however essential and catches should be scientifically documented and included with those of commercial fishers for conservation management of affected marine biodiversity and ecosystem.

Objectives of This Study

The present work developed a methodology to monitor sport and hobby fishing in the Maltese Islands through the use of modified creel surveys, which are sampling surveys that target recreational anglers to collect data regarding the quantity and species caught by this type of fishery. It is used to document gear types, preferred locations and assess the adoption and effectiveness of catch and release practices. It aims to contribute to the information of current utilization of coastal fish resources and provide scientific data on which to implement management criteria directed at their protection and conservation.

MATERIALS AND METHODS

Sampling Strategy

The present work involved collection of detailed data through fieldwork in collaboration with sport fishing clubs, federations, and recreational fishers. On-site species catch data for both sport fishing and hobby fishing was carried out between July 2012 and June 2017 as part of a project to monitor the shore sport fishery in the Maltese Islands. All the 4 sport fishing clubs, local federations and tackle shops participated in the data collection. Simultaneously, between April 2013 and December 2017, a pilot study with shore hobby fishers was integrated to document this fishing activity around the Maltese Islands. Roving access creel-surveys (McCormick et al., 2012, 2013) were used in both cases. The authors had no involvement in the choice of fishing locations which were selected by the clubs or anglers generally after consulting the weather forecasts. During competitions, anglers were very briefly interviewed regarding their fishing method, bait and hook sizes used while fishing close to the end of every competitive event to allow them to exhaust all the different fishing methods (Lockwood, 2000) required for that particular competition. The interview aimed to disturb the anglers a little as possible and only comprised the following three questions:

(1) Which fishing methods did you use?
(2) Which bait did you use?
(3) Which hook sizes did you adopt?

At the end of the competition, catches were weighed and quickly placed on a specially designed rectangular catch board with an affixed scale, photographed and the dead ones removed and counted. All live fish were then released. During hobby fishing observations, the same information was documented at the end of each fishing trip. These were also supplemented with catch photographs supplied by hobby fishers who also provided the location fished and the same information collected during the on-site creel surveys. The use of a keep net was noted in both cases. Hook gape width was measured using a Vernier caliper ($\pm$0.01 mm) from hooks supplied by tackle shops or the anglers themselves. Sea surface temperature was measured on site ($\pm$0.1°C) whenever possible or the mean sea temperature as provided by the Met Office was used when the sea was not accessible (e.g., cliff competitions).

Data Analysis

All catches were standardized to show the catch-per-unit-effort (CPUE: number/weight of fish of a specific species per fishing hour). Club records were used in addition to on-site observations to calculate the mean annual catch by weight based on the complete years documented (2013–2016). The Kruskall Wallis H test was used to determine if there was a difference in the overall mortality across the years. Automatic linear modeling (ALM) was also used to assess the effect of location, duration of competition, time of catch, use of keep net, sea temperature and year of competition on the mortality rate.

The relationship between mortality and the other variables was described in terms of Equation (1):

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \qquad (1)$$

Where y = dependent variable (fish mortality), β_0 =constant variable, $\beta_{1\ldots} \beta_n$ are regression parameters, $X_1, X_2, X_3 \ldots \ldots X_n$ = predictors (location, duration of competition, use of keepnet etc.). In the case of categorical variables, the number of estimated parameters was one less than the number of categories, where the last category is the alisaed term (which is set to zero). E.g., For use

of keepnet, where keepnet = 1 and no keepnet = 0 resulted in the following equation:

$$y = \beta_0 + \beta_1 D + \beta_2 X_2 + \ldots + \beta_n X_n \qquad (2)$$

where D = category variable

If D = 0, then:

$$y = \beta_0 + \beta_2 X_2 + \ldots + \beta_n X_n \qquad (3)$$

If D = 1, then

$$y = \beta_0 + \beta_1 + \beta_2 X_2 + \ldots + \beta_n X_n \qquad (4)$$

The model was selected using a forward stepwise method with the corrected Akaike Information Criterion (AICc) and included predictor variables at $P < 0.05$. All outliers from continuous predictor variables (temperature) were removed and categorical variables (locations) were merged to maximize the association to the target variable (fish mortality). The model with the lowest AICc value was selected (Burnham and Anderson, 2002).

The significance threshold was set at an alpha value of 0.05 in this study as for related studies (Gartside et al., 1999; Veiga et al., 2010; Zischke et al., 2012). All statistical analyses were performed using IBM SPSS Statistics ver.24 (IBM Corporation, Somers, NY, USA).

RESULTS

Fishing Effort

Data was collected during 132 sport fishing competitions in 45 different locations. Information from 2,589 roving-access creel surveys was recorded. This represented 60% of the total open competitions taking place during the study period. One hundred and fifty nine catches by hobby anglers were also documented from 44 different locations. Fishing effort totaled to 11,667 h during competitions and 518 h during hobby fishing observations. The mean annual weight of fish caught during fishing competitions was 680.87 kg (SD ± 99.42). Sport fishing was predominantly male oriented with very few female anglers participating in the sport. Average angler participation during fishing competitions was 9.6 (SD ± 9.4) anglers per event and varied during the study period. The average overall number of fish caught per angler per hour (CPUE$_n$) was 4.52 fish angler h^{-1} (SD ± 4.33) during competitions and 1.97 (SD ± 3.14) fish angler h^{-1} during hobby fishing. During hobby fishing day sessions (47.8% of the sessions documented) 3.02 (SD ± 4.19) fish angler h^{-1} were caught, decreasing to 1.01 (SD ± 0.98) fish angler h^{-1} during the night (52.2% of the sessions documented) and with 7.6% of the fishing trips resulting in no catch. The average weight (kg) of fish caught per angler per hour (CPUE$_{kg}$) was 0.19 kg angler h^{-1} (SD ± 0.18) for all sport fishing competitions. Sports anglers fished for 4.51 (SD ± 0.64) h while hobby fishers spent 3.26 (SD ± 1.41) h fishing per trip.

Fishing Density

Fishing competitions were held in various locations which were chosen by the clubs a few days before the competitions.
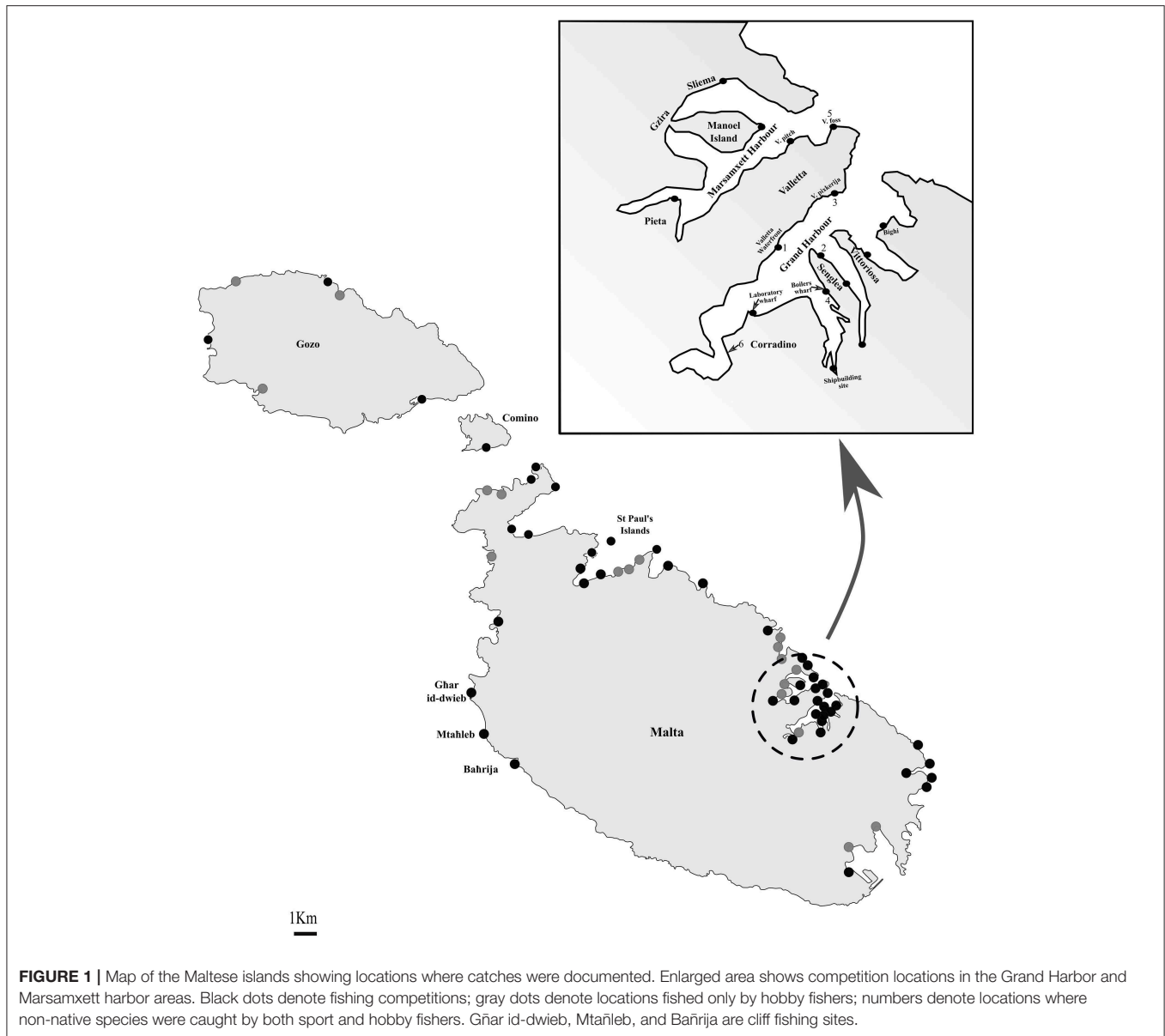
Competitions were held in ports, rocky areas facing the open sea, cliff sites and occasionally beaches. The most popular locations for competitions were Manoel Island (9.9%) and Sliema (8.3%), two sheltered locations enclosed within Marsamxett harbor (**Figure 1**). The latter was also popular with hobby fishers (8.2%) followed by Valletta (Foss) (6.9%). Sliema was also the most frequented by hobby fishers for night fishing (10.8%) while Marsa was the favorite location for day fishing (10.5%). The most popular sites for cliff fishing competitions were Mtaħleb (6.1%) and Baħrija (3.0%). Both sites were also frequented by hobby fishers (3.6 and 1.2%, respectively) for night fishing.

Tackle and Bait Use

Anglers taking part in competitions invested in various types of rods and tackle. Rods varied from light fine tipped graphite rods used mostly during daytime competitions to more robust equipment used at night or during cliff fishing. The favorite rig for both sport and hobby anglers was the paternoster rig setup using a reel rod (**Table 1**). This involved a sinker attached to the end of the line with two hook traces above and used primarily to target bottom fish. Another popular setup among both types of anglers was the pole rod with a fixed float or a reel rod set up with a running float (**Table 1**). In the first setup, a fixed float is used which can be shifted along the line with varying depth. Here, the maximum depth must not exceed the rod length, which is rarely longer than 6 m. The running float permits fishing in deeper waters since a stopper for the float is used anywhere along the line depending on the depth fished. Hobby anglers also used a very simple setup called the free hook system whereby a line with a hook attached at the end was set up on a fishing pole and baited. Such tackle was used primarily during night fishing. There was no restriction on hook sizes, which varied depending on the type of location and time fishing (**Table 2**). Larger hooks were primarily used during the night and cliff fishing competitions while smaller hooks were used during day competitions. A smaller range of hook sizes were used by hobby fishers where hook sizes at both extremes were not utilized.

Recreational fishers routinely used certain fish species and other bait which varied depending on fishing technique and the target fish. The most popular bait was live polychaete worms, with the widely available Korean worm, *Nereis* sp. being the most popular (**Table 3**) during fishing competitions and also popular amongst hobby anglers. Bristle worms, *Eunice* sp. which are collected locally were frequently used for night fishing, while, the American bloodworm (*Glycera dibranchiata*) was also occasionally used and included with the "other bait." The Korean and American worms were purchased at reasonable prices from tackle shops while Bristle worms were harvested locally by divers and sold at premium prices.

Another class of bait used were cephalopods which were generally used in pieces during cliff fishing by night together with various pieces of fish (*Alosa fallax* and *Auxis rochei,* also included with "other bait"). Crustaceans, notably freshwater crayfish and locally harvested mud shrimp (*Upogebia pusilla*) were popular with sports anglers during competitions. The latter is very scarce and sold at premium prices by individuals who harvest them from areas high in sediment. Some anglers opted for the cheaper

FIGURE 1 | Map of the Maltese islands showing locations where catches were documented. Enlarged area shows competition locations in the Grand Harbor and Marsamxett harbor areas. Black dots denote fishing competitions; gray dots denote locations fished only by hobby fishers; numbers denote locations where non-native species were caught by both sport and hobby fishers. Għar id-dwieb, Mtaħleb, and Bañrija are cliff fishing sites.

commercially available freshwater crayfish instead while two clubs prohibited the use of mud shrimp during competitions.

Catch Composition

A total of 51,822 fish belonging to 90 species from 29 different families were identified from the competition catches (**Figure 1**) while 1,000 fish belonging to 31 species were identified from the catches by hobby fishers (**Table 4**). During both competitions and hobby fishing, the Sparidae and Labridae had the highest species richness albeit lower for hobby fishers. The three most frequently fished species by sport fishers were *Coris julis*, *Diplodus annularis*, and *Diplodus vulgaris* which together comprised 33.31% of the total catch. *Diplodus sargus*, *Oblada melanura*, and *Chromis chromis* were the most frequently caught by hobby fishers. Five non-native species were also recorded during fishing

competitions, four of which were recorded locally for the first time. These were the Dusky spinefoot (*Siganus luridus*), the Niger hind (*Cephalopholis nigri)*, the cocoa damselfish (*Stegastes variabilis*), the Dory snapper (*Lutjanus fulviflamma*) and the Indopacific sergeant (*Abudefduf vaigiensis*), with the latter also caught during a hobby fishing observation. All these specimens were caught from the Grand Harbor area which has a very active schedule of cruise liners, grain and cement carrying ships, ship repair, and bunkering activities (**Figure 1**).

Catch and Release

Overall, catch and release (C & R) was practiced by 69% of the anglers during sport fishing competitions while the remaining 31% used water filled buckets. Keepnets were not utilized during cliff competitions since fish could not be released

TABLE 1 | Tackle used during fishing competitions and hobby fishing.

Tackle	Sport fishing competitions					Hobby fishing		
	All events	Day shore	Night shore	Day cliff	Night cliff	All	Day	Night
Paternoster reel	56.5	54.1	61.2	100	100	31.6	19.5	43.2
Paternoster pole	3.8	4.0	1.5	0.0	0.0	0.6	0.0	1.2
Running ledger	8.0	8.4	7.5	0.0	0.0	4.4	2.6	6.2
Running float	8.8	9.4	3.0	0.0	0.0	12	16.9	7.4
Mullet float fishing pole	0.7	0.6	9.0	0.0	0.0	2.5	5.2	0.0
Mullet bolonaise	5.6	6.0	0.0	0.0	0.0	8.2	15.6	1.2
Fixed float pole fishing	13.1	14.0	9.0	0.0	0.0	13.3	24.7	2.5
LRF	0.1	0.1	0.0	0.0	0.0	1.3	0.0	2.5
Free hook	0.1	0.1	4.5	0.0	0.0	17.1	2.6	30.9
Other tackle	3.2	3.4	4.5	0.0	0.0	8.9	13.0	4.9
Total	100	100	100	100	100	100	100	100

Numbers denote percentage.

TABLE 2 | Mean width of hooks frequently used by anglers and their preference by sport fishing and hobby anglers.

Hook size no	Mean gape width (mm)	SD	Fishing competitions					Hobby fishing	
			All events	Day shore	Night shore	Day cliff	Night cliff	Day	Night
6/0	21.05	0.95	0.1	0.0	0.0	0.0	2.4	–	–
5/0	19.53	1.84	0.1	0.0	0.0	0.6	2.4	–	–
4/0	18.31	1.23	0.4	0.0	1.5	0.0	13.4	–	–
3/0	17.03	1.11	0.3	0.0	3.0	0.6	8.5	–	–
2/0	14.80	1.23	0.2	0.0	1.5	1.1	4.9	–	–
1/0	13.39	1.80	0.3	0.0	1.5	1.7	6.1	–	–
1	12.12	1.61	0.3	0.2	3.0	0.6	3.7	2.3	1.2
2	10.79	1.63	0.8	0.4	6.1	0.6	11.0	2.3	5.8
3	9.04	0.80	0.5	0.2	0.0	2.2	8.5	0.0	7.0
4	8.42	0.62	2.0	0.7	6.1	12.2	36.8	4.7	14.0
5	7.75	0.44	1.0	0.3	3	10.6	3.7	1.2	9.3
6	7.21	0.66	2.7	1.3	7.6	23.9	7.3	8.1	15.1
7	6.67	0.32	1.4	0.8	3.0	11.1	0.0	4.7	18.6
8	6.12	0.32	5.2	4.6	7.6	17.8	1.2	8.1	3.5
9	5.47	0.41	1.2	1.3	0.0	0.0	0.0	1.2	0.0
10	5.55	0.52	24.4	25.9	24.2	10.0	0.0	14.0	10.5
11	4.69	0.11	1.5	1.6	0.0	0.6	0.0	2.3	2.3
12	4.70	0.54	29.2	31.7	13.6	2.8	0.0	30.2	12.8
13	4.52	–	0.1	0.1	0.0	0.0	0.0	2.3	0.0
14	4.34	0.82	18.2	19.6	15.2	3.3	0.0	18.6	0.0
15	3.92	0.20	0.3	0.3	0.0	0.0	0.0	–	–
16	3.64	0.41	5.3	5.7	3.0	0.6	0.0	–	–
17	3.44	–	0.1	0.1	0.0	0.0	0.0	–	–
18	3.25	0.24	2.1	2.3	0.0	0.0	0.0	–	–
20	2.67	0.26	0.8	0.8	0.0	0.0	0.0	–	–
22	2.62	–	0.8	0.8	0.0	0.0	0.0	–	–
24	2.41	–	0.6	0.6	0.0	0.0	0.0	–	–
26	2.26	–	0.4	0.4	0.0	0.0	0.0	–	–

SD denotes standard deviation.

from such heights above sea level. Seventy-five percent of the anglers used keep nets when these competitions were excluded. The overall mean mortality rate was 35.80% (SD ± 39.46), 30.35% (SD ± 36.18) during day competitions when cliff competitions were excluded since the latter had 100% mortality.

Only a few night competitions were held and documented so these were not analyzed separately. A total of 32,422 fish were released after competitive events during the study period. Only 23.90% of hobby fishers were observed to use keep nets. A lower mortality rate was observed when keep nets

TABLE 3 | Bait used during fishing competitions and hobby fishing.

Bait	Sport fishing competitions					Hobby fishing		
	All events	Day shore	Night shore	Day cliff	Night cliff	All	Day	Night
Korean worm	40.0	40.7	28.0	46.1	3.5	20.3	20.3	20.2
Frozen shrimp	28.6	29.6	19.4	20.7	6.2	8.5	14.5	3.6
Fresh shrimp	3.1	2.7	0.0	14.0	0.0			
Imported crayfish	1.1	1.2	0.0	0.0	0.0	0.7	0.0	1.2
Mud shrimp	6.2	6.7	0.0	0.0	0.0			
Milk bread	10.8	11.5	18.3	0.0	0.0	11.8	23.2	2.4
Bread	1.8	1.9	2.2	0.0	0.0	14.4	12.7	8.3
Maggots	1.5	1.5	4.3	0.0	0.0	8.5	15.9	2.4
Bristle worm	1.7	0.5	15.1	0.7	49.6	26.1	2.9	45.2
Paddled blood worm	0.2	0.2	0.0	0.0	0.0	0.7	0.0	1.2
Pastella (bait mixture)	0.9	0.9	2.2	0.0	0.0			
Chicken	0.0	0.0	0.0	0.0	0.0	7.8	0.0	14.3
Other	4.1	2.4	10.8	18.5	40.7	1.3	1.4	1.2
Total	100	100	100	100	100	100	100	100

Figures denote percentage.

were used [keep net = 35.91% (SD ± 42.97); no keep net = 81.80% (SD ± 37.07)].

Several measures aimed at reducing the mortality rate and catches of juvenile fish were put in place by the NFSAM in 2017 after consultation with the authors. These included a minimum hook size of gape width 5 mm, water changes every hour when keep nets could not be used, and the removal of visibly manhandled fish from the catch before weighing. The latter measure was also adopted by all fishing clubs. One club also adopted the use of a minimum hook size of gape width 7 mm during cliff fishing competitions.

To assess if these changes were significant in lowering the mortality rate, 11 competitions were documented between January and June 2017. To remove the bias in post-capture mortality that may be present when considering a full year, only the period from January to June was used to establish significance (**Table 5**). The Kruskal-Wallis H test showed that there was a statistically significant difference in mortality between the different years, (2013, $n = 105$; 2014, $n = 197$; 2015 $n = 341$; 2016, $n = 445$; 2017, $n = 230$), χ^2 (4, $n = 1,318$) = 44.55, $p = <0.001$. The post-capture mortality median score was the lowest in 2013 (Md = 7.14) increasing yearly and reaching a peak in 2016 (2014, Md = 11.11; 2015, Md = 12.5; 2016, Md = 18.18) and then decreasing drastically in 2017 (Md = 7.06). Overall mortality in 2017 was however only significantly different ($P = <0.001$) from that in 2016 and 2015.

The linear regression model used to assess the effect of location, duration of competition, time of catch (day/night), use of keep net, sea temperature and year of competition for overall mortality (excluding cliff competitions) revealed that the use of keep net, sea temperature, capture location, and duration of competition were significant predictors of the fish mortality (**Table 6**). (Mortality: $n = 2,067$; mean mortality ± SD: 30.39 ± 36.23; Model AICC: 13,455.28, $r^2 = 0.491$; Intercept Coefficient:

16.89, $P = 0.008$; Keep net coefficient: −44.31, $P < 0.001$; Duration coefficient: 5.60, $P < 0.001$; Sea temperature coefficient: 0.89, $P < 0.001$; Location group 0 coefficient: −5.91, $P < 0.205$; Location group 1 coefficient: 3.09, $P = 0.21$; Location group 2 coefficient: −1.41, $P < 0.15$; Location group 3 coefficient: 1.18, $P = 0.15$; Location group 4 coefficient: 15.79, $P < 0.001$; Location group 5 coefficient: 22.68, $P < 0.001$; Location group 6 coefficient: 4.99, $P = 0.001$. The time of catch and year of competition predictor variables tested did not significantly affect the mortality rate (**Figure 2**).

DISCUSSION

This long-term study documented several shore-based angling options as observed by the diversity of fishing techniques recorded and the numerous fish species caught. Such dedicated and detailed investigations allow an in-depth consideration of the impacts of these activities on the fish communities and the marine ecosystem. The methodology used in this study to document the fish catches can also be applied to fishing competitions taking place outside the Maltese Islands. One example is those organized by FIPS-M (Fédération Internationale de Pêche Sportive—Mer) which has 47 affiliated countries and organizes several international tournaments on a yearly basis. In particular, the European championships of float angling, which follow a very similar modality to fishing competitions documented in this study. Within each participating country including Malta, competitions are also held in which anglers qualify to represent their country in this European championship. The same system of placing fish in keepnets and weighing them at the end of the competition is used, without collecting any information on the fish caught. This method would therefore provide a rapid and cost-effective way to

TABLE 4 | Total catch number and percentage of species caught during fishing competitions and by hobby fishers in this case study.

Family	Species	Common name	Competitions		Hobby fishing	
			Total catch number	Percentage %	Total catch number	Percentage %
Sparidae	*Diplodus annularis*	Annular seabream	5,218	10.08	99	9.91
	Diplodus vulgaris	Two banded seabream	4,397	8.5	64	6.41
	Diplodus sargus	White seabream	333	0.64	146	14.61
	Diplodus puntazzo	Sharpsnout seabream	118	0.23	0	0.00
	Oblada melanura	Saddled seabream	679	1.31	114	11.41
	Lithognathus mormyrus	Sand steenbras	64	0.12	52	5.21
	Pagrus pagrus	Red porgy	565	1.09	0	0.00
	Pagrus auriga	Red banded seabream	3	0.01	0	0.00
	Sparus aurata	Gilt-head bream	45	0.09	69	6.91
	Sarpa salpa	Salema porgy	462	0.89	71	7.11
	Pagellus erythrinus	Common pandora	85	0.16	7	0.70
	Dentex dentex	Common dentex	9	0.02	0	
	Spondyliosoma cantharus	Black seabream	317	0.61	3	0.30
	Boops boops	Bogue	3,478	6.72	55	5.51
Moronidae	*Dicentrarchus labrax*	European seabass	2	<0.01	1	0.10
Labridae	*Coris julis*	Mediterranean rainbow wrasse	7,649	14.78	40	4.00
	Thalassoma pavo	Ornate wrasse	3,656	7.06	15	1.50
	Symphodus tinca	Peacock wrasse	2,467	4.77	5	0.50
	Symphodus roissali	Five spotted wrasse	840	1.62	3	0.30
	Symphodus melops	Corkwing wrasse	223	0.43	0	0.00
	Symphodus mediterraneus	Axillary wrasse	349	0.67	0	0.00
	Symphodus ocellatus	Ocellated wrasse	50	0.10	0	0.00
	Symphodus doderleini	N/A	1	<0.01	0	0.00
	Symphodus rostratus	Pointed-snout wrasse	10	0.02	0	0.00
	Symphodus cinereus	Gray wrasse	2	<0.01	0	0.00
	Labrus merula	Brown wrasse	17	0.03	0	0.00
	Labrus mixtus	Cuckoo wrasse	64	0.12	0	0.00
	Labrus bergylta	Ballan wrasse	19	0.04	0	0.00
	Labrus viridis	Green wrasse	22	0.04	0	0.00
	Xyrichtys novacula	Cleaver wrasse	8	0.02	0	0.00
Scorpaenidae	*Scorpaena notata*	Small red scorpionfish	177	0.34	0	0.00
	Scorpaena porcus	Black scorpionfish	315	0.61	3	0.30
	Scorpaena maderensis	Madeira rockfish	351	0.68	0	0.00
	Scorpaena scrofa	Red scorpionfish	28	0.05	0	0.00
Serranidae	*Epinephelus marginatus*	Dusky grouper	27	0.05	0	0.00
	Epinephelus costae	Goldblotch grouper	39	0.08	0	0.00
	Epinephelus aeneus	White grouper	4	0.01	0	0.00
	Mycteroperca rubra	Mottled grouper	5	0.01	0	0.00
	Serranus scriba	Painted comber	2,917	5.64	16	1.60
	Serranus cabrilla	Comber	967	1.87	1	0.10
	Serranus hepatus	Brown comber	307	0.59	0	0.00
	Anthias anthias	Swallowtail seaperch	818	1.58	0	0.00
	*Cephalopholis nigri	Niger hind	1	<0.01	0	0.00
Bothidae	*Bothus podas*	Wide-eyed flounder	64	0.12	0	0.00
Muglidae	*Oedalechilus labeo*	Boxlip mullet	1,579	3.05	0	0.00
	Chelon labrosus	Thicklip gray mullet	1,388	2.68	48	4.80
	Chelon ramada	Thinlip gray mullet	5	0.01	0	0.00

(Continued)

TABLE 4 | Continued

Family	Species	Common name	Competitions		Hobby fishing	
			Total catch number	Percentage %	Total catch number	Percentage %
	Mugil cephalus	Flathead gray mullet	103	0.2	14	1.40
Scaridae	*Sparisoma cretense*	Parrotfish	3,846	7.43	27	2.70
Pomacentridae	*Chromis chromis*	Damselfish	4,994	9.65	111	11.11
	*Stegastes variabilis	Cocoa damselfish	1	<0.01	0	0.00
	*Abudefduf vaigiensis	Indopacific sergeant	1	<0.01	0	0.00
Mullidae	*Mullus surmuletus*	Striped red mullet	206	0.40	0	0.00
Gobiidae	*Gobius paganellus*	Rock goby	213	0.41	0	0.00
	Gobius niger	Black goby	133	0.26	0	0.00
	Gobius cruentatus	Red-mouthed goby	205	0.40	0	0.00
	Gobius geniporus	Slender goby	102	0.2	0	0.00
	Gobius cobitis	Giant goby	17	0.03	0	0.00
	Gobius fallax	Sarato's goby	6	0.01	0	0.00
	Gobius bucchichi	Bucchich's goby	14	0.03	0	0.00
	Gobius incognitus	Incognito goby	61	0.12	0	0.00
Blenniidae	*Parablennius sanguinolentus*	Rusty blenny	29	0.06	0	0.00
	Parablennius pilicornis	Ringneck blenny	17	0.03	0	0.00
	Parablennius gattorugine	Tompot blenny	43	0.08	0	0.00
Centrachanthidae	*Spicara maena*	Blotched picarel	284	0.55	0	0.00
	Spicara smaris	Picarel	146	0.28	0	0.00
Carangidae	*Trachinotus ovatus*	Pompano	75	0.14	10	1.00
	Pseudocaranx dentex	White trevally	39	0.08	0	
	Seriola dumerili	Greater amberjack	4	0.01	1	0.10
	Trachurus trachurus	Atlantic horse mackarel	82	0.16	6	0.60
Synodontidae	*Synodus saurus*	Atlantic lizardfish	29	0.06	0	0.00
Trachinidae	*Echiichthys vipera*	Lesser weever	5	0.01	0	0.00
	Trachinus draco	Greater weever	4	0.01	0	0.00
Apogonidae	*Apogon imberbis*	Mediterranean cardinalfish	58	0.11	0	0.00
Siganidae	**Siganus luridus*	Dusky spinefoot	1	<0.01	0	0.00
Balistidae	*Balistes capriscus*	Gray triggerfish	1	<0.01	0	0.00
Atherinidae	*Atherina hepsetus*	Mediterranean sand smelt	308	0.60	0	0.00
Muraenidae	*Muraena helena*	Mediterranean moray	101	0.20	0	0.00
Congridae	*Conger conger*	European conger	22	0.04	1	0.10
Ophichthidae	*Echelus myrus*	Painted eel	0	0.00	4	0.40
Dactylopteridae	*Dactylopterus volitans*	Flying gurnard	12	0.02	0	0.00
Belonidae	*Belone belone*	Garfish	31	0.06	6	0.60
Phycidae	*Phycis phycis*	Forkbeard	13	0.03	0	0.00
Lutjanidae	**Lutjanus fulviflamma*	Dory snapper	1	<0.01	0	0.00
Sciaenidae	*Sciaena umbra*	Brown meager	1	<0.01	0	0.00
Haemulidae	*Pomadasys incisus*	Bastard grunt	3	0.01	1	0.10
Scyliorhinidae	*Scyliorhinus canicula*	Lesser spotted dogfish	1	<0.01	0	0.00
Zeidae	*Zeus faber*	John dory	3	0.01	0	0.00
Sphryaenidae	*Sphryaena sphryaena*	European barracuda	0	0.00	1	0.10

Non-native species.

document such catches and collect data on this important type of fishery.

Results indicate that the biological consequences of shore fishing on littoral fish species cannot be ignored, since these were the most targeted by both sport and hobby angling. Of the 90 species recorded, the annular bream, the two banded bream and the Mediterranean rainbow wrasse were the most frequent fish caught, while *Diplodus sargus* was the most pursued species by hobby fishers. Other studies in Mediterranean coastal areas (Spain, Italy, Portugal, and Turkey) on shore fishing had also identified the Sparidae as being predominant in catches by hobby anglers with species including *D. sargus* and *D. vulgaris* being

TABLE 5 | Mortality rates for day shore competitions from January to June 2017.

Year	Mean % All species	Std. deviation	Mean % study species	Std. deviation
2013	25.66	36.32	26.14	38.75
2014	23.71	30.99	21.87	34.80
2015	34.78	39.88	40.69	45.30
2016	32.35	34.87	36.43	42.61
2017	15.50	24.73	21.30	36.25
Total	28.21	34.97	32.11	41.70

TABLE 6 | Predictive model selection using the corrected Akaike's information criterion for mortality rate (AICc).

Model	R^2	AIC_C	$\Delta AICc$
Year	0.022	14,797.224	1341.94
Keepnet	0.435	13,660.939	205.655
Keepnet + Locality	0.478	13,505.906	50.622
Keepnet + locality + sea temperature	0.486	13,475.665	20.381
Keepnet + locality + sea temperature + duration	**49.1**	**13,455.284**	**0**

Bold denotes model used. Year was excluded from the model.

Fitted regression model: Mortality rate = 5.60 Duration +0.89 Sea temperature −44.31 Keepnet − 5.91 Location 0 + 3.09 Location 1 − 1.41 Location 2 − 1.20 Location 3 + 15.79 Location 4 + 22.68 Location 5 + 4.97 Location 6 + 16.89.

the most targeted, together with the Labridae, especially *C. julis,* and Mugilidae (not always defined by species) (**Table 7**). The number of fish caught by hobby anglers was high compared to studies in Portugal by Rangel and Erzini (2007) and Veiga et al. (2010). This may be attributed to experience or the higher quality fishing equipment also observed in use by sports anglers, which consisted of fine tipped graphite rods and thin transparent fluorocarbon lines since both typologies of anglers employed similar fishing setups.
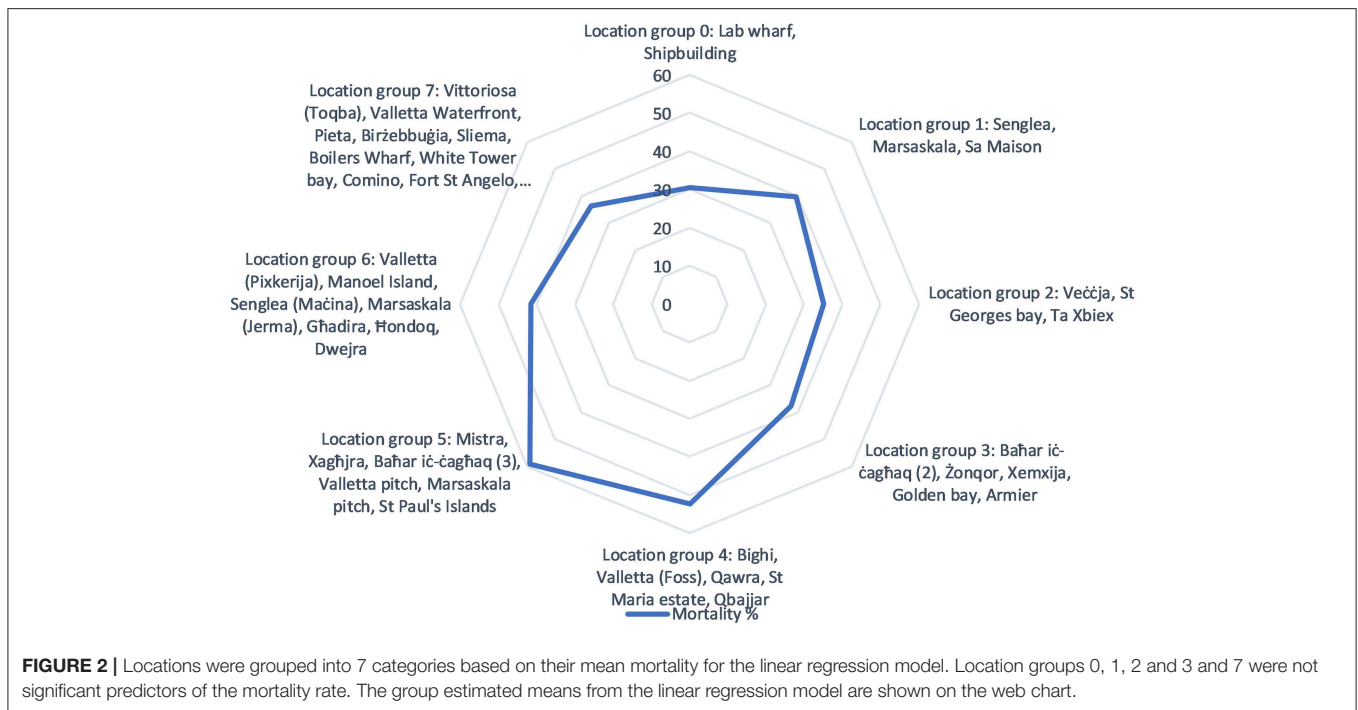
$CPUE_n$ values were higher for sport fishers. Hobby anglers were however observed to catch a smaller number of larger fish than sport fishers. In the latter, size is not important since competitions are won by anglers scoring the highest weight and not by the number of fish. Therefore, there are no minimum size restrictions, with fish being released at the end of the event. Hobby anglers on the other hand tend to target larger fish for consumption besides enjoyment. Consequently, hobby fishers on average opted for larger hooks than sports anglers with the former in some cases opting for very small hooks when practicing speed fishing. This was especially observed in ports to target small sized fish including damselfish (*Chromis chromis*), small saddled bream (*Oblada melanura*), and sand smelts (*Atherina hepsetus*) in which anglers use a small pole rod with a very small float and small baited hook (size 20 or smaller) at the end. Similarly, in Spain, studies on RF by Font and Lloret (2011) and Gordoa et al. (2019) documented lower $CPUE_n$ values than Guerreiro et al. (2011) with sport fishers. $CPUE_{kg}$ was however lower than sports fishing in both cases. Maltese sports anglers catch more kilos of fish per hour than Portugal (0.12 kg angler^{-1} h^{-1}) (Guerreiro

et al., 2011), but less than Spain (0.36 kg angler^{-1}h^{-1}) (Morales-Nin et al., 2015). Due to the inability to weigh the catches outside competitions, the $CPUE_{kg}$ values could not be compared.

A few non-native species were also captured and recorded during sport fishing competitions taking place in areas of high shipping activity (Vella et al., 2015a,b, 2016a,b). The European Code of Conduct on Recreational fishing and Invasive Alien species states that "Anglers should make themselves aware of invasive alien species and partake in education programs designed for this" (Council of Europe, 2014). Citizen science therefore has the possibility of contributing to the knowledge about these species and fill present deficiencies in the available data (ICES, 2017). Collaboration with clubs, hobby fishers and scientists can therefore contribute to the monitoring of such non-native species and collect the required data for management.

Since competition sites were chosen by clubs after consulting weather forecasts, this may have led to numerous competitions being held within the same area throughout the year, with increased impacts on the local fish communities. These generally included sheltered areas located in harbor areas (**Figure 1**), allowing them to be fished throughout the year. Cliff competitions were organized by one club and held mostly in the same two sites on the west coast of Malta, probably due to site accessibility. In one of the sites several disputes with hunters/trappers who owned fields extending to the cliff edge were observed, making use of this site problematic. Such practice should not be promoted, and clubs should aim to identify new alternative venues so as to avoid holding competitions in the same venues several times within the year. This may however be a challenge due to a decrease in venues along the years caused by site closures in harbor locations, which then require a special permit to hold a competition that is not always granted. A small number of events took place in marine protected areas (MPAs), Such MPAs are in place to safeguard *Posidonia oceanica* and more offshore for birds. Clubs inquired with the authorities before regarding the holding of competitions in these sites but were allowed to fish since they did not interfere with the main protection goals of the MPAs which are nonetheless without effective management. In all cases catch and release was practiced. Plans within these protected areas should include fishery management provisions in collaboration with fishing clubs holding fishing competitions within them and contemplate introducing management measures for recreational fishers too, such as seasonal closures that coincide with the spawning period and daily bag limits.

Contrary to what was stated by Khalfallah et al. (2017), C & R is indeed practiced by Maltese recreational anglers. In the aforementioned study no creel-surveys were carried out. There was also no actual attempt to scientifically document catch and release practices. Keepnets were indeed used and more popular during fishing competitions with hobby fishers using them to a lesser extent. The use of keepnet, sea temperature, capture location, and duration of competition were significant predictors of the fish mortality with keepnet use being the most important predictor of fish mortality. Although the mortality rate decreased with keepnet use, this increased during the

FIGURE 2 | Locations were grouped into 7 categories based on their mean mortality for the linear regression model. Location groups 0, 1, 2 and 3 and 7 were not significant predictors of the mortality rate. The group estimated means from the linear regression model are shown on the web chart.

summer months suggesting that fish are subjected to greater stress warmer periods as also documented in other studies (Bartholomew and Bohnsack, 2005). Competitions of longer duration also contributed to an increase in mortality rate together with choice of locality, where certain localities resulted in higher mortality rates. All these localities were characterized by a rocky shoreline which made keepnet use more difficult since these are easily damaged when knocked by the waves against the pointed rocky shore. While the introduction of conservation methods introduced by clubs is laudable, these have shown to have limited effect without the use of keepnets. Results indicate that the keepnet is the most important contributor to fish mortality therefore the effectiveness of other fishery management measures will be reduced when keep nets are not used. Site selection must therefore account for maximal keepnet use to maintain lower mortality rates.

Some of the sampled dead fish were noted to have angler inflicted injuries caused by hook removal. Research by Palme et al. (2016) observed an improvement in the condition of angler-caught fish after anglers attended education programs. Clubs should therefore be encouraged to hold seminars promoting best practices aimed at reducing fish mortality. Educating anglers with the aim of reducing fish mortality is therefore essential considering the numerous competitive events held annually. While catch-and-release angling is an increasingly popular conservation strategy, whether voluntary or in compliance with legislation, related injuries, stress, and effects in behavior may result in post-release mortality or loss of fitness. The survival of released fish is chiefly determined by angler activities, engaging in "best angling practices" and is critical for sustainable RF. Depending on the fish species targeted, different strategies are used by anglers. A balance must therefore be sought to introduce scientifically backed best practices accordingly. Specific tools and

strategies can be unified into RF practices with actual fishing techniques (Brownscombe et al., 2017).

Besides the effects of RF, other possible impacts on coastal fauna may be caused through the use and harvest of exotic live bait (Font and Lloret, 2011). The Korean worm, *Nereis* sp., the American bloodworm (*Glycera dibranchiata*) and imported crayfish used were live-non-native species. In particular, the introduction of the first two species, which are also popular in other Mediterranean countries, may have potential environmental effects particularly due to the lack of awareness amongst anglers and retailers of the harmful effects as a consequence of exotic bait use (Font et al., 2018). In Portugal, a study on *Perinereis aibuhitensis*, an imported polychaete used as bait observed its ability to reproduce in coastal lagoons and estuaries (Costa et al., 2006). Recreational fisheries should however aim to "*prevent the release, spreading and translocation of invasive alien species that can have significant impacts on native fish populations or the environment*" (Council of Europe, 2014). The harvesting of bristle worms, paddled blood worms and mud shrimp is also of concern. The difficulty in obtaining these three species as bait by anglers and their high purchase price should be of concern since it may indicate that all three species are in decline.

Management Measures for Fisheries Sustainability and Safeguard of Ecosystem Services

The exploratory research on hobby fishing using the same methodology as for sport fishing has shown that such methodology can be adopted on a larger scale to collect information on the former. This can also be applied to any shore fishing taking place in the Mediterranean. Surveys should,

TABLE 7 | Species recorded during shore based fishing competitions and hobby fishing in the Maltese Islands and in other countries.

		Sport fishing					Recreational fishing			
Location	Author	Top species	No	%	Fishers surveyed	Author	Top species	No	%	Fishers surveyed
Portugal	Guerreiro et al., 2011	*Belone belone*	236	42.2	–	Veiga et al., 2010	*Diplodus sargus*		44.0	1,321
		Muglidae	107	29.0			*Diplodus vulgaris*		14.0	
		Scomber spp.	100	18.0			*Boops boops*		8.0	
		Dicentrarchus labrax	74	13.2			*Scomber japonicus*		5.0	
						Rangel and Erzini, 2007	*Atherina presbyter*	707		2,081
							Muglidae	583		
							Dicentrarchus labrax	554		
							Trisopterus luscus	318		
Spain	Morales-Nin et al., 2005	*Lithognathus mormyrus*	2,122		1,432	Font and Lloret, 2011	*Serranus cabrilla*	137	36.1	250
		Coris julis	1,247				*Coris julis*	111	29.3	
		Diplodus annularis	1,004				*Diplodus vulgaris*	23	6.1	
		Serramus scriba	867				*Conger conger*	20	5.3	
Turkey						Unal et al., 2010	*Spicara smaris*		31.9	190
							Pomatomus saltatrix		20.0	
							Pagellus acarne		16.9	
							Diplodus vulgaris		7.8	
						Aydin et al., 2013	*Dicentrarchus labrax*		32.2	120*
							Mugil cephalus		12.4	
							Mugil soiuy		12.1	
							Pomatomus saltatrix		11	
						Tunca et al., 2012	*Diplodus sargus*		21.0	50
							Sparus aurata		16.4	
							Dicentrarchus labrax		10.5	
							Mugil sp.		7.86	
						Tunca et al., 2016	*Diplodus annularis*			260**
							Diplodus vulgaris			
							Dicentrarchus labrax			
							Mugil cephalus			
						Tunca et al., 2018	*Trachurus trachurus*			874
							Pomatomous saltatrix			
							Mugil cephalus			
							Sarda sarda			
Maltese Islands	This study	*Coris julis*	7,649	14.8	2,589	This study	*Diplodus sargus*	146	14.6	159
		Diplodus annularis	5,218	10.8			*Oblada melanura*	114	11.4	
		Chromis chromis	4,994	9.7			*Chromis chromis*	111	11.1	
		Diplodus vulgaris	4,397	8.5			*Diplodus annularis*	99	9.9	

*16.7% of respondents also attended recreational activity by boats.
**respondents also included boat based recreational fishers.

besides documenting catches, angler traits and fishing trips, also aim to collect demographic information to quantify the angling population, both shore-based and boat based, including spearfishing activities together with the economic value of this fishery. This is important to quantify fishing effort and catch rates for the Maltese Islands which must be considered together with commercial catches when devising complex fishery management plans with catch limits. Such limits must be based on data collected from catch surveys to be an effective conservation measure (Veiga et al., 2010). Plans should also include angler education programs and enforcement of the minimum landing

sizes, particularly with hobby fishers since these practice C & R to a much lesser extent. This would ensure that the mortality of juvenile fish is reduced allowing each fish to reproduce at least once in its lifetime. A better rotation of competition sites in which competitions are held, together with higher keepnet use should also be encouraged to reduce biodiversity impacts and ensure sustainable use of resources. Other options such as cutting the line before releasing a deeply hooked fish (Alós et al., 2009) and the establishment of minimum hook sizes are also recommended to reduce post-release mortality (Alós et al., 2008). However, since RF activity has major social repercussions, stakeholder

participation in the management processes and decision making is essential to ensure successful implementation through research knowledge transfer and participation of stakeholders.

DATA AVAILABILITY

The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

ETHICS STATEMENT

We declare that we have abided by the University of Malta's Research Ethics Review Procedures.

AUTHOR CONTRIBUTIONS

SA and AV contributed to all aspects of the research work presented here including the conception and design. SA collected the data. Both authors were involved in the drafting of the manuscript and gave approval for publication.

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