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GHOST MED: ASSESSMENT OF THE IMPACT OF LOST FISHING GEAR IN THE FRENCH MEDITERRANEAN SEA

Abstract

Lost and abandoned fishing gear affects all marine habitats, both coastal and offshore habitats such as bathyal habitats, including canyons. Not only professional fishing nets, longlines and fishing traps are concerned, but also recreational fishing tackle (fishing lines, lead weights, hooks, etc.). This lost gear causes various forms of negative impact including ghost fishing, that has been extensively studied for several decades. However, the lack of information on the quantification of lost gear and the assessment of impacts other than ghost fishing is critical worldwide. The aim of the Ghost Med program is (i) to quantify the lost fishing gear in the Mediterranean and characterise the habitats concerned, (ii) to address federate underwater observers and citizen science to better collect data on fishing gear loss events, (iii) to assess their impact on species and habitats, and (iv) to propose tools to managers in order to prioritize, or not, their removal. The protocol is based on an assessment of the environmental and seascape impact of the lost gear as well as the technical risks involved in its removal. Each of these parameters was measured using several criteria, such as the number of mobile species trapped in the gear, the number of fixed species damaged or uprooted and the alteration of the habitat relief. All these criteria are weighted by a score which will then be used to calculate the lost gear Removal Aid Index (RAI). This simple-to-use protocol should help Marine Area managers to determine whether gear removal should be considered. This protocol is currently used as a basis for the assessment and removal of fishing nets in France, and could be extended to all Mediterranean coasts.

Key-words: Ghost Med Program, lost fishing gear, ghost fishing, Mediterranean, coralligenous.

Introduction

More than 8 million metric tons (t) of waste are discharged into the global oceans each year. The marine garbage consists mainly of land origin waste, while the main source of marine litter is the merchant marine fleet. The amount of lost and discarded nets has only been sketchily estimated, but Macfadyen *et al.* (2009) estimated that they represented around 10% of the marine waste. In the Mediterranean Sea, the impact of lost fishing gear (LFG) is of importance because of the high intensity of artisanal fishing activities off the coast and the offshore industrial fishing effort, involving the use of various devices: gillnets, trammel nets, trawls, longlines, traps, etc. In the coastal zone, recreational fishing activities also contribute in a significant way to the LFG in the form of fishing lines, lead, lure, etc. Fishing gear lost in the Mediterranean Sea has been estimated at between 2637 and 3342 tons per year (Golik, 1997); nevertheless, the overall assessment remains uncertain, and often only concerns small geographical areas. Professional fishing activities are regulated by very strict guidelines. Most fishermen follow the rules because of the cost of the fishing gear; in addition, they have an interest in adopting environmentally friendly practices in order to ensure sustainable resources. The loss of fishing gear is mostly accidental, for example due to rough weather conditions, lack of familiarity with the marine areas, user conflicts or gear drifting with the current.

The LFG has various forms of impact on the marine environment. Firstly, the best-documented is ghost fishing, which generates the unintentional and unnecessary trapping of mobile fauna. The more recent the LFG the more the ghost fishing is abundant (Ayaz *et al.*, 2006). The impact decreases over time, but could last over considerable periods if the net remains deployed in the water column. Moreover, it acts with a cascade effect because the trapped organisms attract other predators or scavengers, which are in turn trapped, and so on. LFG also damages the benthic habitat and the species attached to the substrate and alters the functioning of the habitat. The risk of chemical pollution linked to the presence of LFG is based in the introduction of synthetic materials into the trophic chain of ecosystems. Finally, they present a significant danger to the users of the sea, namely, navigators, swimmers and divers. On the other hand, the colonization on old LFG submerged for a long time can constitute new complex structures, sometimes with heritage value species. This aspect must be considered for the overall assessment of the impact of LFG because their removal may be more harmful for the habitat than beneficial.

In the Mediterranean Sea, information on LFG is sparse and incomplete. The aim of this study is: (i) to quantify the LFG in the French Mediterranean and characterise the habitats concerned; (ii) to address federate underwater observers and citizen science to better collect data on fishing gear loss events; (iii) to assess their impact on species and habitats, and (iv) to propose tools to managers to prioritize, or not, the removal of lost gear. The aim of the Ghost Med program is to coordinate the available information, initially with regard to French waters, with a view towards extending the investigation to the Mediterranean as a whole.

Materials and methods

Since 2015, a database has been constituted to gather all the data available on LFG in the French Mediterranean Sea. This database collects observations from three sources: (i) scientific, (2) managers and (3) citizen science. The scientific observations come from scientific campaigns usually devoted to naturalist knowledge such as Natura 2000 site descriptions, Medseacan and Corseacan missions for the exploration of Mediterranean canyons (Fourt & Goujard, 2012), and seabed mapping. The managers observations are provided by *in situ* observations of field-based staff. The citizen observations are provided by an online data recovery form (<https://www.mio.univ-amu.fr/ghostmed/en/form/>) that enables members of the public to declare the observation of LFG. The form provides for the entry of at least the following information: type of fishing gear, depth, concerned marine habitat, geographical position, date of observation and identity of the observer. A 'Comments' box is provided to allow for any additional details. To federate underwater observers and citizen science, social networks, the development of a website, participation in conferences, trade fairs and press releases were used.

Environmental, seascape and technical criteria are used to assess the impact of LFG on the marine environment. Each criterion is quantified by a set of relevant parameters. Each parameter is assessed by a semi-quantitative or a qualitative scale, and a score is assigned. The sum of the scores gives the assessment of the criterion. Note that the scores can be negative because some impacts may have a positive effect, e.g. the colonization of the fishing gear.

Parameters for environmental impact (EI) (Tab. 1).

- The **colonization** of the fishing gear is assessed within four colonization stages: (0) without epibiosis; (1) by filamentous algae; (2) by macroalgae and hydrozoa; and (3) by encrusting epibiosis (bryozoa, macroalgae, annelida, etc.). The more developed the colonization is, the less the removal of the gear would be appropriate.

- The **trapped mobile fauna** is quantified by the number of individuals trapped in the LFG on the basis of a semi-quantitative scale.
- The **removed fixed species** concerns all the benthic species fixed to the substrate that have been torn off by the action of the fishing gear. It is estimated by the number of individuals removed in the LFG.
- The **damaged fixed species** are species that undergo necrosis or breakage due to contact with the LFG. This is assessed by the number of individuals damaged by the LFG.
- The **presence of outstanding species** concerns the species that have colonized the LFG. Outstanding species are species presenting heritage value, such as protection status and rarity, and/or commercial value.
- The **obstructed cavities** are quantified by the number of cavities that are no longer accessible for mobile fauna.
- The **abrasion of the substrate** is the observation or not of a friction effect of the LFG on the substrate which would then damage the colonization.
- The **habitat creation** is when the LFG sustains an ecological role for the marine fauna such as nursery, hideout or pantry.

Tab. 1: Parameters for assessing the environmental impact (EI) of lost fishing gear.

Parameter	Assessment	Score
Colonization	Stage 0	0
	Stage 1	-2
	Stage 2	-4
	Stage 3	-6
Trapped mobile fauna	0	0
	1 to 5 individuals	2
	> 5 individuals	5
Removed fixed species	0	0
	1 to 10 individuals	1
	> 10 individuals	2
Damaged fixed species	0	0
	1 to 10 individuals	1
	> 10 individuals	2
Presence of outstanding species	Yes	0
	No	1
Obstructed cavities	0	0
	1 to 10 cavities	1
	> 10 cavities	2
Abrasion of the substrate	No	0
	Yes	1
Habitat creation	Yes	-2
	No	2
Total		-8 to 15

Parameters for seascape impact (SI) (Tab. 2). The impact is assessed according to five criteria, with ratings between -2 and 5. The sum of the scores of these criteria provide a basis for estimating the seascape impact of the LFG. The total of the scores range from 15 (very negative) to -2 (positive effect on the seascape). The "seascape alteration" criterion is based on the observation of a visual alteration of the seascape. For example, a large net laid flat on a seabed will profoundly alter the seascape, while on its own, a fishing line placed across a coralligenous habitat will not.

- The **distance of visibility** is the distance at which the LFG is visible.
- The **extent of impact** corresponds to the surface concerned by the LFG (usually the surface area occupied by the gear on the bottom).
- The **seascape alteration** is the recognition or not that there is an alteration of the seascape.
- The **qualifying adjective** used to qualify the alteration of the seascape could be neutral, positive or negative.
- The **relief** created by the LFG may or not alter the natural relief of the site. For example, if the gear is lying on a rocky scree, it tends to detract from the relief, whereas if it is deployed in the water column, it enhances the relief.

Tab. 2: Parameters for assessing the seascape impact (SI) of lost fishing gear.

Parameter	Assessment	Score
Distance of visibility	< 1 m	1
	From 1 m to 5 m	2
	> 5 m	3
Extent of impact	< 5 m ²	1
	From 5 m ² to 20 m ²	3
	> 20 m ²	5
Seascape alteration	No	0
	Yes	3
Qualifying adjective	Neutral	0
	Negative	2
	Positive	-2
Relief	No alteration	0
	Diminution of the relief	2
	Enhancement of the relief	-2
Total		-2 to 15

Parameters for technical risk (TR) (Tab. 3). The technical risk is considered with regard to the diver's intervention or the technical equipment required for the removal of the LFG. The technical risk is composed of two criteria that alone can tip the decision on whether to remove the fishing gear.

- The **depth** of the LFG.
- Attachment of the LFG **to the bottom** is a criterion that modulates the time spent by divers on the bottom and the use or not of specific tools.

Tab. 3: Parameters for assessing the technical risk (TR) of removing the lost fishing gear.

Parameter	Assessment	Score
Depth	≤ 20 m	1
	20 to 50 m	2
	> 50 m	3
Attachment to the bottom	Relatively easy	0
	Difficult and time-consuming	2
Total		1 to 5

Removal Aid Index (RAI). The aim of this index is to assist managers in their decision-making for the removal of nets. The calculation is based on the use of the environmental impact (EI), seascape impact (SI) and the technical risk (TR):

$$RAI = \frac{EI + SI}{TR}$$

The RAI ranges from -10 to 30. The higher the value, the more it will be advisable to remove the LFG. The technical risk is placed in the denominator because the higher the risk, the less the removal is a priority. This means that fishing gear with a maximum environmental and landscape impact of 30, but with a maximum technical risk of 5, will never be given priority for removal. To interpret the RAI, we use 3 classes of decision:

- 20 < RAI ≤ 30: the removal of the LFG is strongly recommended, priority 3;
- 10 < RAI ≤ 20: the removal of the LFG is recommended, priority 2;
- 0 < RAI ≤ 10: the removal of the LFG is not a priority, priority 1;
- 10 < RAI < 0: The removal of the LFG is not recommended, priority 0.

Results

The database includes 1256 observations of LFG (121 manager observations, 111 citizen observations and 1024 scientific observations; Tab. 4). The number of scientific observations was high until 2015, because we began to collect scientific data from scientific campaigns such as the campaigns in the Mediterranean canyons Medseacan and Corseacan (900 observations), and we reviewed all available studies on habitat description and mapping (e.g. Houard *et al.*, 2012; Charbonnel *et al.*, 2013). The Ghost Med team currently includes 12 scientists, 7 managers and 70 citizen observers.

Tab. 4: Total number of observations collected in the database. Natura 2000: habitat studies of Natura 2000 sites conducted by coastal oceanography and marine environment offices; GIS Posidonie: observations collected in different GIS Posidonie studies; CG06: French local council of the Alpes-Maritimes, Ghost Med: present program on LFG.

Date	Total number of observations	Main sources	Number of citizen observations
2005	3	Natura 2000	1
2006	6	Natura 2000	1
2007	12	Natura 2000	1
2008	59	Natura 2000	1
2009	494	Medseacan	0
2010	440	Corseacan	5
2011	20	Natura 2000	2
2012	5	Natura 2000	3
2013	44	GIS Posidonie, CG06	2
2014	32	Ghost Med	20
2015	35	Ghost Med, FFESSM	13
2016	25	Ghost Med	16
2017	18	Ghost Med	7
2018	63	Ghost Med	39

Among the data, some relate to Mediterranean canyons and others to coastal habitats (356 observations). The main coastal habitat concerned for the database is the coralligenous habitat (Tab. 5). The damage to coralligenous habitats is much greater than for infralittoral rocky reefs. Cnidarians and bryozoans can be broken or injured by contact with nets. Among the 1256 listed LFG, 50 have been removed.

The use of the RAI in several cases led to contrasting results, depending on the situations. This index has the advantage of being objective and based on parameters that can be quickly assessed *in situ*. It is a tool proposed to managers in order to prioritize, or not, the removal of lost gear. Of the 10 cases investigated *in situ*, we obtained values ranging from -5 to 30. The weakest values concerned old lost nets that were completely colonized and/or on soft substrates, and so not obstructing cavities. The highest RAI value was

obtained for fishing gear lost on a shallow bottom and not attached to the rock; many species were trapped in the net and it had uprooted and damaged several species fixed on the bottom; it also obstructed numerous cavities and its movements abraded the substrate; this gear was not colonized and did not create any habitat; it therefore had a very strong negative environmental impact. From a seascape point of view, this LFG was extensive, visible and strongly altered the seascape. This net has a maximum RAI value (30), and its removal was therefore highly recommended because of its severe environmental and seascape impact and because the technical risk is limited. Even if the environmental impact of the deeper LFG, especially in the marine canyons, is often significant, their removal is not a priority, mainly because of the technical risk related to the depth.

Tab. 5: Number of observations of LFG according to habitats and the type of fishing gear.

Coastal habitat	Number of observations	Type of fishing gear	Number of LFG
Canyons	900	Fishing nets	393
Coralligenous	202	Longlines	315
Macroalgae-dominated infralittoral rocky reefs	79	Fishing tackle (lead, lure, fishing hook, etc.)	248
<i>Posidonia oceanica</i> meadow	28	Undetermined	230
Artificial reefs	18	Fishing lines	58
Wrecks	15	Traps	4
Sandy bottoms	9	Ropes	4
Coastal detrital bottoms	5	Trawl nets	4

Discussion and conclusions

The contribution of the citizen science is essential to have new reports of sightings when working on extensive geographical areas; however, this concerns mainly the sites most popular among scuba divers. This is why it is essential to collect information from environmental managers and scientific campaigns. In this context, collaboration with fishers is important for receiving early warning when they lose fishing gear. The coralligenous habitat is one of the coastal habitats most affected by LFG, and is very sensitive to their mechanical impact. The erect species are the most sensitive to the abrasion due to fishing nets and to their removal, due to the pressure exerted. The Ghost Med program enhances efforts to address and mitigate the incidence and impact of all kinds of lost or abandoned gear, to support decision-making for their removal and to adopt mechanisms to monitor and reduce discards. It could now be extended to cover the whole of the Mediterranean Sea.

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