Economic assessment of abandoned, lost and otherwise discarded fishing gear (ALDFG) in the fishery sector

of The Republic of Cyprus

Ruben Savels, Leander Raes,
Marios Papageorgiou and Stijn Speelman

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1. Introduction

1.1. Background and objective of the study

This policy brief has been prepared as part of the 'Plastic Waste Free Islands - Mediterranean' (PWFI-Med) project, which is implemented in Menorca (Spain) and the Republic of Cyprus by IUCN, the International Union for Conservation of Nature, and funded by the Didier and Martine Primat Foundation. The project is part of the broader 'Close the Plastic Tap' programme of the Global Marine and Polar Programme (GMPP) at IUCN.

The purpose of PWFI-Med is to demonstrate effective, quantifiable solutions to addressing plastic leakage from islands. The project has three main goals: (1) to improve the knowledge of waste generation and policy recommendations to reduce plastic waste generation and enhance disposal; (2) to enhance adoption of plastic leakage reduction measures by tourism, fisheries and waste management sectors and value chain development; and (3) to develop a Plastic Waste Free Island blueprint in collaboration with regional bodies. The project was implemented from January 2019 to March 2022 (IUCN, 2021a).

This report focuses on the Republic of Cyprus and builds upon previous assessments titled "*National Guidance for Plastic Pollution Hotspotting and Shaping Action Report for the Republic of Cyprus*" (IUCN-EA-QUANTIS, 2020) and "*Governing plastic waste management in the Republic of Cyprus: Assessment of legal, policy and institutional frameworks*" (Iovinelli A., 2021).

To support this project, an economic assessment was performed of costs of current plastic flows and costs of potential future intervention scenarios were modelled. The focus on the fishing sector was chosen as it was identified to be one of the main contributors to plastic leakage in the Republic of Cyprus due to the high leakage of fishing gear into the marine environment (IUCN-EA-QUANTIS, 2020). This phenomenon is often referred to as 'Derelict Fishing Gear' (DFG), 'Abandoned, Lost or otherwise Discarded Fishing Gear' (ALDFG) or 'Ghost Gear' (GG). Due to its increasingly recognized importance by the global community, it is the focal point of this report.

This report gives an overview of the relevant literature concerning the sources, impacts and possible management and/or policy measures of *ghost gear*, which is supplemented by the outcomes of a survey to give insight into the situation in the Republic of Cyprus. Building upon this, a selection of management and/or policy measures have been assessed by means of a cost analysis to identify the preferred measures from an economic point of view in order to support policy-makers in adopting cost-effective leakage reduction measures.

1.2. Marine plastic pollution, ALDFG and ghost fishing

1.2.1. Marine plastic pollution

Marine litter is a global environmental concern (Galgani et al., 2019). Estimations indicate that between 60 and 80 percent of this litter is plastics (Derraik, 2002; Thevenon et al., 2014; Barboza et al., 2019). The abundance of plastics in the marine environment can be accounted to different factors (Abalansa et al., 2020), these are: the wide use and high consumption rate of plastics (Law, 2017; Lebreton et al., 2017, Almroth and Eggert, 2019); its physical features (such as durability) (Almroth and Eggert, 2019) and the low recycling rates and poor waste management practices (Law, 2017), leading to large quantities entering the marine environment. Jambeck et al. (2015) estimated that between 4.8 million and 12.7 million metric tons of plastics yearly enter the marine environment, an amount that is expected to double in the next decade if no action is taken (Boucher et al., 2019, 2020)

Plastics in the marine environment have several adverse environmental and socio-economic impacts (UNEP/MAP, 2015a; Galgani et al., 2019). Economic impacts include negative impacts on recreational uses and losses in touristic values (Gilman et al., 2021), but also negative implications for the fishing and aquaculture sector (Galgani et al., 2019, Gilman et al., 2021). Adverse effects on the marine environment and ecosystems can be caused by ingestion or entanglement in litter and fishing gear (Lusher et al., 2018; Barboza et al., 2019) or by endocrine disrupting action of chemical additives found in plastics (Hermabessiere et al., 2017).

The main sources of marine plastics are land-based, but sea-based sources such as fishing and shipping activities nevertheless have an important share in total plastic leakage into the marine environment (Thevenon et al., 2014, Richardson, 2019a). The fishing sector is responsible for the leakage into the marine environment of Abandoned, Lost or Discarded Fishing Gears (ALDFG), which is considered a particularly troublesome waste fraction (Desphande et al., 2020; Link et al., 2019; Kuczenski et al., 2022).

1.2.2. ALDFG and ghost fishing

The fishing sector was identified as a significant contributor to marine litter in the oceans in a report on 'Marine plastic debris and microplastics' (Kershaw, 2016) by the United Nations Environment Program (UNEP). Academic literature also recognises this (Thevenon et al., 2014; Richardson et al., 2018) and Gilman et al. (2016) point out that ALDFG not only plays a vital role in marine plastic pollution but also is a cause of major ecological concerns such as ghost fishing[1]. As a consequence, over the past decades there has been increasing international recognition of the need for multilateral efforts to address transboundary adverse ecological and socioeconomic effects of ALDFG (Gilman et al., 2021). Along this line, the scale of ALDFG impacts on fisheries, marine ecosystems and associated human users inspired the United Nations (UN) to call upon member countries to take actions to reduce ALDFG (Richardson, 2021).

Notwithstanding the increasing international attention to the problem of ALDFG, knowledge on the magnitude of the problem is limited (Macfadyen et al., 2009; Gilman, 2015; Gilman et al., 2016). Most estimates have been limited to specific gear types and/or geographic locations, largely due to the nature of fishing gears being tailored for target species, which can vary widely across geographic areas (Richardson et al., 2021). Based on a meta–analysis of ALDFG, Richardson et al., (2019b) estimated that 5.7 percent of all fishing nets, 8.6 percent of all traps and 29 percent of all lines are lost to the world's oceans each year. Due to the rapid expansion of fishing effort and fishing grounds and the transition to synthetic, less-expensive, more durable and more buoyant materials used for fishing gear, the amount, distribution and effects of ALDFG have likely risen in recent decades (Gilman et al., 2021; Hardesty et al., 2021; Kuczenski et al., 2022). The distribution of ALDFG in the marine environment is very heterogeneous, as it is for instance considered to be the main type of submerged marine debris while comprising an estimated 46 percent of the Great Pacific Garbage Patch (NOAA, 2015; Lebreton et al., 2018).

ALDFG may be the result of intentional or unintentional phenomena. Fishing gear may be **abandoned** (= deliberately non-retrieved) in a context of illegal, unreported or unregulated (IUU) fishing activities. Fishing gear may be **lost**

1 Ghost fishing is the ability of ALDFG to continue trapping and killing marine life

(= accidental loss at sea) due to gear conflict, improper gear storage or extreme weather conditions, or it can be **discarded** (= deliberate disposal at sea) when there is a lack of shore-side collection facilities for end of life gear, high costs of gear disposal, the occurrence of damaged gear or space constraints (Al Masroori et al., 2009; Macfadyen et al., 2009; Gilman, 2015; Richardson et al., 2018; Goodman et al., 2021).

ALDFG has diverse negative impacts on marine environments, wildlife, and the fishing sector (Richardson et al., 2019a). It results in economic losses for the fishing sector (such as the replacement cost of gear and the costs and time necessary to clean-up after interaction with ALDFG) and hazards to navigation at sea (NOAA, 2015; Richardson et al., 2018). One of the most significant impacts of ALDFG is ghost fishing, which is the ability to continue catching target and non-target marine animals. Ghost fishing contributes to increased mortality of marine animals such as fish, crustaceans, marine mammals, sea turtles and seabirds and is especially detrimental to species that are endangered and/or protected. Fisheries themselves are impacted by ghost fishing from an economic perspective through decreased populations of target species and the increased resources needed to capture target species (NOAA, 2015; Richardson et al., 2021). Besides, ALDFG also causes negative environmental impacts similar to those caused by debris at sea in general, such as ingestion, dispersion of exotic organisms and species, changes in habitats and introduction of synthetic material into the marine trophic network (Link et al., 2019).

Macfadyen et al. (2009) categorize measures to reduce ALDFG as preventive (avoid the occurrence of ALDFG in the environment), mitigation (reduce the impact of ALDFG in the environment) and curative (remove ALDFG from the environment). Examples of preventive measures are spatial management to minimize gear conflict and gear loss, gear marking (Al Masroori et al., 2009; Macfadyen et al., 2009; Gilman, 2015; Richardson et al., 2019a), reducing excess capacity (Matthews and Glazer, 2009; Gilman, 2015) and the provision of port reception and/or collection facilities (MacFayden et al., 2009; Gilman, 2015) and the creation of economic incentives or disincentives (Gilman, 2015). Mitigation measures include the adoption of biodegradable gears or other gear modifications (Matshushita et al.,2008; Macfadyen et al., 2009; Gilman, 2015). Curative or remedial measures finally focus on localisation, retrieval and disposal or recycling of ALDFG. These include reporting schemes and survey programmes, but also economic incentive programmes to encourage retrieval and delivery of ALDFG (Gilman, 2015; Richardson et al., 2019a).

Preventive measures are considered to be most cost-effective, while mitigation measures such as the adoption of biodegradable gears or other gear modifications are less widely adopted as many may increase costs through reduced effectiveness and/or higher prices of fishing gears. Curative measures are considered to be less effective than preventative measures, but the localisation, retrieval and disposal or recycling of ALDFG can still be cost-effective compared to the costs arising from leaving ALDFG in the environment (Macfadyen et al., 2009).

1.2.3. Marine plastics in the Mediterranean Sea

The Mediterranean Sea is widely regarded as one of the most threatened environments. Due to its high population densities, lack of consistent waste-management schemes, large influxes of tourists and hosting 30 percent of global maritime traffic, it faces significant pressure from plastic pollution. This problem is exacerbated by the basin's limited exchanges with other oceans (UNEP/MAP, 2015a).

The total stock of plastic accumulated in the Mediterranean Sea is estimated to be 1,178,000 tonnes, with a possible range from 53,500 to 3,546,700 tonnes. Annual plastic leakage is estimated to be 229,000 tonnes, with a low and high estimate of 150,000 and 610,000 tonnes respectively (Boucher and Bilard, 2020). It should be noted that the contribution of sea-based sources (for which ALDFG is the predominant contributor) has not been assessed in Boucher and Bilard (2020) due to a lack of data. Other reports on the Mediterranean however state that sea-based sources can contribute 26 to 34 percent of all marine litter (UNEP/MAP, 2015a).

Despite the scarcity and inconsistency of data on ALDFG in the Mediterranean, it has been recognized as an issue of major concern. Recent research carried out across the Mediterranean indicates that ALDFG may account for a large or even the largest part of marine litter items recorded. Additionally, fisheries related litter items account for some 35-50 percent of items found on the seafloor and are among the top 10 items recorded on beaches. There is a strong recognition of the marine litter issue by interviewed fishers and fisheries-related groups, with 91 percent of the respondents considering it a serious or moderate problem and a majority (64 percent) stating that it is a growing problem (UNEP/MAP, 2015b). Additionally, 52 percent of respondents reported that they experience problems with marine litter caught in their nets often or all the time. Almost half of the respondents were able to indicate marine litter hotspots, stressing their role in the localization and retrieval of marine litter (UNEP/MAP, 2015b).

Close to half of the surveyed fishers stated to not have waste bins on board, while 38 percent admitted to throw litter overboard and 40 percent of the respondents were not satisfied with the waste collection facilities at the ports, identifying both a behavioural and infrastructural cause for sea-based sources of marine litter. Looking specifically at ALDFG, some 37 percent admitted to dumping their waste gears on land, since according to 67 percent there are no specific collection points for waste gears at ports and marinas, signalling that the improvement of waste collection facilities is needed. Another overwhelming majority (76 percent) stated no measures are undertaken to support the sustainable management of used or lost fishing gear. The majority of respondents (71 percent) considered the issue of ghost gear as a serious (42 percent) or moderate (29 percent) problem. Around half of the respondents (47 percent) felt that it is a growing problem and some 41 percent of the respondents considered the impacts of ghost gear as a serious problem. A large majority (98 percent) of fishers expressed willingness and interest to participate in a ‘fishing for litter’ measure, in which fishers collect marine litter caught in their fishing gears at sea and dispose of it in waste collection infrastructure at the port upon return (UNEP/MAP, 2015b).

2. Case study: The Republic of Cyprus

The Republic of Cyprus is located in the eastern Mediterranean Sea. It is the third largest and third most populous country in the Mediterranean Sea, with an area of 9,251 km2 and a population size of 875,899 in 2019 (EUROSTAT, 2021). In the same year, it had a GDP of $36,991 billion (PPP) with an economy mostly based on services (85.5 percent), industry (12.5 percent) and agriculture (2 percent of GDP) (CIA, 2021).

At the end of 2018, the fishing fleet of the Republic of Cyprus consisted of 812 fishing vessels, divided over different fleet segments, namely, '*vessels using polyvalent passive gears only*', '*purse seiners*' and '*demersal trawlers and/or demersal seiners*'. Within this first segment, the vessels using polyvalent passive gears only with length between 0 and 6m and between 6 and 12m compose the small-scale inshore fleet and operate mainly with bottom set nets and bottom longlines, targeting demersal species. This small-scale inshore fleet constitutes the large majority (737 vessels or 91 percent) of the Cypriot fishing fleet (DFMR, 2019).

This segment in turn is divided into three categories: vessels with fishing license category A, B or C. The vessels with fishing license category A or B make up the professional segment and consist of 323 vessels. Landings of this segment consist mainly of demersal species such as *Spicara smaris*, *Boops boops*, *Mullus barbatus*, *Mullus surmuletus*, *Pagellus erythrinus* and cephalopods such as *Octopus vulgaris*, *Loligo vulgaris* and *Sepia officinalis*. Relatively large quantities of *Sparisoma cretense*, *Spicara maena* and *Siganus* spp. are also caught. Trammel nets and set gillnets are the most commonly used fishing gears in this segment, followed by set longlines.

The fishery sector has a limited contribution to the country's economy (less than 0,5%), but it is nevertheless an important sector for the fisheries dependent areas for direct

Map 1: Location Republic of Cyprus in the Mediterranean Sea (Source: Google Earth)

Picture 1: Traditional small-scale fishing vessels (Marios Papageorgiou)

employment (vessel owners and crew members) and auxiliary services such as fish taverns and restaurants, fishmongers, gear repair, vessel repair and construction, fishery tourism and for the families of fishers who help getting the fish out of the nets (Prellezo & Carvahlo, 2020).

2.1. Plastic pollution hotspots in the Republic of Cyprus

According to the '*National Guidance for plastic pollution hotspotting and shaping action, Country report Cyprus'*, about 92,588 tonnes of plastic waste was generated in 2018, with plastic waste generation per capita amounting to 94 kg/cap/year. This waste has an average collection rate of 93 percent, but no recycling facilities are present in the country. Around 11 percent of plastic waste is exported for recycling. Some seven percent of plastic waste generated in the Republic of Cyprus is mismanaged (stemming from littering and uncollected waste), while 756 tonnes of plastic waste leak into waterways, corresponding to a one percent leakage rate and a leakage of about 0,8 kg/cap/year (IUCN-EA-QUANTIS, 2020).

Looking at the **application hotspots** of plastic waste mismanagement and leakage in the Republic of Cyprus, *plastic bags* and *plastic lids and caps* are the top contributors to plastic leakage in absolute terms with a respective mismanaged waste index of 10 and 14 percent and a respective leakage rate of 1 and 2 percent, leading to 107 and 106 tonnes of plastic waste leakage respectively. *Fishing nets* rank third with an absolute leakage of 84 tonnes, while its mismanaged waste index and leakage rate are as high as 48 percent and 16 percent respectively.

Looking at the **sector hotspots** of plastic waste mismanagement and leakage in the Republic of Cyprus, the *packaging* and *automotive-tyres sectors* have a respective mismanaged waste index of 11 and 6 percent and a leakage rate of 1 and 2 percent, leading to 325 and 167 tonnes of plastic waste leakage respectively. The *fishing sector* is close behind with an absolute leakage of 93 tonnes, while its mismanaged waste index and leakage rate are 7 and 28 percent respectively.

Looking at the **regional hotspots** of plastic waste mismanagement and leakage in the Republic of Cyprus, plastic leakage from fishing activities is likely to substantially contribute to the total plastic leakage in the Republic of Cyprus (12 percent of total leakage).

Based on these outcomes, the focus on the fishing sector was established.

2.2. Legal and policy instruments to manage and reduce marine plastic litter in the Republic of Cyprus

In the Republic of Cyprus, several legal and policy instruments are in place to manage and reduce marine plastic litter (Arroyo Schnell et al., 2017; Iovinelli, 2021). Within the Programme of Measures (PoM) under the Marine Strategy Framework Directive (MSFD), 2 targets related to marine litter are put in place. "*The marine environment of Cyprus is considered to be in good environmental status if: (1) the amount of marine litter on beaches and on the seafloors is minimized and, if possible, effectively eliminated, and (2) mortality of Caretta caretta individuals (loggerhead sea turtles) due to entanglement by marine litter, and subsequent stranding, is minimized and, if possible, effectively eliminated*".

For the fishing sector, the Programme of Measures includes encouraging and implementing a "fishing for litter" programme and the promotion of awareness by informing professional and amateur fishers about marine litter to reduce littering from fishing activities (Arroyo Schnell et al., 2017). A "fishing for litter" scheme has been implemented and launched in the Republic of Cyprus, and the initiative is to be expanded.

The assessment of legal, policy and institutional frameworks governing plastic waste in the Republic of Cyprus identified certain gaps and challenges with regard to implementing the relevant EU waste policies, such as the lack of infrastructure and systems for collecting recyclables, the lack of coordination between different administrative levels and the lack of capacity at local level (Iovinelli, 2021).

3. Methodology

This study employed mixed qualitative-quantitative methods (Newman & Ridenour, 1998) entailing literature review and a survey of which the interpretation fed into the construction of a cost analysis. The literature review drew upon previous reports published within the Plastic Waste Free Islands-Med project and an array of academic, governmental and non-governmental publications.

3.1. Data collection

A survey on general fishery aspects and ALDFG was drafted following the guidelines in FAO documentation on fishery surveys, namely '*Handbook for Fisheries socio-economic sample survey - principles and practice*' (Pinello et al., 2017) and '*Sample-based fishery surveys: A technical handbook*' (Stamatopoulos, 2002).

The survey was pilot-tested among a small sample of participants prior to the main survey. Testing occurred in May 2021, after which the survey was updated and responses were collected with a final version of the survey from June to August 2021.

The surveys were implemented and performed using the survey software *Qualtrics*. The reference year used in the survey and the further assessment is 2019. The target population were fishers of the professional small-scale inshore fleet segment, which consists of 323 vessels, of which only about 150 remain active in 2021 according to the fishing community. The target population therefore consists of 150 vessels, of which 109 were necessary to ensure a statistically significant (95 percent confidence level, 5 percent margin of error) sample. Due to time and participation limitations, only 88 vessels were surveyed (ensuring a 95 percent confidence level at a 7 percent margin of error).

Map 2: Survey locations
(Source: own elaboration based, Google Earth)

Table 1: number of vessels surveyed per fishing port

Kato Pyrgos Fishing Shelter	**3**
Limassol Harbour	**17**
Larnaka Fishing Shelter	**8**
Ormidhia Fishing Shelter	**3**
Zygi Fishing Shelter	**14**
Paphos Harbour	**5**
Pomos Fishing Shelter	**3**
Latchi Harbour	**8**
Agios Georgios Pegeias Fishing Shelter	**6**
Agia Napa Fishing Shelter	**16**
Agia Triada Fishing Shelter	**5**

3.2. Cost estimates

Estimating the costs of a scenario or intervention is the first step to carry out a more detailed cost or cost-effectiveness analysis. It illustrates the differences in costs arising from implementing different types of interventions. The focus is here on the costs of interventions related to reducing ALDFG. For a cost or cost-effectiveness analysis, additional data on the benefits arising from fishing activities, as well as potential new revenues generated by the proposed interventions will need to be collected, and are not considered in this study.

In this study, the costs incurred currently by the fishery sector are calculated for a Business As Usual (BAU) scenario. Additionally, the costs arising from the potential interventions are estimated and compared. A sensitivity analysis is further performed to study how the results of the different scenarios change when key input variables are changed.

For each scenario the costs generated over a period of one year are listed, after which the the

Picture 2: Traditional fishing shelter in Cyprus, accommodating only small-scale fishing vessels (Marios Papageorgiou)

total cost for each intervention is calculated by summing all relevant costs

The reference year for all data used in the analysis is 2019.

3.3. Conceptual framework

The assessment in this policy brief will focus on the interactions between the fishery sector, marine plastic waste (including ALDFG) and the fish stocks and specific interventions to reduce ALDFG. These interactions are pictures in yellow in Figure 1. The main focus are the interactions with ALDFG; interactions with other marine plastics, as well as other impacts of marine plastics (Figure 1, in blue) are also present and important (the marine ecosystem, other sources of marine plastic waste and sectors impacted by marine plastic waste among others), but are not included in this assessment.

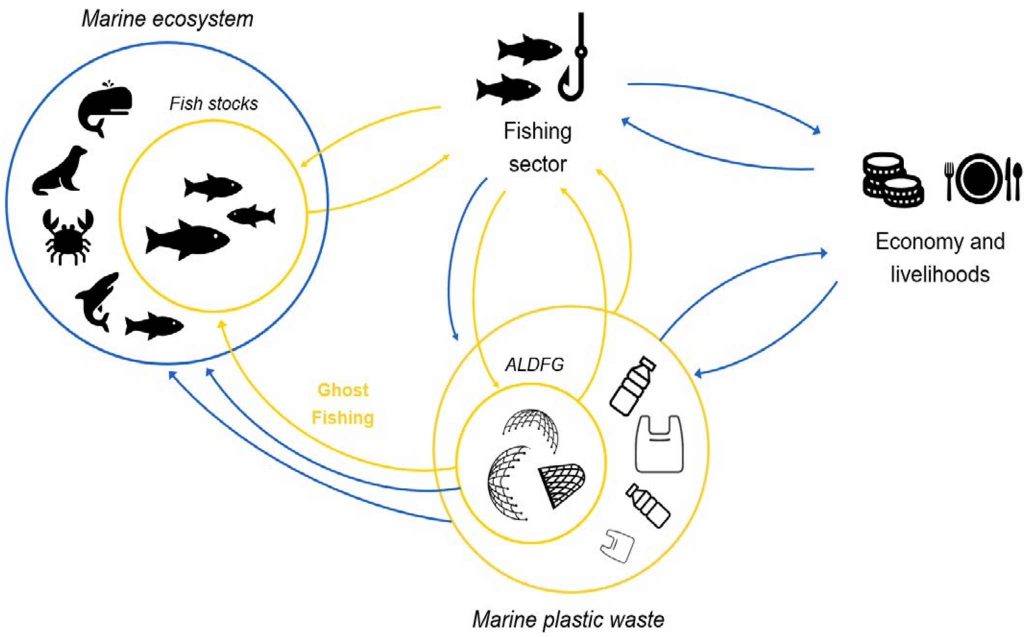

Figure 1: Conceptual framework of the assessment

4. Results

4.1. Fisheries and ALDFG

4.1.1. Demographic

A total of 88 fishers were surveyed across 11 fishing shelters and harbours (Table 1) spread across the coast of the Republic of Cyprus (Map 2). The respondents had an average age of 56 years with a few younger fishers (Figure 2). A large majority (98 percent) had Cypriot nationality, while one fisher had Egyptian nationality. A majority of fishers (90 percent) had a fishing licence category A, while the remaining fishers had a fishing licence category B.

The surveyed fishers derived on average 73 percent of their household's income from fishing in 2019, with 48 percent of fishers deriving at least 90 percent of their household's income from fishing (Figure 3). All surveyed fishers are members of a fisher's organization, while none are part of a cooperative.

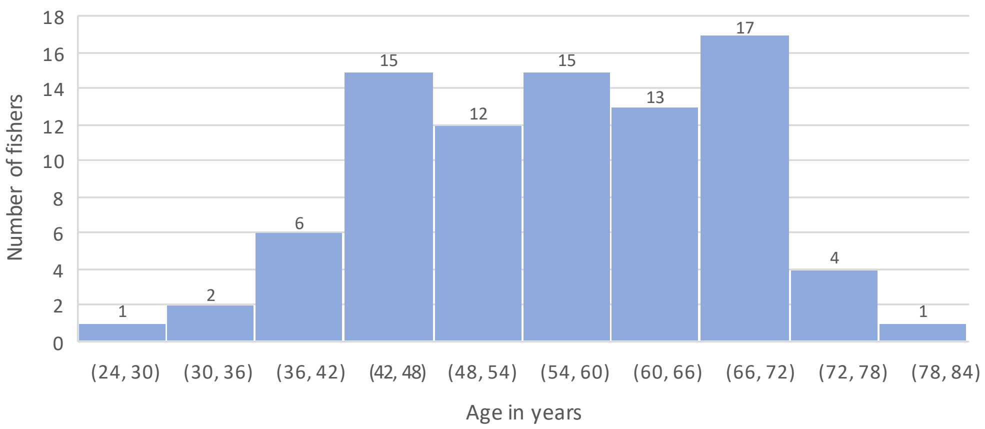

Figure 2: Age distribution of fishers

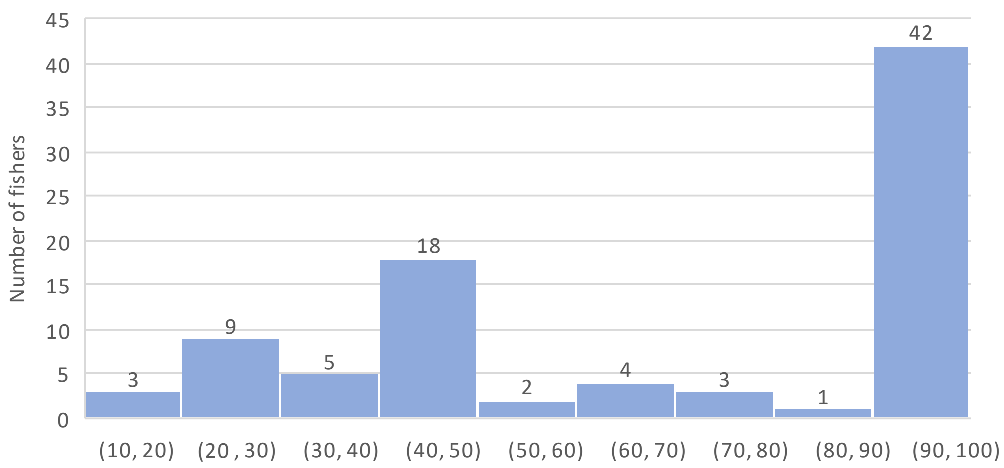

Figure 3: Proportion of household income from fishing

Picture 3: Small-scale fishing vessel off Akamas peninsula, Cyprus (Marios Papageorgiou)

4.1.2. Fishing effort

Concerning the fishing effort of the surveyed fishers, an average of 154 fishing trips were performed in 2019, with a large majority of fishers performing between 90 and 210 trips (Figure 4). The average duration of a fishing trip in 2019 was 7.5 hours, with a relatively large variability (Figure 5).

Trammel nets (61 percent) and gillnets (23 percent) were the most frequently deployed fishing gears in 2019, with set longlines (13 percent) and traps (3 percent) playing a lesser role in the total fishing effort by the surveyed fishers (Figure 6).

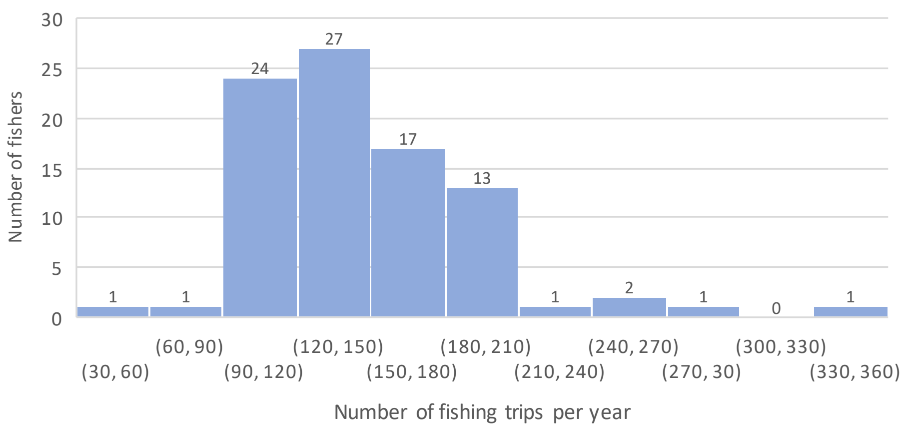

Figure 4: Distribution of the number of fishing trips per year

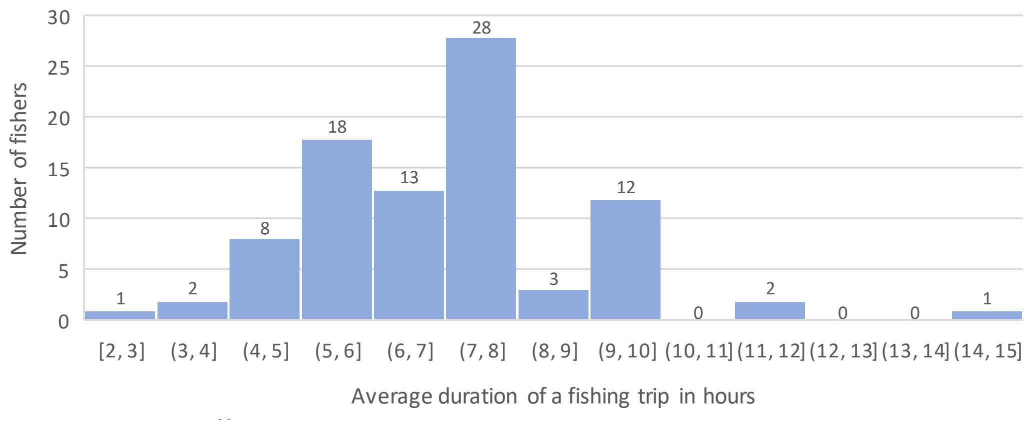

Figure 5: Distribution of fishing trip duration

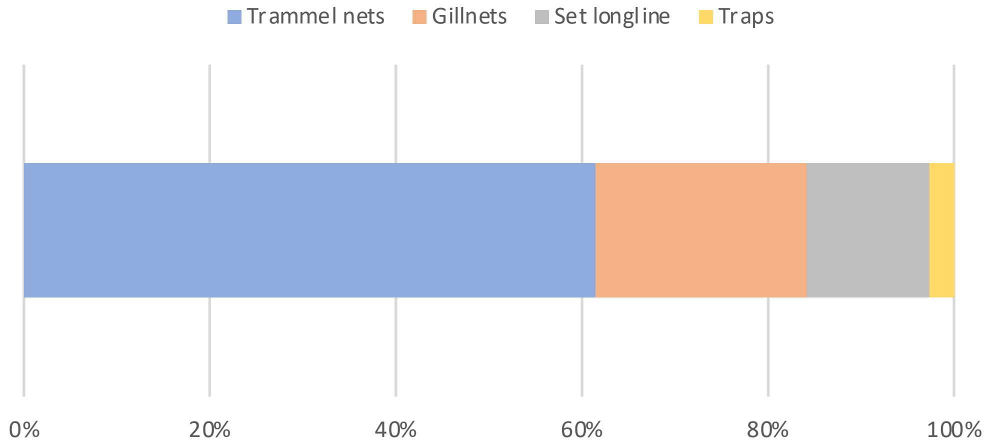

Figure 6: Share of each fishing gear type in the total fishing effort

4.1.3. Abandoned, Lost or Otherwise Discarded Fishing Gear

About 20 percent of the surveyed fishers state to have encountered and interacted with ALDFG at sea. This interaction was responsible for a downtime and clean-up time of 4 minutes per fishing trip for the average fisher (Figure 7), or on average 20 minutes considering only those who stated they encountered ALDFG (Figure 8). Additionally, the direct damages incurred to the interaction with ALDFG totalled 34€ in 2019 for the average fisher (Figure 9), or an average of 167€ in 2019 considering only those who stated they encountered ALDFG (Figure 10).

About 17 percent of the surveyed fishers stated to have lost their fishing gear at least once in 2019, the main causes being conflicts with the seafloor and with other gears (Figure 11).

About 7 percent stated to have deliberately abandoned or discarded their fishing gear at least once in 2019, with the main identifiable cause being time or space constraints (Figure 12).

On average, a fisher abandoned and lost one trammel net in 2019, with the majority of fishers abandoning or losing none but few fishers abandoning or losing a significant number of trammel nets, with one fisher stating to have abandoned 20 trammel nets in 2019, and another one stating to have lost 15.

Picture 4: Trammel nets, used to target a variety of different fish species (Marios Papageorgiou)

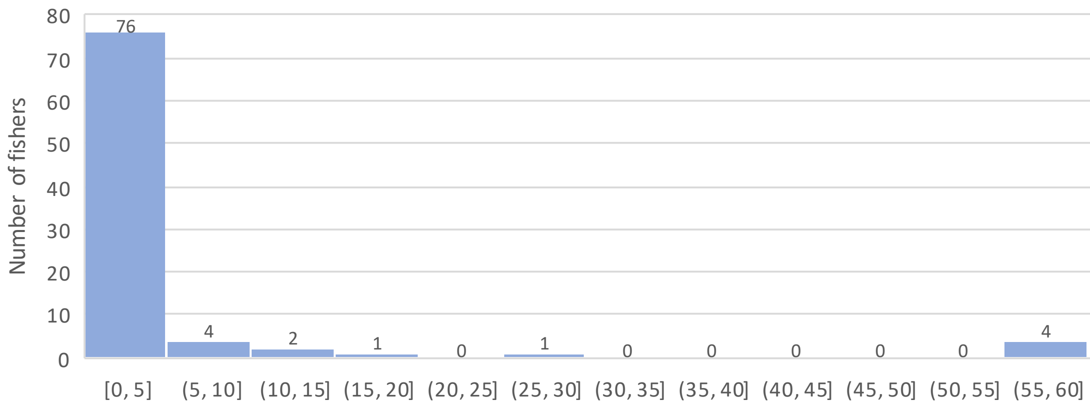

Figure 7: Downtime and clean-up time per fishing trip due to interaction with ALDFG (all respondents)

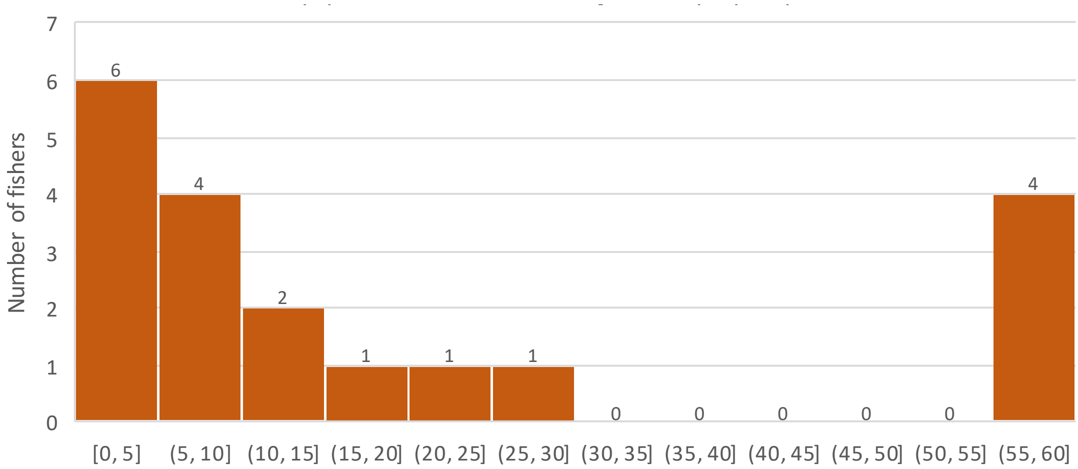

Figure 8: Downtime and clean-up time per fishing trip due to interaction with ALDFG (only respondents who encountered ALDFG)

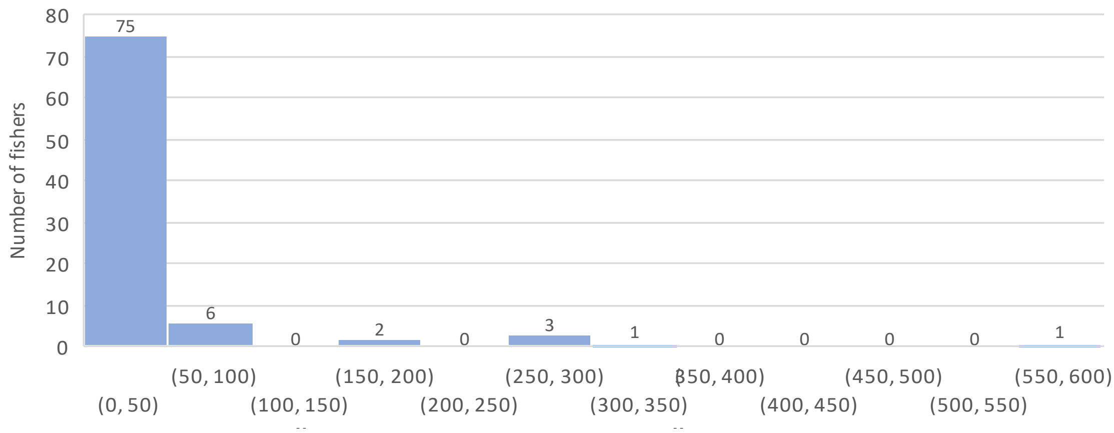

Figure 9: Cost of gear and other damage due to interaction with ALDFG (all respondents)

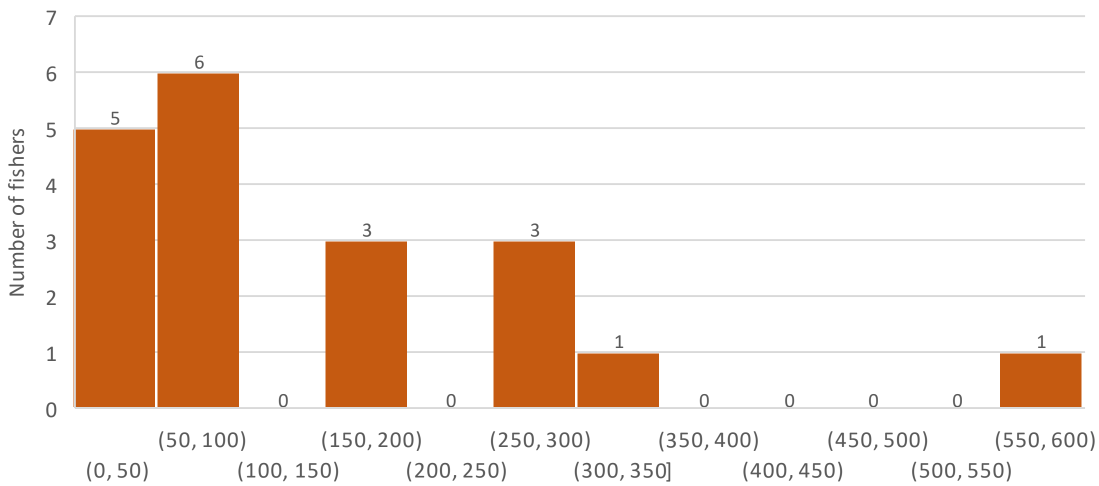

Figure 10: Cost of gear and other damage due to interaction with ALDFG (only respondents who encountered ALDFG)

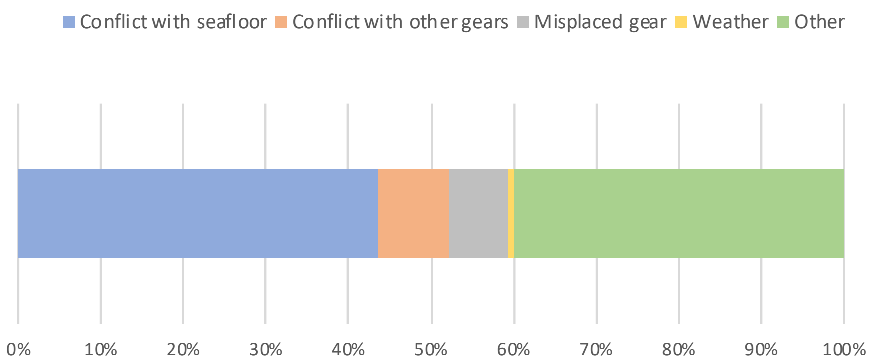

Figure 11: Causes of losing fishing gear

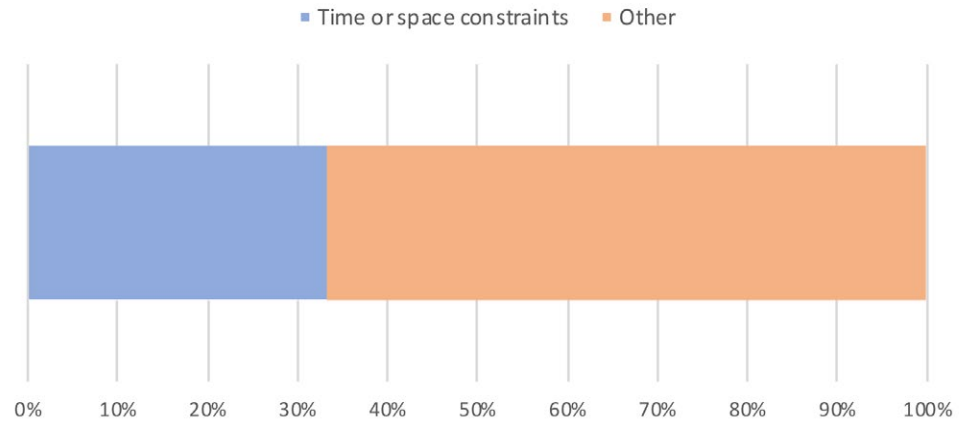

Figure 12: Causes of abandoning and discarding fishing gear

4.1.4. Spatial pattern of fishing grounds and ALDFG

Fishers indicated the location of their fishing grounds by making use of maps covering six distinct marine regions covered by the small-scale fishing fleet (Map 3) and additionally indicated where they encountered and/or interacted with ALDFG (Map 4). Below an overlay of these six maps: **map 1** covers *Kato Pyrgos Fishing Shelter*, *Pomos Fishing Shelter* and *Latchi Harbour*; **map 2** covers *Agios Georgios Pegeias Fishing Shelter* and *Paphos Harbour*; **map 3** covers *Limassol Harbour*; **map 4** covers *Zygi Fishing Shelter*; **map 5** covers *Larnaka Fishing Shelter* and *Ormidhia Fishing Shelter;* and **map 6** covers *Agia Napa Fishing Shelter* and *Agia Triada Fishing Shelter*. Individual maps (1 to 6) can be consulted in the Annex.

Map 3: Location of fishing grounds (Source: own elaboration)

Map 4: Location of encountered ALDFG (Source: own elaboration)

4.1.5. Policy framework

According to the surveyed fishers, the government website is the main source of information concerning fishery policies and regulations, followed by the website of the fisher's organization (Figure 13).

When asked which measures to reduce ALDFG are being used, their absence or presence was not unanimously indicated. However, a majority of fishers indicated that spatial management and effort regulations and gear marking to indicate ownership are being used, while again a majority indicated that no port-side collection facilities and no requirements to report loss are being used (Figure 14).

When asked about the perception of the effectivity of measures to reduce ALDFG (ranging from not very effective, quite effective to very effective), management measures such as spatial management and effort regulations were perceived to be very effective, as were clean-up or recovery of fishing gear and economic incentives for the collection of old gear. Technical measures, such as biodegradable gear and gear modification to reduce loss were generally perceived as being not very effective (Figure 15).

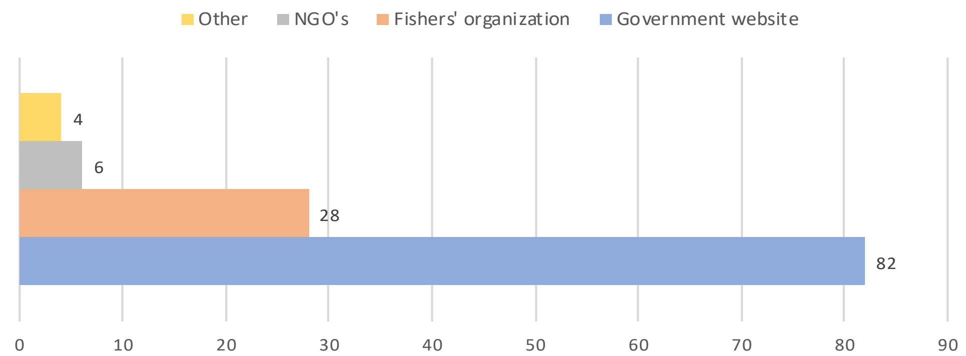

Figure 13: Use of different sources of information on fishery policies and regulations

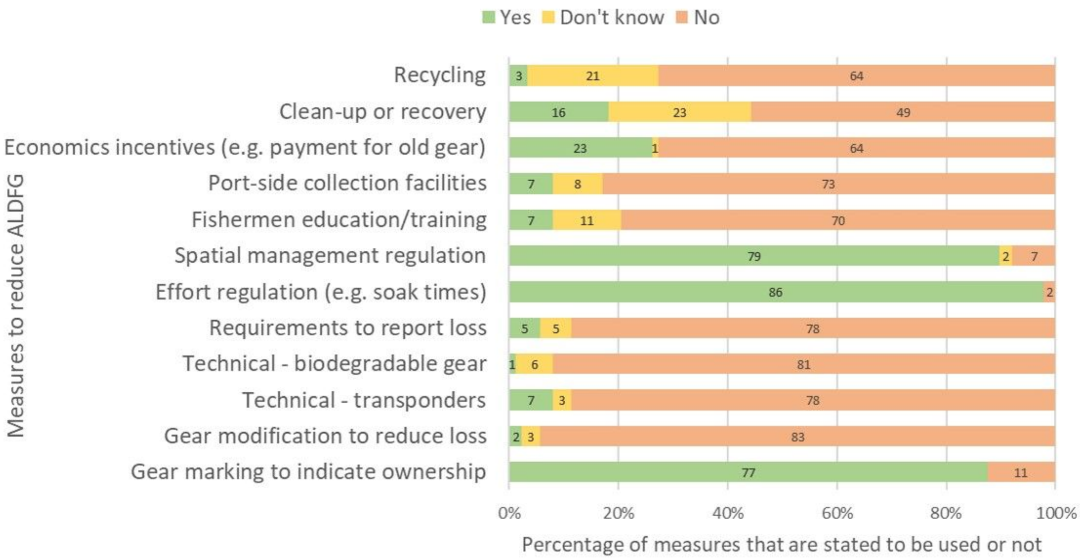

Figure 14: Presence or absence of measures to reduce ALDFG according to respondents

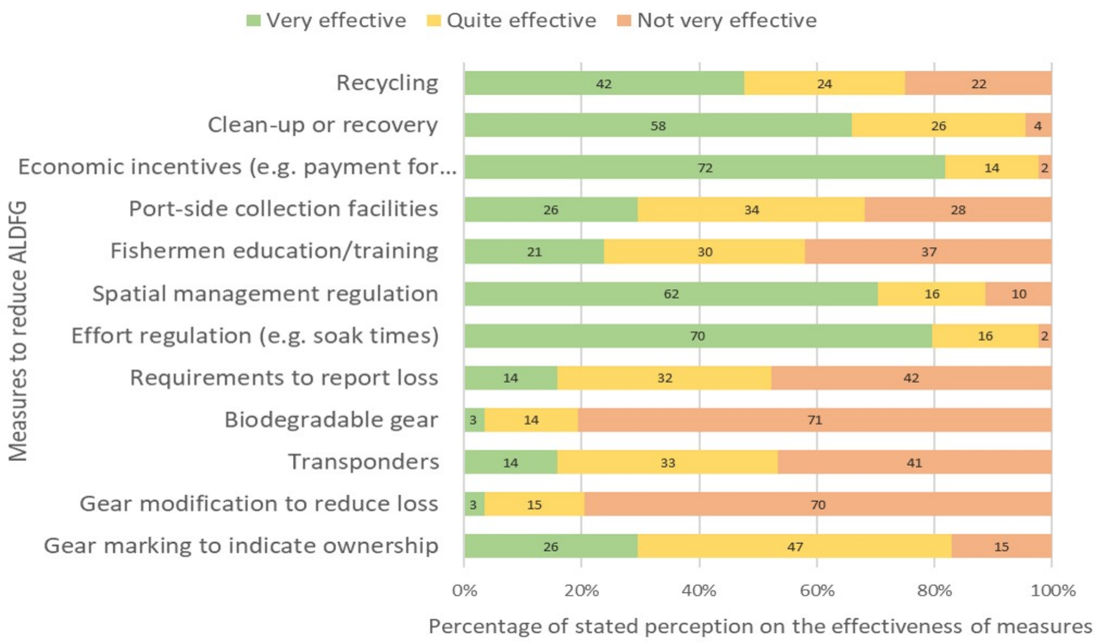

Figure 15: Respondents' perception of the effectiveness of measures to reduce ALDFG

4.2. Results cost analysis

4.2.1. Interventions to reduce ALDFG and its impacts

Based on the measures to reduce ALDFG and its impacts found in the literature on the one hand (Macfadyen et al., 2009; Gilman, 2015; Richardson et al., 2019a), and the stated perception of fishers on the effectiveness of measures, two possible interventions are considered in this assessment, namely: gear tracking and recovery and a deposit refund scheme for fishing gear.

Gear tracking and recovery is considered to be a curative measure and therefore often less cost-effective compared to preventative measures (Macfadyen et al., 2009). However, the localisation, retrieval and disposal or recycling of ALDFG can still be cost-effective given the costs arising from leaving ALDFG in the marine environment (Macfadyen et al., 2009). Fishing gear recovery is already performed routinely in several regions and countries (Gilman, 2015), while scientific literature is increasingly gathering and reporting data on the technical, environmental and economic specifics of gear recovery in different fisheries (e.g. Goodman et al., 2021, Richardson et al., 2019a), with evidence pointing towards gear recovery as having either a low (Brown & Macfadyen, 2007) or a high cost-effectiveness (Gilardi et al., 2010).

A deposit refund scheme is considered to be a preventative measure that is generally stated to help facilitate waste collection, reduce littering and material leakage and encourage recycling. Deposit refund schemes have been used for many years for glass bottles, but are also increasingly applied to plastic beverage bottles (Watkins et al., 2019). A deposit refund scheme is considered to be part of (and often the first step of) an 'Extended Producer Responsibility' (EPR), which is defined as "an environmental protection strategy to reach an environmental objective of a decreased total environmental impact from a product, by making the manufacturer of the product responsible for the entire life-cycle of the product and especially for the take-back, recycling and final disposal of the product." (Lindhqvist, 2000). EPR policies and schemes for fishing gears are advocated for by environmental organizations, and are to be implemented by European Union Member States by 31 December 2024 (IUCN, 2021b; Directive (EU) 2019/904).

Gear tracking and recovery is explored in this assessment as it is a necessary step to remove the existing fishing gear in the marine environment, while a deposit refund scheme on fishing gear is additionally explored as a first step in the implementation of EPR policies and schemes.

The cost analysis was performed based on the data gathered by the socio-economic survey and, where necessary, complemented by data from the literature and by expert knowledge. The costs were estimated for an average small-scale fishing vessel.

4.2.2. Costs of the interventions

In the **Business As Usual (BAU) scenario**, the costs considered are: *Fixed costs* (e.g. insurance, license renewal); *Operational costs* (such as fuel, bait or lubricants); *Maintenance and repair costs* (e.g. vessel, engines, machinery); *Investment costs* (new engines or machinery); *Fishing gear costs* (maintenance and repair, replacement of old or abandoned, lost or discarded fishing gear); and costs related to the impact of *ALDFG* (damage and delays due to ALDFG); *Damage due to non-ALDFG plastics* (damage and delays due to other plastics); and *Ghost fishing costs* (value of fish caught in ghost nets) (Table 3).

In the **Gear tracking and recovery (Intervention A) scenario**, the *Ghost fishing costs* are assumed to become zero, while additional *Gear recovery costs* are incurred.

In the **Deposit Refund Scheme (Intervention B) scenario**, the *ALDFG costs* and *Ghost fishing costs* decrease. Besides, additional *Deposit costs* are incurred. Here, deposit values of 15 percent (Intervention B.1) and 30 percent (Intervention B.2) of the purchase price of fishing gear are explored.

In this analysis, the focus is placed on trammel nets as they are the main gear deployed and additionally are considered to be the type of ALDFG with the highest ghost fishing potential (Macfadyen et al., 2009; Gilman et al., 2016). This focus means that trammel nets are the only fishing gear included in the assessment of the interventions. The inclusion of the other fishing gears (gillnets, set longlines and traps) could influence the outcomes of the assessment.

4.2.3. Costs for an average vessel

To calculate the costs for the average vessel, the average of every cost was calculated (Table 3). The costs for an individual vessel might, however, differ from this average.

On the **cost** side, *Fixed costs* and *Investment costs* make up a small part of the total cost structure. *Operational costs*, *Maintenance and repair costs* and *Fishing gear cost* have by far the largest share in the cost structure. In the Business as Usual scenario, *ALDFG costs*, *Other plastic damage costs* and *Ghost fishing costs* are estimated to make up around 2.5 percent of the total cost structure. In the Intervention A scenario, *ALDFG recovery costs* arise which are based on the estimated cost of recovery per gear and the number of gears that are abandoned and lost. These costs make up about 4.4 percent of the total cost structure in this scenario. In the Intervention B.1 and B.2 scenarios, *Deposit costs* arise which are based on the deposit cost per gear and number of gears purchased per year. These costs make up 3.7 percent and 7.1 percent of the total cost structure in these respective scenarios.

4.2.4. Range of ghost fishing costs

A sensitivity analysis is performed to study how the results of the different cost scenarios change when certain key input variables are changed. Since ghost fishing and its associated costs are difficult to quantify, several estimates from the literature were used to make a **low**, **medium** and **high** estimation of ghost fishing costs (Brown & Macfadyen, 2007).

In the **low ghost fishing** scenario, ghost fishing costs were estimated to be 0.41 percent of the total value of fish landings, based on an average in the Mediterranean context (MacMullen, 2004). In the **high ghost fishing** scenario, ghost fishing costs are assumed to be 2.96 percent of the total value of fish landings, based on an average in the north-east Atlantic context (Sancho et al., 2003). For the **medium ghost fishing** scenario, ghost fishing costs were estimated to be 1.61 percent of the total value of fish landings, based on the average in the Baltic context (Tschernij & Larsson, 2003; MacMullen, 2004).

The effect these changes have on *Ghost fishing costs* for the average vessel is elaborated for the BAU and Intervention scenarios in Table 2 and Figure 17.

4.2.5. Overview cost estimates

Table 3 provides an overview of the costs of the BAU and intervention scenarios. The BAU scenario has the lowest average costs per vessel, the DRS scenarios the highest. This is due to the costs related to the deposit made when purchasing gear. The lowest costs related to the impact of ALDFG are for the intervention that proposed to track and recover lost gear, as

Table 2: Ghost fishing costs under low, medium and high ghost fishing scenarios

Ghost fishing costs	Low ghost fishing	Medium ghost fishing	High ghost fishing
BAU	€22	€89	€164
Intervention A	€0	€0	€0
Intervention B.1	€13	€53	€98
Intervention B.2	€13	€53	€98

Table 3: Costs under medium ghost fishing impact, average fishing vessel 2019

	Business As Usual (EUR)	Intervention A: Gear tracking and recovery (EUR)	Intervention B.1: Deposit Refund Scheme 15% (EUR)	Intervention B.2: Deposit Refund Scheme 30% (EUR)
Fixed costs	174	174	174	174
Operational costs	3,053	3,053	3,053	3,053
Maintenance and repair costs	1,893	1,893	1,893	1,893
Investment costs	241	241	241	241
Fishing gear costs	3,423	3,423	3,423	3,423
ALDFG costs	93	0	56	56
Other plastic damage costs	40	40	40	40
Ghost fishing costs	89	0	36	36
ALDFG recovery costs	-	403	-	-
Deposit costs	-	-	343	685
TOTAL COSTS	**9,006**	**9,227**	**9,258**	**9,601**

the aim of this intervention is to not leave any ALDFG in the marine environment so it cannot damage vessels or ghost fish.

Figure 16 shows how costs change under the different ghost fishing scenarios. Only the gear tracking and recovery intervention remains the same, as the impact of ALDFG is assumed to be fully addressed.

The costs presented here did not consider the impact of potential benefits. The main benefit for the fishing sector is revenue generated through the sale of fish and depends on the price fishers receive for their catch. If the price is low, then there is a high possibility that fishing is not a profitable enterprise. In addition, fishers receive income from subsidies. These are not related to measures taken to reduce ALDFG and will thus not have an impact on the profitability of the proposed interventions versus the BAU. Apart from specific subsidies, the interventions do have potential revenue streams.

In the case of gear tracking and recovery, the sale of recovered fishing gear could generate additional revenue. However, for the average vessel analysed in this study, this additional income is estimated to be only around 28€ per year, not enough to offset the higher costs of this intervention as compared to the BAU (221€ higher for an average vessel under the

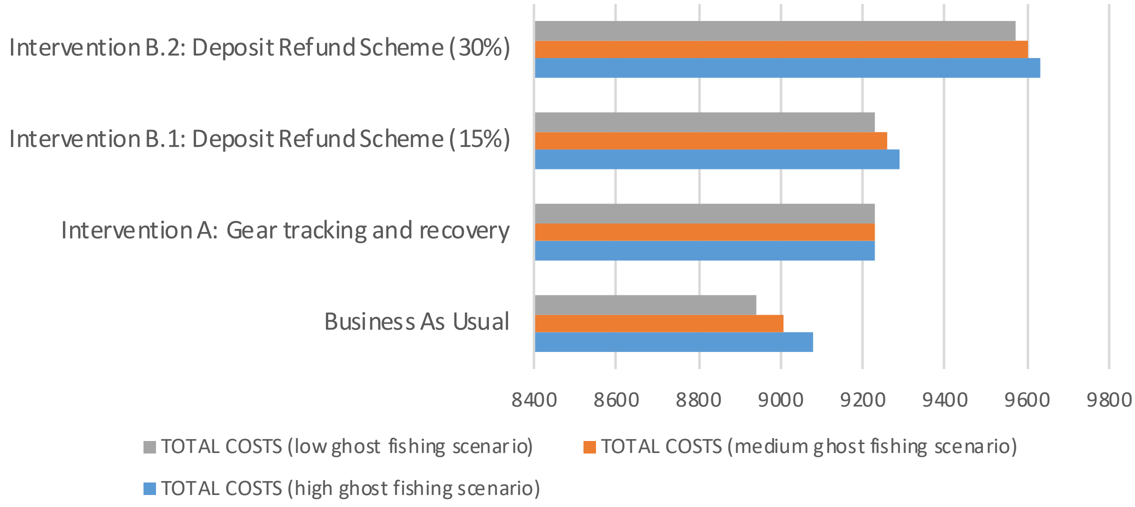

Figure 16: Total costs BAU and interventions under different ghost fishing scenarios in euro

medium ghost fishing scenario). In order for this intervention to be more profitable, better prices for recovered gear, for example through the development of markets for recycled products, may be needed.

For the DRS interventions, the lower costs due to ghost fishing, and the 'revenue' from deposit refunds are estimated to be higher than the higher costs of this intervention as compared to the BAU. For the DRS 15% scenario the revenue from returned is estimated at 326€, versus a higher cost of 252€; for the DRS 30% scenario the revenue from returned is estimated at 651€, versus a higher cost of 595€. Thus, when fish prices allow for a positive net benefit of fishing, these interventions are estimated to be more profitable than the BAU.

The focus of this analysis has been the impact of ghost fishing on the fishery sector itself. However, there are broader impacts related to ghost fishing and marine plastics that were not included. Reducing these impacts can have broader positive impacts.

5. Broader impact

When ghost fishing occurs, it does not only impact the stocks of economically important species targeted by the fishery sector, but it can also have harmful impacts on vulnerable, endangered and protected species , and cause damage to benthic marine habitats such as coralligenous reefs (Link et al., 2019; Angiolillo Fortibuoni, 2020) and seagrass meadows (NOOA, 2016; Gerstenbacher et al., 2022).

In the case of ALDFG, one of the main impacts is caused by entanglement. For example it has been estimated that entanglement in fishing gear caused an annual decline of 4-6 percent in the fur seal population (Derraik, 2002). Whereas entanglement of turtle species, among other marine animals, in ALDFG has also been observed (Gunn et al., 2010).

These two examples are relevant for the Republic of Cyprus as the island's sea biodiversity includes the Mediterranean monk seal (*Monachus monachus*) and two marine turtles, the Green turtle (*Chelonia mydas*) and the Loggerhead turtle (*Caretta caretta*) (Department of Environment, 2014). These species, specifically the monk seal, are in need of protection (Table 4).

The coastal waters of the island also harbour 197 fish species and various species of crabs, sponges and Echinodermata (Department of Environment, 2014). In addition, the sea is characterized by diverse habitats. For example, the angiosperm *Posidonia oceanica*, endemic to the Mediterranean, develops large seagrass beds along the coasts at depths between 5 to 40 metres. Reefs can be also be found, at depths below 25 metres (Department of Environment, 2010; Kletou et al., 2020). It is one of the few areas in the Mediterranean Sea where lower and upper Miocene coral reefs can be found (Coletti et al., 2021). Marine litter, including ALDFG also has a negative impact on these marine ecosystems (NOOA, 2015; Angiolillo and Fortibuoni, 2020). Furthermore, the degradation of marine habitats will also affect the health of fish populations, which can also affect the fishing sector.

Picture 5: Green Sea Turtle (Shutterstock)

ALFGD can also have wider economic impact. For example, marine plastics can negatively affect the tourism industry, especially when it is reliant in part on beach tourism (e.g. Ballance et al. 2000; Krelling et al. 2017).

Table 4: IUCN Red List status marine animals Republic of Cyprus

Popular name	Scientific name	IUCN Red List status
Green turtle	*Chelonia mydas*	Endangered
Loggerhead turtle	*Caretta caretta*	Vulnerable
Mediterranean monk seal	*Monachus monachus*	Endangered

Source: https://www.iucnredlist.org/species/

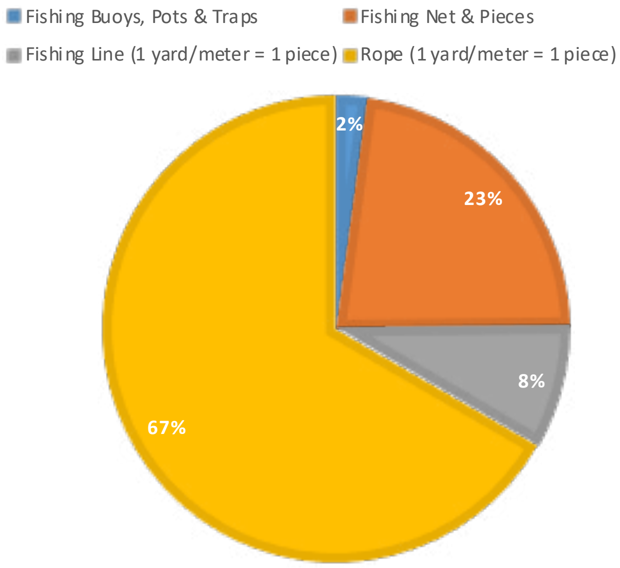

Figure 17: Fishing items collected in Republic of Cyprus through beach clean-ups in 2019 (Source: https://www.coastalcleanupdata.org/reports)

Part of this beach litter can consist of ALDFG and other fishing gear. However, in the case of the Republic of Cyprus, in 2019 only 0.83 percent of all items collected through beach clean-ups and reported on the TIDES database[2] was fishing gear, of which 23 percent was fishing nets (Figure 17).

Mediterranean fisheries and the marine environment are of course also impacted by a much broader range of issues, such as overfishing (FAO, 2018); alien species (Zenetos et al., 2012; Katsanevakis et al., 2016); the overall impact of increased pollution, including marine macro- and microplastics from different countries and sources (Gérigny et al., 2019; Rotjan et al., 2019; Boucher and Bilard, 2020), as well as the increasing impact of climate change (e.g. Kim et al., 2019; Moulec et al., 2019; Chaikin et al., 2021). The reduction in ALFDG alone, will not be enough to improve the overall health of the Mediterranean Sea.

Picture 6: Mediterranean monk seal (Luigi Budone/Archipelagos-Ambiente e Sviluppo Italia)

2 TIDES: Trash Information and Data for Education and Solutions, available at: https://www.coastalcleanupdata.org

6. Discussion, conclusions and recommendations

6.1. Discussion

The small-scale inshore fishing fleet consists of a relatively old population of fishers who depend on fishing for the majority of their household's income. The main fishing gears used are trammel nets and gillnets. About 20 percent of fishers have encountered and interacted with ALDFG, while 17 percent stated to have lost fishing gear and 7 percent stated to have abandoned or discarded fishing gear. The negative consequences of ALDFG are thus caused by a minority of fishers, but potentially affect the whole fishing fleet.

The main causes for gear loss are stated to be conflicts with the seafloor and other gears, while the main cause for the abandoning or discarding of fishing gear is stated to be time or space constraints. On average, a fisher abandoned, lost and discarded one trammel net, with again a minority of fishers being responsible for high numbers of fishing gear ending up in the marine environment.

Mapping the fishing grounds is an important first step in the localization of ALDFG in the marine environment, as they are most commonly found in the vicinity of fishing grounds (Macfadyen et al., 2009). Additionally, fishers are shown to be an important source of knowledge on the specific location of ALDFG, which makes it possible to prioritize recovery attempts and improve cost-efficiency. Our mapping of fishing grounds and the location of ALDFG is an important first step in a systematic recovery of fishing gear. Furthermore, the (mandatory) reporting of gear loss, with specifications on the location, could be implemented to ensure a quick recovery as to minimize the negative consequences of ALDFG in the marine environment. ALDFG retrieval programmes and data collection could go hand in hand to reduce its impacts and generate additional information on the causes and effects of ALDFG (Richardson et al., 2019).

Fishers' perception of the effectiveness of certain measures is important, since their knowledge is context-specific, while fishers might feel more inclined to adopt measures if they think they are effective. Existing measures such as spatial management and effort regulations are considered to be very effective, and should therefore be kept in place or even improved. Additionally, clean-up or recovery of fishing gear and economic incentives for the collection of old gear are considered to be very effective, and were therefore included as interventions in the cost-benefit analysis. Surprisingly, technical measures such as biodegradable gear and gear modification to reduce loss were perceived to be not very effective, potentially due to the often perceived reduced effectiveness or higher cost price (Macfadyen et al., 2009).

Although not specifically assessed in this analysis, the two interventions could be combined. The combination of Gear tracking and recovery and a Deposit Refund Scheme for fishing gear could have potential mutualistic effects on the reduction of ALDFG and its impacts and the costs associated with it. Gear tracking and recovery decreases *ALDFG costs* and *Ghost fishing costs* to zero, but increases the total costs due to the high *Gear recovery costs*. A DRS for fishing gear on the other hand would decrease ALDFG at the source, leading to a reduction in the total costs. When combining both interventions, the costs of fishing gear recovery could be partially compensated by the reduction in *ALDFG costs* and *Ghost fishing costs*, while the higher value of the fishing gear in a DRS could increase the incentives to recover the fishing gear from the marine environment.

Combining the implementation of these two interventions might however pose additional challenges, as both would need to be adjusted to the other to create the necessary incentives for fishers. Ideally, the deposit value should be equal to or higher than the cost to recover a piece of fishing gear, which in turn would be additionally incentivized if the avoided costs by recovering the gear are higher than the recovery cost.

Since the causes of ALDFG depend on the gear being either lost, abandoned or discarded, solutions should be tailored to tackle the underlying cause. Gear tracking and recovery might be primarily used for tackling lost fishing gear, while a DRS for fishing gear would give incentives to reduce abandoning and discarding fishing gear.

The implementation of coordinated gear recovery efforts, in combination with the requirement to report gear loss, could reduce the costs of ALDFG and ghost fishing for fishers and additionally omit many of the environmental impacts of ALDFG if recovered early after loss. Given the assumptions made in this study, the cost analysis points at gear tracking and recovery as bringing more costs, if the recovery costs were to be borne by the fishers themselves. Charging the fishers who lost their fishing gear for the recovery might however create disincentives for the reporting of gear loss. Further data should be collected to assess the costs of recovering gear in its specific context.

The implementation of a deposit refund scheme for fishing gear could reduce ALDFG and its associated costs by increasing both the cost price of a new piece of fishing gear (and

Picture 7: Ghosts nets as part of the reef system. Located at Kakoskali MPA, Cyprus (Carlos Jimenez)

thus disincentivizing losing, abandoning or discarding it) while additionally incentivizing the collection of waste gears in return for the deposit value (and thus dis-incentivizing ALDFG and improper disposal on land, while incentivizing the recovery of ALDFG already in the marine environment).

6.2. Recommendations

Existing policies on (plastic) waste management at the EU level, and in particular those on waste fishing gears, should be implemented as soon as possible, in line with the recommendations in Iovinelli A. (2021). Several measures to reduce ALDFG and its impact are however in place in the Republic of Cyprus, although not all fishers are equally aware of this. Given that the most important source of information on fishery regulations and policies is the government website, more effort should be put in the outreach of this information to fishers.

If the existence and sustainable operation of the small scale fishing fleet is to be supported, attention should go to the problem of marine plastic pollution and in particular ALDFG, as it is estimated to contribute significantly to the overall cost structure of the fishing fleet. As the costs occurring in the fishing operations go beyond marine plastic pollution, attention should likewise be given to the other drivers that decrease benefits and increase costs.

The implementation of gear tracking and recovery may eliminate ALDFG and its impacts, but if the cost of recovery is to be borne by the fishers, it is estimated to reduce the profitability of the sector. The implementation of a Deposit Refund Scheme for fishing gear may however not eliminate ALDFG and its impacts, but is nevertheless estimated to have a positive impact on the profitability of the sector. Although not explicitly explored in this study, combining the two different interventions might generate mutualistic effects where implementing one might incentivize the other, which may have a positive impact on the benefits of the small scale fishing fleet while at the same time reducing ALDFG and its negative impacts.

In addition, the localization of ALDFG may help understanding the impact of the seafloor, depths, currents, gear from other vessels and help create a model of potential areas of ghost gear accumulation within the Mediterranean.

6.3. Limitations

Although our study makes a first significant effort to assess the situation regarding ALDFG and its impact on the small scale fishery sector in the Republic of Cyprus, this analysis was however limited in scope and could therefore not include all relevant aspects.

Apart from the marine species targeted by the fishers, the impact of ALDFG on the marine ecosystem was not included in this analysis, although it is widely recognized to be significant (Richardson et al., 2019a). This impact is associated with costs, which are not taken into account and therefore make this assessment of costs an underestimation. The *Ghost fishing costs* used in the analysis were based on findings from the literature stating the percentage of fish landings value that can be lost due to ghost fishing, and are not based on and linked with the collected data on ALDFG.

The interventions may in reality have more complicated effects on the behaviour of fishers and of the costs and benefits they are confronted with, but were however not assessed within this study.

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Annex

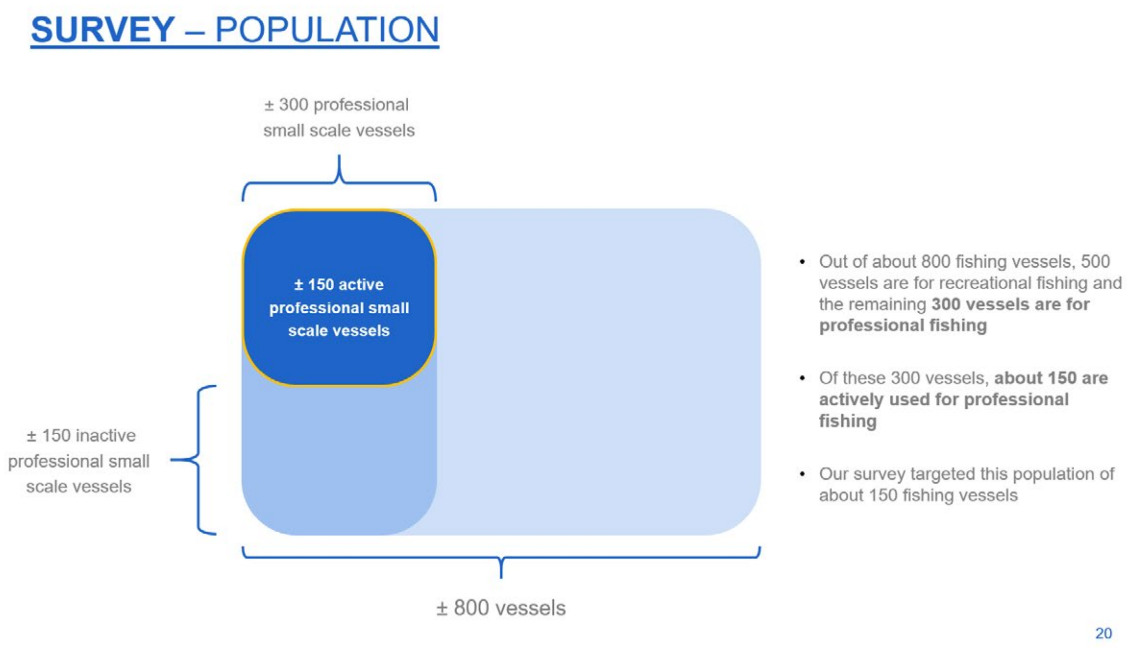


Figure A1: Survey population

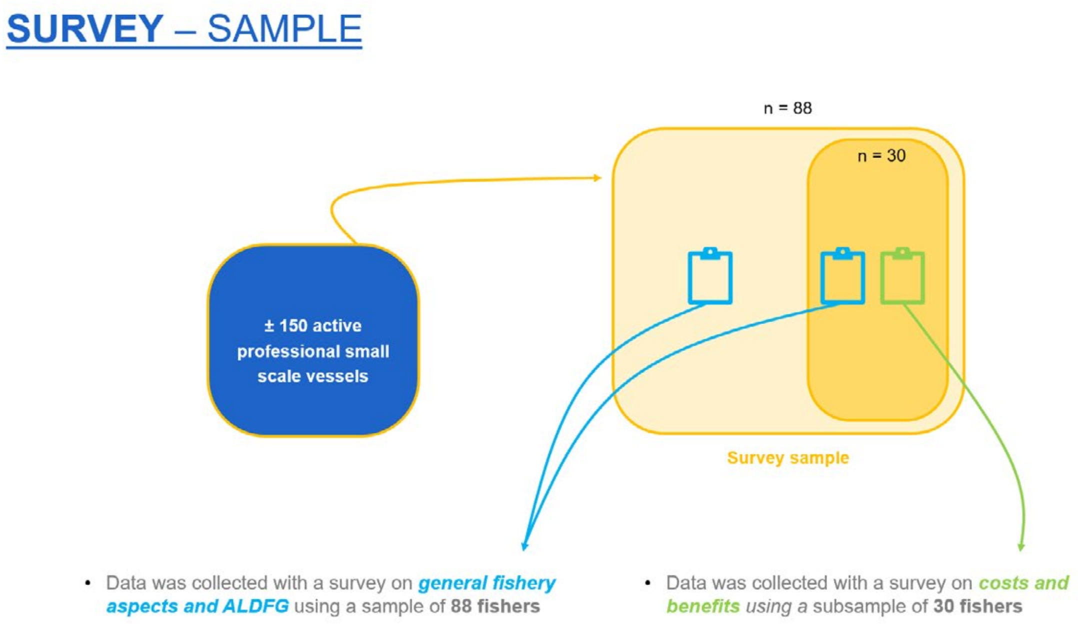
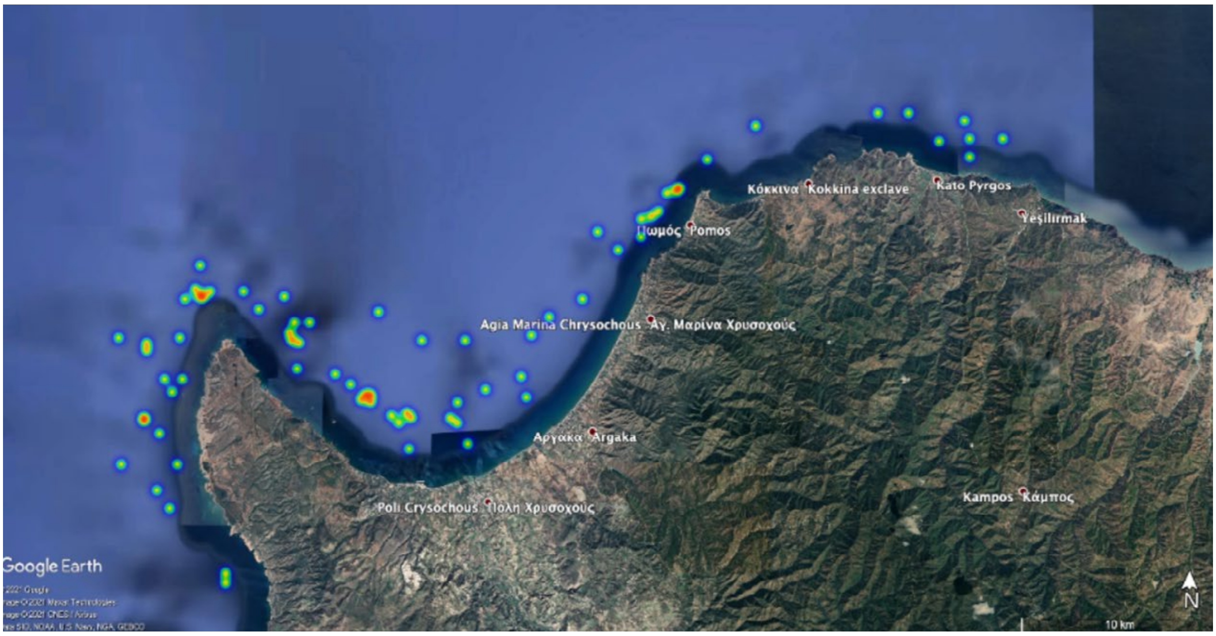


Figure A2: Survey sample

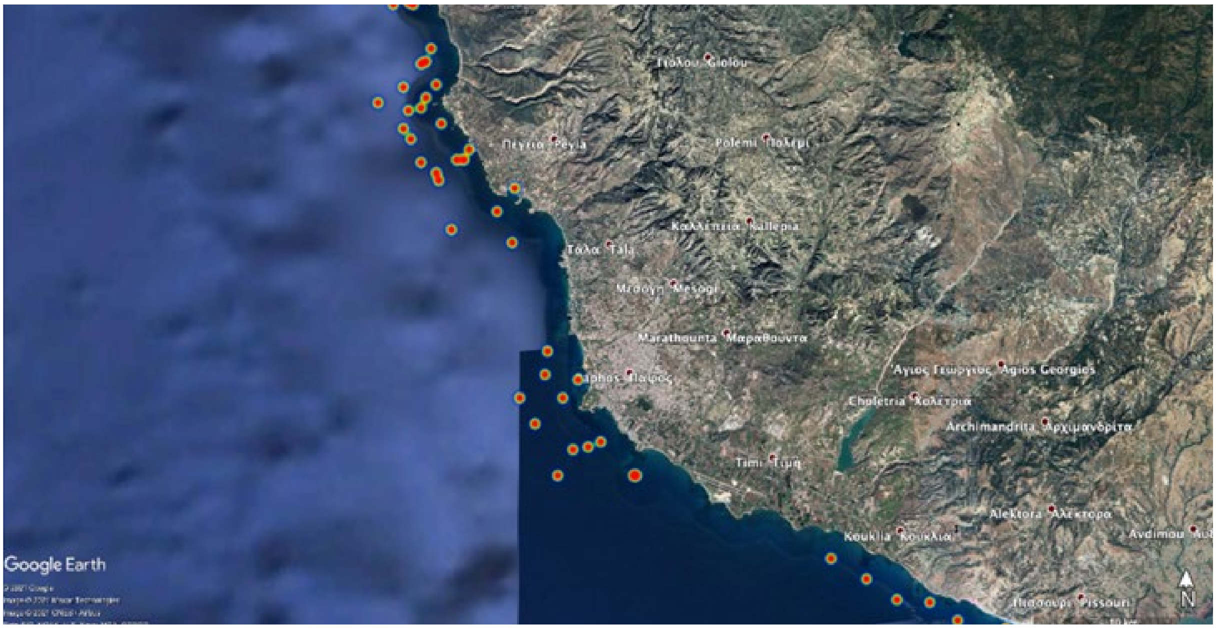
Maps Kato Pyrgos Fishing Shelter, Pomos Fishing Shelter and Latchi Harbour



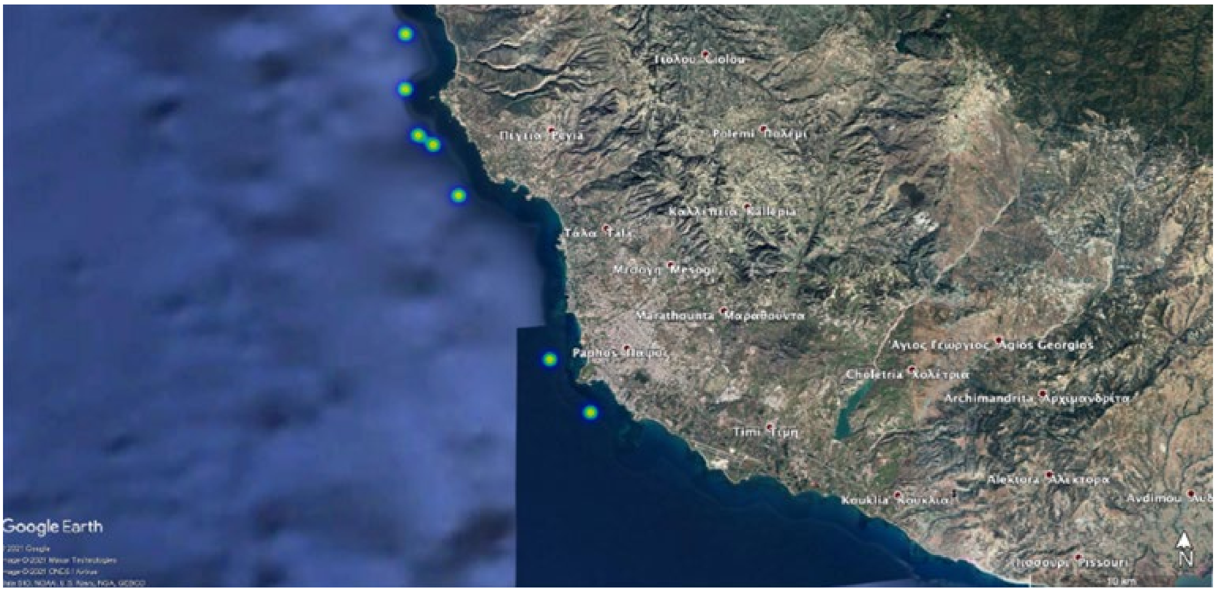
Map A1: Location of fishing grounds, Kato Pyrgos Fishing Shelter, Pomos Fishing Shelter and Latchi Harbour

Map A2: Location of encountered ALDFG, Kato Pyrgos Fishing Shelter, Pomos Fishing Shelter and Latchi Harbour

Maps Agios Georgios Pegeias Fishing Shelter and Paphos Harbour



Map A3: Location of fishing grounds, Agios Georgios Pegeias Fishing Shelter and Paphos Harbour



Map A4: Location of encountered ALDFG, Agios Georgios Pegeias Fishing Shelter and Paphos Harbour

Maps Limassol Harbour

Map A5: Location of fishing grounds, Limassol Harbour

Map A6: Location of encountered ALDFG, Limassol Harbour

Maps Zygi Fishing Shelter

Map A7: Location of fishing grounds, Zygi Fishing Shelter

Map A8: Location of encountered ALDFG, Zygi Fishing Shelter

Maps Larnaka Fishing Shelter and Ormidhia Fishing Shelter

Map A9: Location of fishing grounds, Larnaka Fishing Shelter and Ormidhia Fishing Shelter

Map A10: Location of encountered ALDFG, Larnaka Fishing Shelter and Ormidhia Fishing Shelter

Maps Agia Napa Fishing Shelter and Agia Triada Fishing Shelter

Map A11: Location of fishing grounds, Agia Napa Fishing Shelter and Agia Triada Fishing Shelter

Map A12: Location of encountered ALDFG, Agia Napa Fishing Shelter and Agia Triada Fishing Shelter

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