GHOST

TECHNIQUES TO REDUCE THE IMPACT OF GHOST FISHING GEARS
AND TO IMPROVE BIODIVERSITY IN NORTH ADRIATIC COASTAL AREAS

LIFE-GHOST
Final Publication

TECHNIQUES TO REDUCE THE IMPACTS OF GHOST FISHING GEARS AND TO IMPROVE BIODIVERSITY IN NORTH ADRIATIC COASTAL AREAS
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Authors:
Da Ros L., Alfarè L., Delaney E., Fiorin R., Moschino V., Nesto N., Picone M., Riccato F., Tonin S.

Editorial and Design project: Syscom.it Srl , Udine

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CONTENTS

FOREWORD

The LIFE-GHOST project "Techniques to reduce the effects of ghost fishing gears and to improve biodiversity in North Adriatic coastal areas" was co-funded by the European Commission under the LIFE+ Biodiversity programme (2012 programming).

Thanks to innovative approaches, the project helped assess the presence and effects of "ghost nets" and other fishing gear lost or abandoned in the so-called *tegnùe*, sub-tidal rocky outcrops along the Veneto coastline.

The project involved three Italian partners - the Institute of Marine Sciences (National Research Council, Venice) as project coordinator, the Department of Design and planning in complex environments (University IUAV of Venice), and the private company Laguna Project. The project started in 2013 and ended in 2016, with a total budget of €1,127,020, €544,763 of which were provided by the EU.

This report describes the results of the three-year project, and provides a general overview of the ghost net phenomenon and its impact on the sea environment and associated economic activities. It examines the operational procedures used both to assess the magnitude of the problem in the North Adriatic, and to recover ghost nets effectively, with no further damage to the ecology of affected areas.

Each chapter focuses on different aspects of the project - preparatory, concrete, monitoring and dissemination actions -as is always the case with LIFE projects. After presenting the aims and the environmental context, we describe the preparatory field investigation to update bibliographic references and to map ghost nets. We then examine how we removed fishing gear from the seabed, and assessed the technical feasibility of suitable mechanical and chemical treatments to reuse collected materials. At the same time, we identified the most effective recycling procedures to manage end-of-life fishing gear responsibly. This activity was carried out in collaboration with local authorities and fishing sector leaders.

Nets were removed using operational protocols specifically designed for the project in coastal areas particularly rich in biodiversity like the *tegnùe*. We monitored the recovery of the rocky habitat ecosystem, and assessed the economic value of increased biodiversity, showing that environmental recovery interventions are economically sustainable.

The final chapters focus on the communication tools and networking activities used in the project to emphasise results. These activities prompted increased awareness and knowledge on environmental problems among citizens and stakeholders, and enabled us to establish dynamic relationships between members of the scientific and manufacturing sectors – a first step towards future joint initiatives aimed at identifying solutions for the reduction of ghost nets and other plastic waste in the sea.

1. THE PARTNERSHIP

National Research Council – Institute of Marine Sciences (CNR-ISMAR)
(Project coordinator)

Team ISMAR: Luisa Da Ros, Loredana Alfarè, Alfredo Boldrin, Eugenia Delaney, Vanessa Moschino, Nicoletta Nesto

Founded in 2001, the Institute of Marine Sciences of the National Research Council (CNR-ISMAR) joins Italian CNR institutes from Ancona, Bologna, Genova, La Spezia, Lesina (Foggia), Trieste and Venice that carry out research on coastal areas and the sea, in fields such as the evolution of oceans and their continental margins; the influence of climate change on oceanic circulation, acidification, bio-geochemical cycles and marine productivity; aquatic habitats, their ecology and pollution, and natural and anthropogenic factors with economic or social effects on aquatic ecosystems.

University IUAV of Venice – Department of Design and Planning in Complex Environments
(Project partner)

Team IUAV: Stefania Tonin, Margherita Turvani, Laura Fregolent, Greti Lucaroni

The IUAV University of Venice is the second school of architecture and planning founded in Italy in the early 1920s. The Department of Design and planning in complex environments promotes curricula and research in planning, design and management in the field of land uses, socio economic transformations in the city, territory and the environment. It develops research methodologies on different territorial and temporal scales to explain the evolution of structural and systemic links that define areas.

Laguna Project s.n.c.
(Project partner)

Team Laguna Project: Federico Riccato, Riccardo Fiorin, Marco Picone

Established in 2006, Laguna Project is a company involved in environmental monitoring of the North Adriatic and Venice lagoon ecosystems. Its main activities are quantitative sampling of benthic, planktonic and fish fauna in fresh and transitional water and open sea, visual censuses of benthos and nekton, fish and mollusk stock monitoring, environmental impact assessment, taxonomic identification of macro and meio benthic fauna, and monitoring of coastal and transitional waters.

2. THE LIFE-GHOST PROJECT

2.1 Background

Accidentally or intentionally abandoned in the sea and transported by currents without substantial biodegradation, “ghost nets” may long continue to catch uncontrollably not only fish and other vagile organisms, but also endangered and protected species, such as turtles.

Seabirds diving to capture trapped fish, cetaceans and other marine mammals may also become entangled. It is estimated that over one million birds and 100,000 marine mammals die globally each year by becoming entangled in ghost nets, or by ingesting plastic originated from them. In addition, several studies on static gear show that the loss of marine resources due to “ghost fishing” may be about 10% of the target population (UNEP, 2005).

Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) may be a navigational hazard when it gets caught in propellers and rudders, ultimately causing considerable damage to vessels. It can also physically and functionally alter the benthic habitat and increase recreational activity risks, especially for divers. Ghost nets and gear may be dragged by sea currents for long distances, thus contributing to the transport of potential alien species, which are major threats to the biodiversity of marine ecosystems.

Lastly, it should be borne in mind that nets, being made of plastic, can last for long periods in the sea. The mechanical effects of boats, waves, storms and strong winds tend to shatter them into gradually smaller plastic fragments that increase the concentration of microplastic particles in the water column and in sediments. The threat posed by microplastics to marine environments has only recently come to the fore.

According to a recent report by the UN Environment Programme, 6.4 million tons of waste are discharged into the sea every year, and 10% of them (640,000 tons) are associated with fishing activities (trawl nets, floating trawls, ropes, trammel nets, gillnets and mussel socks).

As regards the Mediterranean, data about the presence of ghost nets are scarce, although trammel nets and pots are widespread, and the numerous fishing vessels – especially of the Italian and Greek fishing fleets (FAO 2013).

ALDFG mapping and removal operations were carried out not only by the LIFE-GHOST project, but also by DeFishGear (Derelict Fishing Gear Management System in the Adriatic Region) and by GIONHA (Governance and Integrated Observation of Marine Natural Habitats) which spread the knowledge of this phenomenon.

2.2 Environmental context

The so-called *tegnùe* are submerged rocky outcrops of partial biogenic origin found in the North Adriatic, specifically along the belt of sea between Trieste and Chioggia. The *tegnùe*, although discontinuously distributed on the sea bottom, generally occur along three parallel bands placed at 3-5 miles, 10-12 miles and 20 miles from the coast, with depths ranging from 8 to 40 m (Stefanon & Boldrin, 1979; Mizzan, 1995). They are scattered formations that occupy surface areas varying from a few to several thousand square meters. These rocky substrates crop out from the seabed to heights ranging from a few decimetres to a few metres (Mizzan, 2010).
The first studies on the *tegnùe*, aimed at characterising their morphology and structure (Stefanon, 1967, 1970; Braga & Stefanon, 1969; Stefanon & Mozzi, 1972, Stefanon & Boldrin, 1979) explained that these submerged outcrops are made of three types of rocks - clastic sedimentary rocks produced by carbonate cementation of sediments or organogenic debris; sedimentary rocks originated from chemical processes leading to carbonate precipitation and sediment cementation due to methane seepage; calcareous bio-concretions derived from the stratification of animal and plant builders provided with calcareous shells.
These rocky outcrops in shallow eutrophic waters favour the growth and expansion of animal and plant assemblages rich in species and biomass due to the vertical gradient given by the elevation from the sandy bottom and the abundance of suspended organic matter and sediments as food sources.
Typical biological communities of this habitat are sponges, tunicates, coelenterates (anthozoan and anemones colonies), polychaetes (especially serpulids), bivalves, crustaceans, barnacles and bryozoans. Due to great water turbidity, there are fewer plant than animal species, mainly benthic algae of the *Rhodophyta* group.

The species of community interest identified in the surveyed area are pelagic species passing by or stopping only for grazing. They include *Caretta caretta* (marine turtle), *Chelonia mydas* (green turtle) and the marine mammal *Tursiops truncatus* (common bottlenose dolphin). These habitats also host several other species worthy of protection, including the bivalve mollusc *Pinna nobilis*, listed under strict protection among the species of community interest (annex IV of Directive 92/43/EEC).

The attractive effect of *tegnùe* that offer sheltered areas for reproduction and the protection of juveniles, together with the great productivity of the North Adriatic basin favour the development of a rich, diversified fish community, which is often of commercial interest. Therefore, it comes as no surprise that these areas attract great numbers of professional and recreational fishermen, as well as divers who are particularly keen on the rich local biodiversity.

2.3 Aims

Acknowledging the internationally documented need to promote initiatives that tackle ALDFG problems effectively, the LIFE-GHOST project (2013-2016) aims at assessing the presence of "ghost" nets and other lost or discarded fishing gear in the North Adriatic and their impacts on the *tegnùe* ecosystem. In addition, the project assesses the economic value of ecosystem benefits associated with biodiversity improvement following ALDFG removal, and analyses how to manage this waste - reducing its accumulation in the sea - by identifying appropriate disposal methods and recycling solutions for the ALDFG plastic components.

The aims of the project are:

- to assess the presence and impact of ALDFG on *tegnùe* biodiversity;
- to promote recovery and conservation measures for these habitats by drafting appropriate management strategies;
- to assess the economic value of ecosystem benefits associated with biodiversity improvement resulting from ALDFG removal;
- to assess the impact of ghost nets on fish and zoobenthic communities living in the rocky outcrops and neighbouring areas;
- to improve ecosystem biodiversity by using mapping and recovery procedures for ghost nets;
- to put forward economically sustainable proposals for proper landfilling and disposal of recovered and/or disused nets through their recycling into new production chains.

Field activities were addressed on a sea area of about 50,000 km^2 off the Veneto coast, and focused on 15 natural and artificial hard substrates for a total surface area of 21.25 km^2.

3. THE ACTIONS

3.1 Setting up a database on rocky outcrop biodiversity and economic valuation of ecosystem services

Information updating on North Adriatic *tegnùe* was carried out with two aims: 1) to critically categorise and evaluate data on the biodiversity of these habitats by drawing up a database; 2) to check the scientific literature on economic valuation research of similar ecosystems to carry out this specific assessment.

3.1.1 Biodiversity database

A biodiversity database on fish and macrozoobenthic populations of submerged rocky outcrops of the Veneto coast enabled us to update and organise existing information on this topic.

This preparatory action helped us to analyse ecologically the habitats to be protected and assess the economic value of this unique ecosystem. It also provided basic knowledge for later project activities aimed at gauging the efficiency of measures in terms of biodiversity increase.

The database was drawn up by collecting and examining all bibliographic information on fish and macrozoobenthic populations already reported in natural and artificial hard substrates along the Veneto coastline. Useful data were qualitatively and quantitatively organised.

We examined about 70 papers and 10 technical reports in total, taking into account any record, including quantities, on species lists clearly related to specific areas (i.e. to each specific *tegnùa*) and specific periods of time. This led to further analysis of the geological characterisation of the areas, their ecological indices (when available), and location.

The information we gathered showed that macrozoobenthos and fish biodiversity data regarded 50 North Adriatic sites. Most of the investigated areas were *tegnùe* (43), the others were artificial reefs built in the past 10-15 years along the Veneto coastline to protect Venice from high tides (5), and wrecks of the merchant ships Villa and Wrmark (2) (Fig. 1). We clearly identified 740 species mainly belonging to the phyla Mollusca (38 %), Crustacea (16.4%) Anellida (12.2%). Among them, 12 species are protected (i.e. already found in well-known protection lists) (Tab. 1) and 97 species are commercially exploited. We can conclude that fish and macrozoobenthos richness in these areas was greater than in other Mediterranean coralligenous habitats (Ballesteros, 2006).

Fig. 1 - Geographic location of the 50 sites used in the database.

Shannon (HSH) and Simpson (HSI) diversity indices, exclusively calculated for records reporting abundance as n. of individuals m^{-2}, showed high biodiversity values generally similar throughout all the *tegnùe*. In particular, the Shannon and Simpson indices had a mean value of 3.9 ± 1.4 and 0.8±0.2, respectively, both indicative of great community complexity (Fig. 2).

Species	Class (Order)	Phylum/ Subphylum	List of protected species	Economic interest
Aplysina aerophoba	Demospongiae	Porifera	ASPIM annex II; UNEP-RAC/SPA annex II	
Aplysina cavernicola	Demospongiae	Porifera	UNEP-RAC/SPA annex II	
Geodia cydonium	Demospongiae	Porifera	ASPIM annex II; UNEP-RAC/SPA annex II	
Homarus gammarus	Malacostraca	Crustacea	ASPIM annex III; BERNA Ap. 3	+
Lithophaga lithophaga	Bivalvia	Mollusca	ASPIM annex II; BERNA Ap. 2; Habitat Ap. 4; UNEP-RAC/SPA annex II	+
Maja squinado	Malacostraca (Decapoda)	Crustacea	ASPIM annex III; BERNA Ap.3	+
Paracentrotus lividus	Echinoidea	Echinodermata	ASPIM annex III	+
Pinna nobilis	Bivalvia	Mollusca	ASPIM annex II; Habitat Ap. 4; UNEP-RAC/SPA annex II	
Sciaena umbra	Actinopterygii	Vertebrata	ASPIM annex II; BERNA Ap. 3	+
Spongia (Spongia) officinalis	Demospongiae	Porifera	ASPIM annex II; BERNA Ap. 3	+
Tethya sp.	Demospongiae	Porifera	ASPIM annex II; UNEP-RAC/SPA annex II	
Umbrina cirrosa	Actinopterygii	Vertebrata	ASPIM annex III; BERNA Ap.3	+

Tab.1 - Species in protection lists.

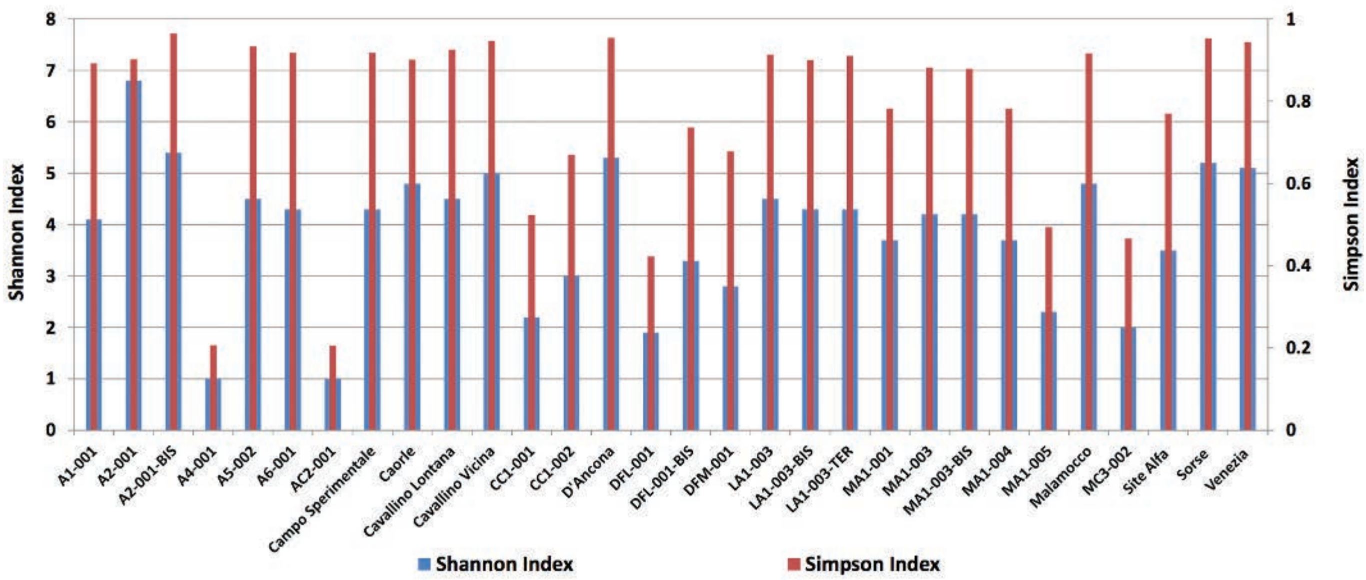


Fig. 2 - Diversity indices calculated in the sites and included in the database.

3.1.2 Preliminary bibliographic research for economic valuation

The aim of this preparatory action was to collect necessary information to provide reliable and realistic economic valuation of biodiversity improvement in the *tegnùe*. It was carried out in 2 ways - firstly by reviewing and analysing the economic literature for state-of-the-art contingent valuation methods and by identifying the main ecosystem services (i.e. the economic benefits for man) provided by the *tegnùe* habitat.
Secondly, by drawing up a first draft of the valuation scenario and of the questionnaire to be submitted to structured focus groups.
The review of the literature on contingent valuation methods of marine biodiversity and ecosystems similar to the *tegnùe*, i.e. coral reefs, allowed us to choose the best method. In particular, we acquired important information on the price range from which to infer willingness to pay (WTP), payment methods, how to estimate WTP and how to provide information in the questionnaire to obtain reliable economic results. In addition, we selected the main *tegnùe* ecosystem services and functions by comparing them with coral reef habitats (see Table 2).

Food production
Habitats for resident and transient populations
Production of raw materials (algae, sand, etc.)
Recreational activities (recreational fishing, tourism, scuba diving, etc.)
Regulation of natural and anthropic disturbances (the conservation and maintenance of nutrients, coast and sediment protection, etc)
Cultural, educational and religious opportunities and uses

Tab.2 - Functions and services provided by the tegnùe.

The results of the literature review allowed us to draw up the questionnaire that was submitted to focus groups of Venetians. The interviews helped us understand the people's real perception and knowledge about *tegnùe*, verify that the information provided was complete and understandable, check the plausibility and comprehension of ecosystem services and functions, and identify the methods of payment that will provide the WTP for the analysed good.

3.2 Mapping and quantifying ghost nets on rocky habitats of the North Adriatic Sea

This preparatory action quantified ALDFG in the *tegnùe* of the Veneto coastline and was divided into two stages. First we identified the probably impacted areas through interviews with fishermen, reported records by scuba divers and environmental data analyses. Mapping of ALDFG in the identified areas was then performed by coupling echosounding techniques (suitable to identify rocky outcrop profiles and to detect ALDFG) and Underwater Visual Census (UVC) observations.

3.2.1 Identification of the most affected areas

The areas to be mapped in detail were identified by combining data from original echosounding observation and other information from three main sources:

- analysis of literature and Internet sources from which the GPS positions and associated toponyms of over 200 rocky outcrops in the Gulf of Venice were localised;
- with the cooperation of the Venice Coastguard, we tracked Blue Box systems installed on 20 trawling vessels (length > 15 m , 26% of the local fishing fleet) in different periods, which enabled us to identify their busiest fishing routes;
- the questionnaires given to fishermen and scuba divers provided insight on ALDFG sightings within the examined area as well as indications of potential areas where loss or disposal of derelict fishing gear is more probable.

All the information were then used to identify areas where the presence of ALDFG was most likely, classified as: very high, high or medium probability of ALDFG occurrence. The criteria were: 1) ALDFG occurrence reported by scuba divers; 2) trawling gear loss and/or possible gillnet entanglement reported by fishermen; 3) overlap between Blue Box tracks and rocky outcrops location.

A total of 22 areas were then classified according to these criteria, as shown in Fig. 3.

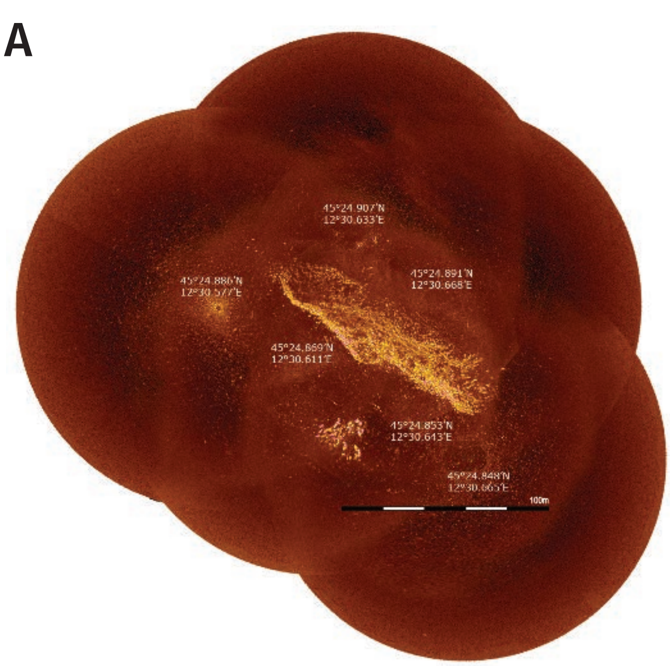
Fig. 3 – Map of the most probably ALDFG affected areas within the LIFE-GHOST intervention area.

3.2.2 ALDFG mapping activity

We performed detailed acoustic and underwater surveys in "very high probability" and "high probability" areas of ALDFG occurrence to map the rocky outcrops, draw up high-resolution geo-referentiated maps, and quantify ALDFG (and any other type of marine litter visualised).

We mapped 15 natural outcrops and one artificial reef close to the coast, i.e. a total area of 20 km^2 and 1.25 km^2, respectively.

Echosounding used a High Resolution Scanning Sonar (HRSS) head coupled with Windows(r) based Sonar Processing Software, which provided a very detailed HD snapshot of the target areas near (up to 100 meters) the sonar head. The geo-referentiated images were then assembled for the final maps (Fig. 4).



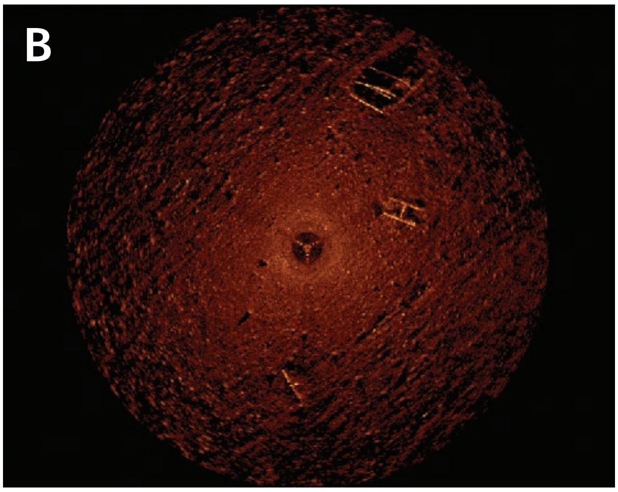


Fig. 4 - (A) Tegnùa Cavallino Vicina. Example of graphically processed seabed images obtained with a HRSS-MS1000 sonar. (B) Detail of metal frames on the bottom.

Underwater surveys allowed us to identify ALDFG previously localised through HRSS on each *tegnùa*. According to its operational characteristics, ALDFG was then classified into four main categories:

- passive fishing gear (such as trammel nets and gillnets);
- active fishing gear (such as trawl nets and floating trawls);
- fishing waste (such as ropes, sheets, stays, mooring posts, sheaths, metallic frames, etc.)
- aquaculture waste (such as mussel socks).

Mapping activities revealed 347 pieces of gear and other fishing waste in 8 natural rocky outcrops (out of the 15 monitored), and in the artificial reef in front of the Lido Island (Fig. 5). According to this result, and taking into account that at least 3000 individual *tegnùe* are estimated to outcrop in the Gulf of Venice (Gordini et al., 2010), we assume that the number of ALDFG lying on the rocky bottom of this area is not far from 60,000.

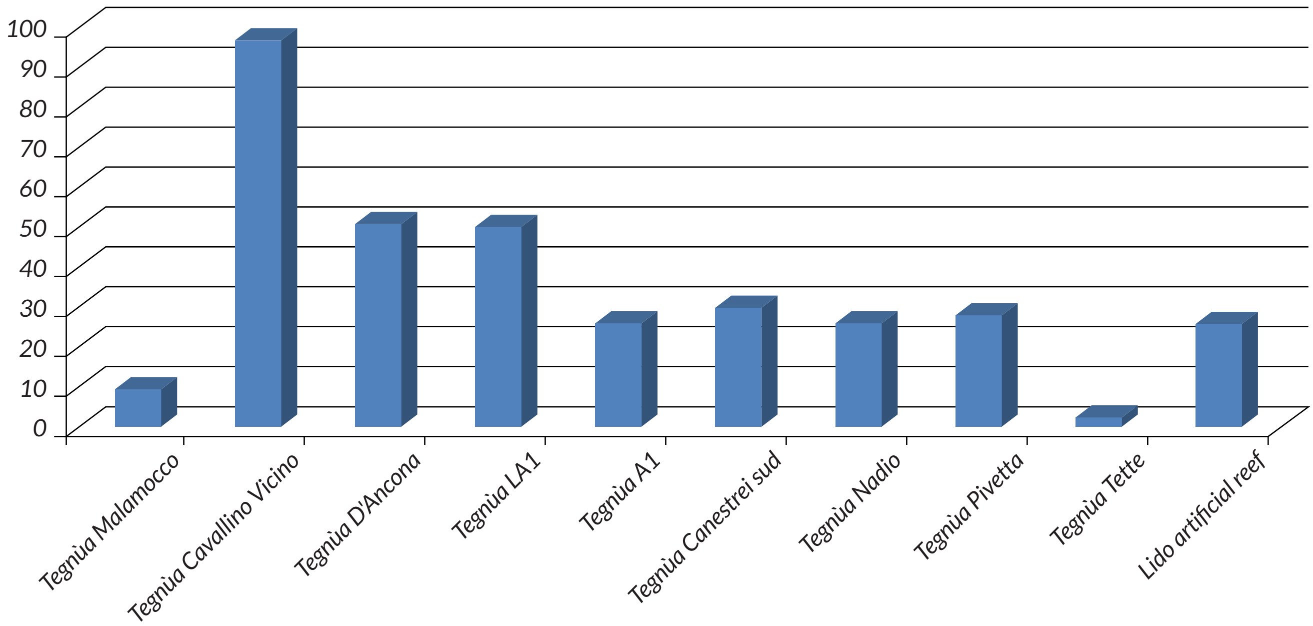


Fig. 5 – ALDFG identified in the monitored areas.

The items observed are mainly active gear and general fishing waste (36% and 31%, respectively), whereas passive gear and aquaculture waste are less abundant (23% and 10%, respectively) (Fig. 6).

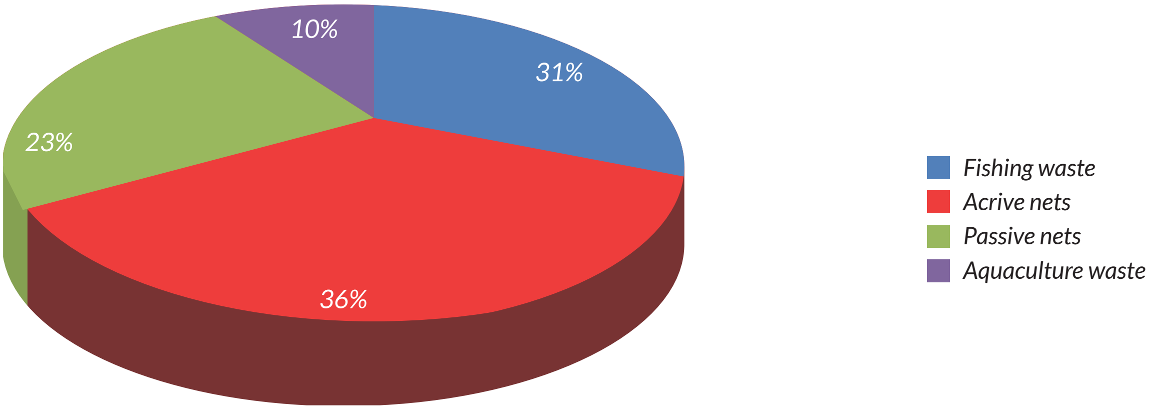


Fig. 6 - Percentages of the 4 ALDFG categories found on the seabed of the analysed areas.

The results of the mapping activity enable us to infer that most ALDFG is localised in the largest and highest *tegnùe* within 3 miles from the coastline, and in those closest to the main fishing vessel routes. Active gear is equally distributed along the entire area both within and beyond 3 miles. Consequently, we can assume that the main cause of their loss is accidental hooking on yet unknown *tegnùe* during fishing activities that use trawl nets (it should be noted that this type of fishing is forbidden within 3 miles). In contrast, finding fishing waste assembled in specific areas suggests voluntary abandonment of old and damaged gear/equipment. Lastly, accidental loss due to adverse marine weather conditions or to fishing gear conflicts, in particular with trawl nets, is the suggested main cause of passive gear in the area.

Although generally scarce and found on a small number of gear specimens, encrusting fauna, in particular sponges, bryozoans, oysters and scallops, were increasingly distributed on rigid structures, ropes and sheets. A similarly poor colonisation of nets is mainly attributed to the limited number of colonial ascidians (*Aplydium* conicum). It must be noted that cuttlefish (*Sepia officinalis*) and squid (*Loligo vulgaris*) sometimes use nets or parts of them as substrates to lay their eggs. Among the few trapped organisms, the most abundant were crustacean decapods, in particular the crab *Dromia personata*.

3.3 How to remove and recycle ghost nets affecting the tegnùe biodiversity

Removing all detected fishing gear from the analysed *tegnùe* had a twofold outcome: first, to clean up 21.25 Kmq^2 of rocky sea bottom rich in biodiversity, and to restore ecological conditions typical of non-impacted areas; secondly, to demonstrate the technical feasibility of some recovery/recycling options for the plastic components of fishing nets, which are greater in number and cause the worst environmental damages. Samples of the removed nets were processed differently thanks to small-scale experiments with the collaboration of local private companies.

3.3.1 Field activities and removal protocols

Removal activities were carried out in affected areas as shown by the echosounding field analyses and subsequent underwater observations. In particular, all the 8 natural areas and the artificial reef where ALDFG was observed were completely cleaned up. More occasional retrievals were also performed in extra-study areas following specific sightings by citizens.

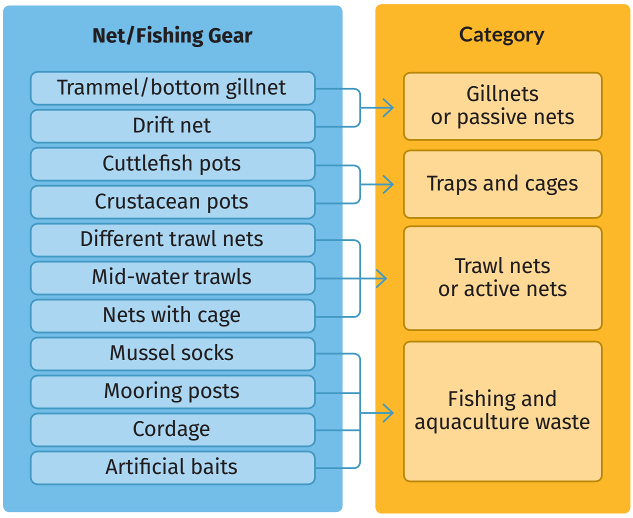
ALDFG retrieval by SCUBA divers was difficult, dangerous, expensive and time-consuming, and required good coordination between scientific and diving teams. However, this procedure is necessary when operating in shallow sea areas where creepers or similar equipment, generally used on sandy seabeds to retrieve large lost or abandoned pelagic nets, cannot be adopted for their damaging consequences on both habitat and species, the preservation of which is the aim of the action itself.

A technical protocol for ALDFG removal was developed for the project, and specifically designed for rocky marine areas where biodiversity might be threatened. The procedure took into account that “soft” techniques were required to avoid any further damage to habitat and organisms.

The various phases of the removal process, which are outlined as practical protocols in the Hands-on Manual (distributed by the LIFE-GHOST project and available for download at http://life-ghost.eu) focus on the preliminary field investigations and desk study on recovery feasibility, with field retrieval and final onshore reception. The technical approaches described could easily be adapted to similar environmental contexts by tweaking them to specific operational conditions. The main procedural steps are summarised as follows:

1. identification of the ALDFG type and its main components (Fig. 7);
2. evaluation of the degree of entanglement with the substrate (Fig. 8);
3. assessment of possible removal effects on protected fauna and flora;
4. removal planning;
5. onshore delivery of removed ALDFG to appropriate waste collection points.

362 pieces of ALDFG, for a total dry weight of 513.54 kg (Fig. 9) were removed from the seabed. Removed ALDFG data analysis showed that "fishing and aquaculture waste" and "passive gear" were the most abundant - 34% and 32% of the total ALDFG, respectively. Less relevant were "active gear" (26%) and "pots and traps" (8%).



Net/Fishing Gear	Plastic materials	Lead/tin	Iron/steel	Concrete
Trammel/bottom gillnet	x	x		
Drift net	x			
Cuttlefish pots	x			
Crustacean pots	x			
Trawl nets	x	x		
Mid-water trawls	x	x		
Nets with cage	x		x	
Mussel socks	x			
Mooring posts		x	x	x
Cordage	x			
Artificial baits	x	x		

Fig. 7 - ALDFG types and their constituent materials.

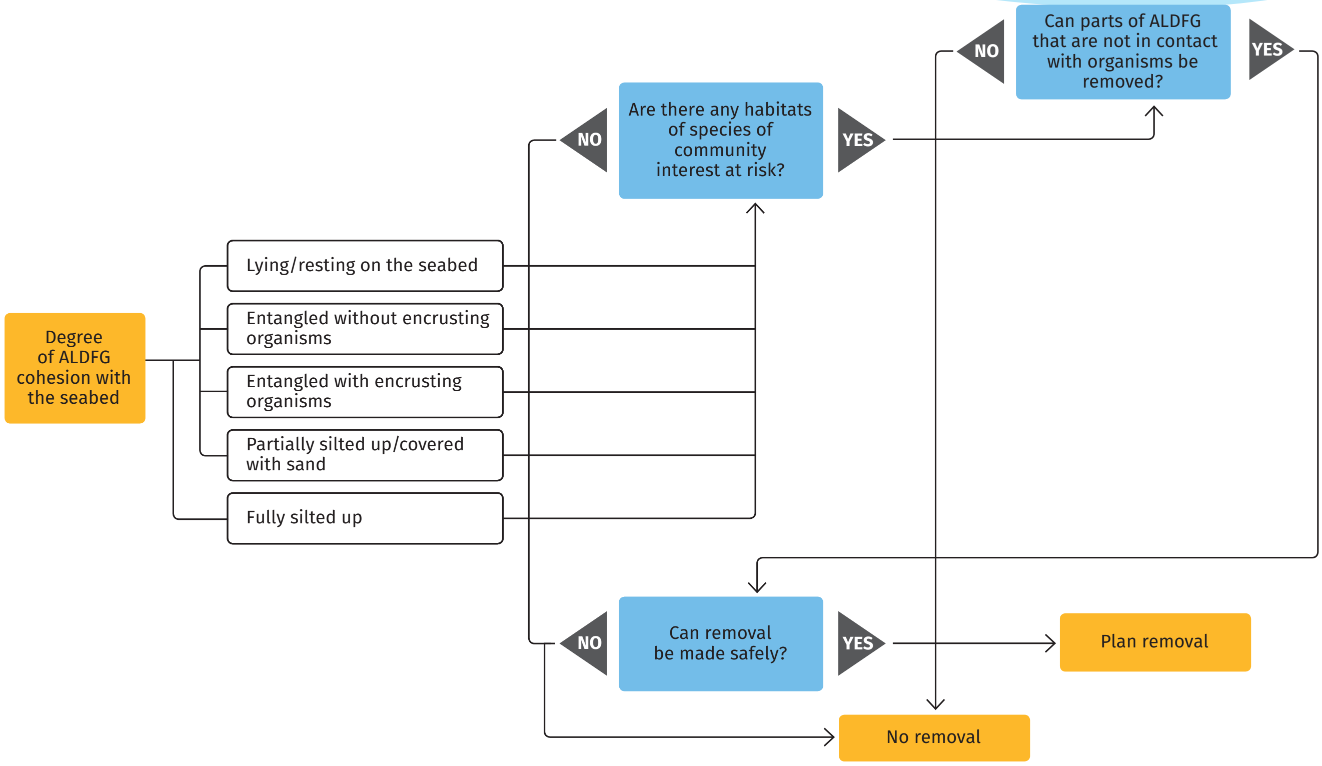


Fig. 8 - Different ALDFG entanglement conditions and disposal options.

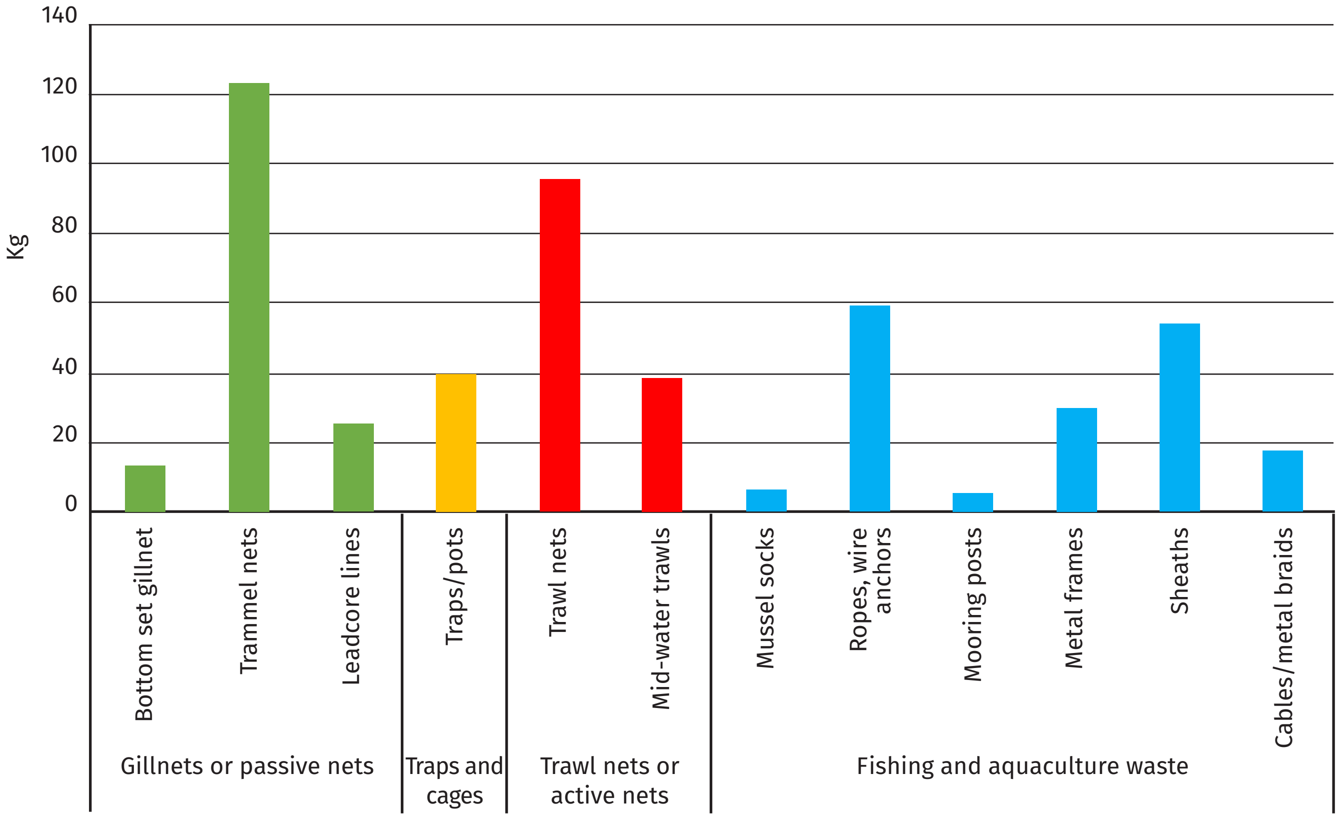


Fig. 9 - Types and quantities of ALDFG retrieved in the analysed areas.

3.3.2 Developing an ALDFG disposal/recycling strategy

In circular economy, at each stage of a product's lifecycle (from its design to its final phase) we should focus on potential reuse and recycle options of the materials used for manufacturing the product itself, which should turn into new resources to be re-introduced into the production cycle, overcoming the old concept of waste (with all its negative connotations).

In the legislation package on circular economy presented by the European Commission, waste management plays an important role and, by supporting the options that issue the best environmental results, it sets a waste management ranking that places prevention at the top, followed by preparation for reuse, recycle, energy recovery and , finally, disposal (Fig. 10).

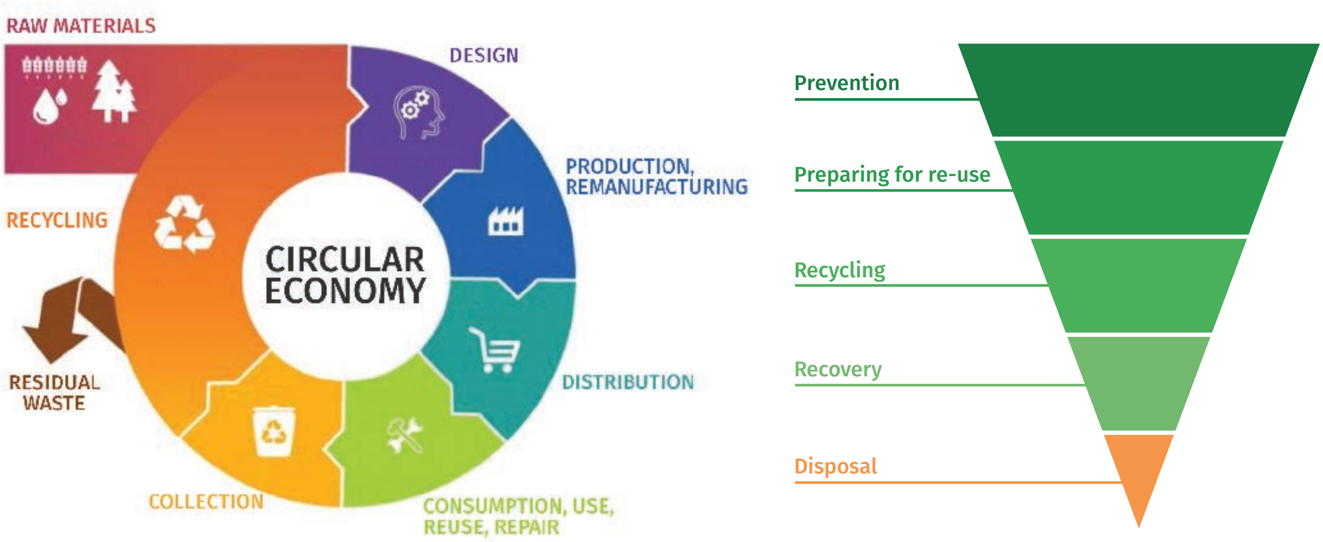


Fig. 10 - Principles of circular economy and waste hierarchy.

Among the materials to be recycled, particular attention is given to plastic. The use of plastic items in Europe is steadily increasing, while recycling levels are still lower than 25%, and approximately 50% of plastic is disposed in landfills. The Commission wants to devise a strategy to address the challenges posed by plastics and to adopt measures to reduce marine litter significantly.

In this framework, the project activities were planned to provide guidelines for a management system for fishing gear in the final phase of its lifecycle. Once adopted, the management system will help reduce the effects of fishing gear abandonment in the sea and, based on the waste hierarchy, limit landfill disposal.

The main causes of voluntary ALDFG abandonment in the sea are absence of onshore delivery infrastructures, irresponsible behaviour, poor knowledge of available technologies, and adverse marine weather conditions.

Taking this into account, and to define an appropriate waste management system, the project aimed to:

- analyse the local context which provided the regulatory framework of fishing waste management and identify the logistic-organisational aspects associated with the delivery and transport of materials to treatment plants and their costs;
- carry out an experimental study starting from material characterisation and analysis of ALDFG samples removed from the seabed, which included experimental tests of both cleanup and recycling of the materials to be recovered (not only abandoned but also discarded nets).

The waste management strategy includes discarded/seized nets and aquaculture waste recovered from seabeds as well as discarded/confiscated ones during activities involving local and national stakeholders.

At present, the Venetian fishing ports often lack infrastructures suitable for the delivery of discarded fishing gear, and fishing operators keep asking for an organised collection system (Fig. 11).

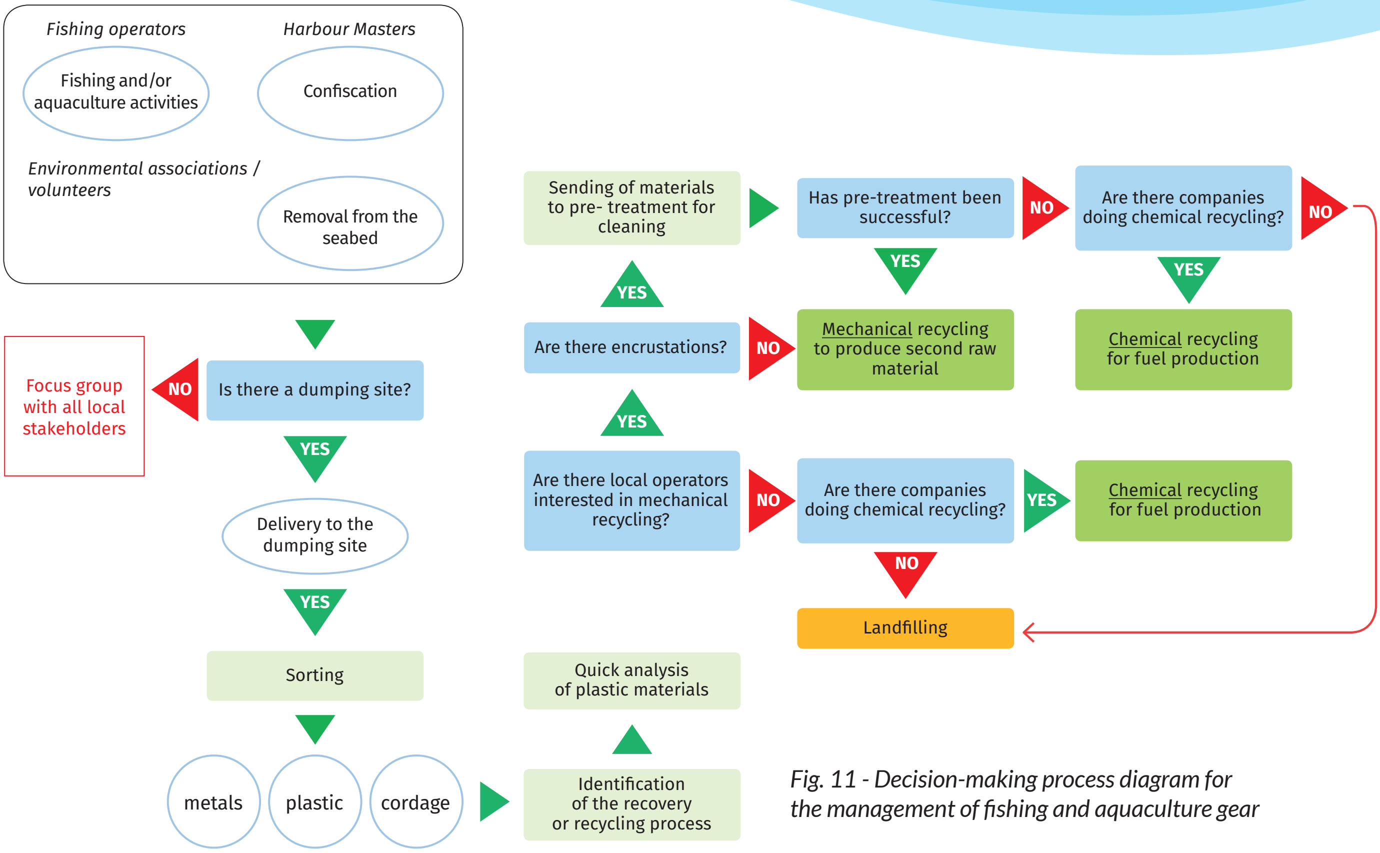


Fig. 11 - Decision-making process diagram for the management of fishing and aquaculture gear

Analysis of the local situation highlighted local governance deficiencies and the need to create fishing port infrastructures; identify management costs and who must bear them; identify alternative disposal options to landfill.

During the project, fishermen reported that their fishing operations at sea are often complicated by the huge amounts of floating plastic litter originating from mussel farming at sea. Mussel farmers lamented the same problem, blaming the lack of disposal facilities.

The results of the local survey thus indicated how to optimise the management strategy for fishing nets and gear, identifying two crucial steps, the first dealing with onshore disposal of abandoned, discarded or removed nets, and the second regarding waste collection and transport. The most effective option for collection, considering both the cost/benefit ratio and the level of satisfaction of fishermen, is periodic collection through specific campaigns. Delivery should be in specific areas supervised by day and inaccessible at night.

The results of the experimental study allowed us to identify the materials used to manufacture the fishing gear retrieved from the seabed - their plastic parts (essentially, the nets) are generally made of polyamide, polypropylene and polyethylene.

Although market research to identify local companies dealing with waste-to-energy processes and the recycling of plastic materials excluded the waste-to-energy option due to the high chlorine levels in the recovered material and to problems associated with net shredding, mechanical recycling is technically feasible. Furthermore, among the various suitable local plants, some offered both to perform the requested cleanup treatments and to run proper recycling tests, showing the applicability of their industrial process in this specific field. A possible alternative to mechanical recycling is chemical pyrolysis recycling, which could produce second-generation fuels. Unfortunately, there are no authorised plants in Italy, which ruled out any experimental trials with our samples.

The results of the recycling tests made with materials recovered from the seabed were positive, an efficient cleaning system was developed, and the materials obtained were later shredded, densified and extruded (to turn the plastic materials into new products) (Fig. 12).

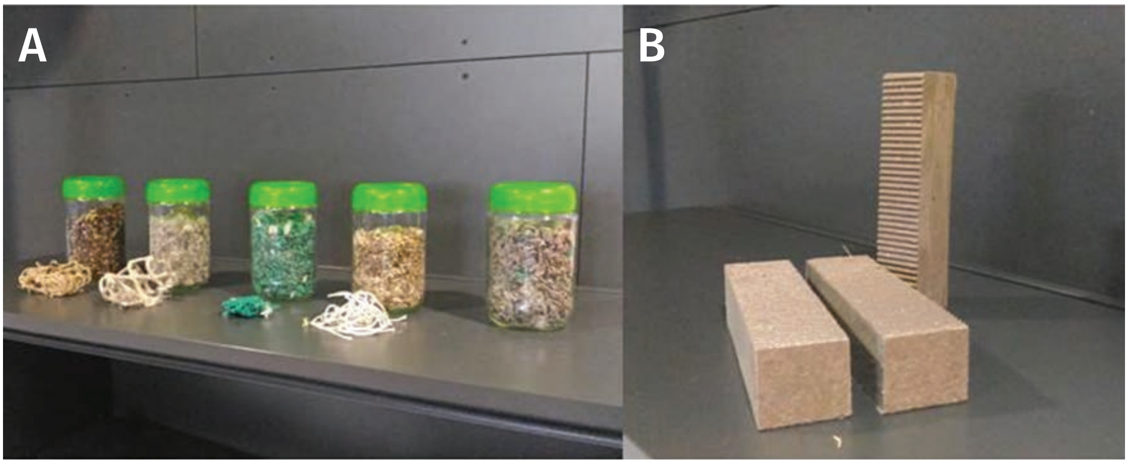


Fig. 12 – Fig. 12 – Net samples subjected to A) shredding, and B) densification and extrusion.

3.4 Developing a Regulation proposal for ALDFG management

We drew up a Regulation Proposal for policy makers, and a Code of Conduct for fishing operators. Although from different viewpoints, both documents identify and recommend individual and/or governance measures to prevent and mitigate the ALDFG phenomenon, at least in the regional context considered by the project.

The two documents were produced after analysing both the international and Italian legislative frameworks, as well as the local situation. In particular, we focused on:

- both voluntary and compulsory principles and policies in force worldwide and associated with waste management that mitigate and reduce the effects of lost and abandoned fishing gear in the marine environment;

- the numbers, types and different locations of ALDFG collected during monitoring, to identify the main causes of ALDFG in the *tegnùe*, and the most suitable management options to avoid -or at least reduce - its occurrence.

The legislative framework is very complex and, to deal with this issue properly, we referred to guidelines and principles which, although developed in different fields, are ultimately associated with two macro-areas, the protection of the sea and its resources, and waste management.

Strategy and regulation analyses highlighted that all authorities (European, Italian and regional) generally agree on both the principles and their application. The legislation fully covers waste management in sea environments. Indeed, the provisions regarding the two macro-areas contemplate many situations, and provide operational instructions for the prevention, management and mitigation of marine litter, including ALDFG. For instance, as regards the management of accidentally or intentionally abandoned sea waste, there are several measures that would manage the issue efficiently if properly applied.

Our preliminary activities highlighted that, although various measures have already been used to handle the problem of ALDFG effectively, at local level they are insufficient to prevent its occurrence. Basically, current regulations cannot be applied along the Venetian coast. Most of the Veneto fishing fleet moors in areas which are not classified as "ports", but docks, even city piers. As a consequence, the fishing fleet is substantially not included into the existing legislation for port areas and for port reception facilities for ship-generated waste, that also included fishing vessels. Clearly, the mooring sites not classified as port areas do not require adequate facilities for the collection of waste deriving from fishing activities. Fishing and aquaculture operators take advantage of this situation assuming that lack of adequate facilities for the collection of their waste, including discarded fishing gear and nets, somehow condones their abandoning it along the quays or in the sea.

3.4.1 Code of Conduct

Fishing and aquaculture operators were involved in an awareness-raising process aimed at sensitising and teaching them sustainable practices and behaviours for more responsible and safer fishing activities, essentially how to manage the waste generated by their activities and to limit loss and discarding of fishing gear. This process ended with a "CODE OF BEST PRACTICES TO REDUCE LOST AND ABANDONED FISHING GEAR AT SEA". In particular, in addition to promoting more responsible and safer fishing activities, the Code also protects fishermen's profits, and contributes to the preservation of fish stocks, also by limiting the risk for commercially exploited species to get entangled in ghost nets.

The best practices and behaviours in the Code of Conduct are divided into 4 sections:

1) how to mark and identify fishing gear correctly;
2) avoid fishing in areas at high risk of gear loss and in adverse weather conditions;
3) always retrieve lost gear;
4) how to manage properly the waste produced or collected during fishing activities, including fishing gear and mussel socks.

The Code was negotiated with local fishermen during technical meetings held at the main Venetian fishing fleet sites (Caorle, Chioggia and Porto Tolle), which revealed they approved of it and that it was already partially applied.

3.4.2 Regulation Proposal

The conclusions of the project related to the technical recommendations and instructions identified as effective tools for the sustainable management of ghost nets at local level were filed at the Veneto Regional Council as motion n. 173 "THE REGION USES CONCRETE STRATEGIES AND PROJECTS TO REDUCE SEA WASTE", to which the technical document "Operational recommendations for the effective management of abandoned, lost or discarded fishing gear (ALDFG)" (also called Regulation Proposal) was annexed.

The Proposal summarises the measures and operational guidelines to reduce the abandonment of fishing gear and nets in the sea, in particular setting up adequate onshore reception facilities and consultation activities with mandatory consortia for waste recycling and recovery; identifying a regional waste management fishing plan; assessing viable options to recycle and reuse these materials with the best technologies available.

The recommendations are intended not only to treat and mitigate ALDFG effects, but also to prevent their long-term occurrence. The proposed measures combine recommendations taken from international guidelines (such as those developed by FAO, Fisheries And Aquaculture Technical Paper No. 523, UNEP Regional Seas Reports and Studies No. 185, "Abandoned, lost or otherwise discarded fishing gear"), and local ones from project activities associated with ghost net management in the Veneto region.

Part of these guidelines, specifically concerned with fishing management, were adopted by the Department of hunting and fishing of the Venice province in the local "Plan for fishing resource management in the lagoons of the province of Venice". In particular, one specific measure, the A12-R "Interventi per la riduzione dell'abbandono di attrezzi da pesca e per la riduzione della pesca fantasma"(Measures to reduce fishing gear and ghost fishing), which modified the regulation to introduce the obligation to signal ALDFG loss due to adverse weather conditions or other unforeseeable events, was introduced in the Province plan thanks to the LIFE-GHOST project.

3.5 Monitoring and assessment of the effects of ALDFG removal on biodiversity

ALDFG entangled on sub-tidal rocky outcrops or lying on them is a source of stress for marine ecosystems associated with ghost fishing - undoubtedly the best-known effect of ALDFG (Macfadyen et al., 2009; Large et al., 2009; Good et al., 2010, Arthur et al., 2014 -), with the release of microplastics and/or other contaminants that ultimately enter the sea food-chain (Sundt et al., 2014), and with the alteration of benthic communities due to physical disturbance, abrasion and “plucking” on the encrusting fauna and flora (Macfadyen et al., 2009).
ALDFG removal from the *tegnùe* enabled us to *ex post* assess the recovery capacity of benthic and fish communities freed from their stress factor. Monitoring of benthic and fish communities started a few days after ALDFG was removed on 5 sub-tidal rocky outcrops selected as test areas, and 5 seasonal surveys were carried out from December 2014 (T0) to June 2016 (T4).

Non-destructive techniques (Molin et al., 2008; Ponti et al., 2011 Thresher e Gunn, 1986; Francour, 1999) were adopted to monitor the benthic communities, i.e. photographic techniques for benthic fauna and flora, and underwater visual census for fish. The data collected (number of individuals, species, taxa, and coverage per each species and taxon) were used to calculate three biodiversity indices (species richness, Margalef and Shannon indices) and to assess community recovery.

Index values were compared with those of corresponding reference areas. The community was deemed completely recovered when the values of the measured indices reached at least 75% of the value of the same indices in the reference area. Reference samples were taken from *tegnùe* areas not affected by ALDFG, and a scarcely affected sub-tidal rocky outcrop was used as reference area for the fish community.
Results showed that the benthic community gradually improved in each of the 5 monitored areas. Only in *tegnùa* LA1, and only regarding number of taxa and the Margalef index, values after the 15-month monitoring (at T4) were not comparable with those of the reference area (Fig. 13).

Fig. 13 –Evolution of benthic populations in tegnùa areas freed from ALDFG (T0 = immediately after ALDFG removal, T1 = 4 months later T2 = 7 months later, T3 = 11 months later, T4 = 18 months later).

Recovery of the benthic community regards the horizontal growth of encrusting fauna, as vertical development is negligible. This comes as no surprise, since vertical growth of many taxa, such as *Porifera* and *Tunicata*, requires longer periods (up to several years) than those considered by the project (Turon et al., 1998; Garrabou and Zabala, 2001; Pansini et al., 2011; Lopez-Legentil et al., 2005).
As regards the fish community, the indices showed non -linear progression; a biodiversity increase was however observed at the end of the monitoring period (at T3 and T4), when indices reached values similar to the annual mean in the reference site.
Pelagic fish showed very small variations in abundance and richness throughout the 18-month monitoring, confirming our hypothesis that ALDFG presence/absence does not affect this community significantly. On the other hand, benthic fish were more sensitive to ALDFG, as a positive correlation between ALDFG removal and abundance of benthic and cryptobenthic species revealed. This is probably due to the increased availability of recesses, clefts and fissures in the rocky outcrops which are used as permanent sheltering and nesting grounds (especially for blennies, gobies, scorpionfish, conger eels, sciaenids) or as temporary hiding places for hunting and stalking (Fig. 14).

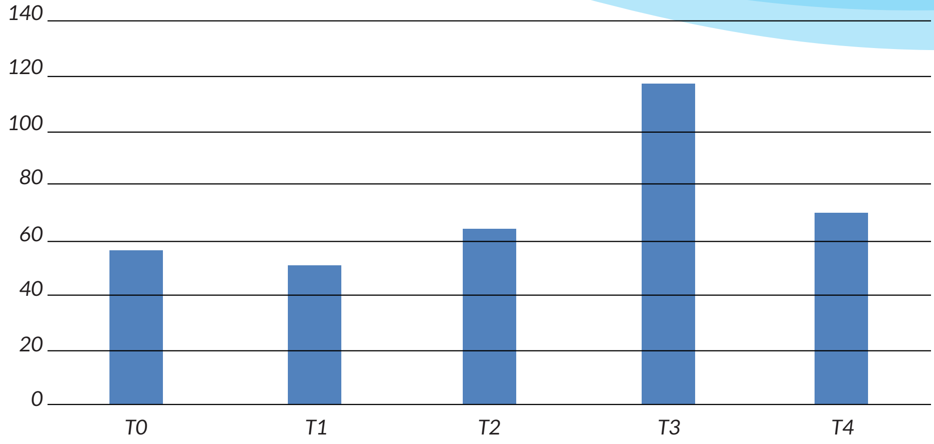


Fig. 14 - Trend of specimen number of benthic and cryptic species, cumulative for the 5 study areas.

3.6 Contingent valuation and cost-benefit analysis

The *tegnùe* ecosystem provides functions and services that have biological value and economic importance for people, and must therefore be protected. Proper economic assessment may support national and local governments when deciding about protection of the *tegnùe*, their services and functions. Cost-effectiveness of different measures and policies to regulate, manage and improve the *tegnùe* are very helpful.
This activity estimated the economic value of biodiversity improvement in the *tegnùe* after partial or total ALDFG removal. We devised a contingent valuation questionnaire which is a non-market assessment method that estimates the value of goods that do not have a market price, like most natural resources. The assessment questionnaire was fine-tuned with several focus groups (13 in total, 9 in this action) in four Italian cities (Venice, Bari, Rome, and Livorno) with a total of 107 participants, and with the help of marine biologists.
Table 3 shows the main socio-demographic characteristics of focus group members.

Characteristics	**Bari (N=17)**	**Livorno (N=18)**	**Roma (N=16)**	**Venezia (N=56)**
Average family income	24.118,03 (17.137,92)	20.278,14 (9.467,20)	23.906,59 (19.684,56)	26.116,48 (19.074,85)
Average age	39,41 (13,08)	37,00 (13,35)	41,94 (14,05)	39,37 (12,06)
Degree	0,35 (0,49)	0,33 (0,49)	0,37 (0,50)	0,30 (0,46)
High school diploma	0.53 (0.51)	0.39 (0.50)	0.50 (0.52)	0,62 (0,49)
Employed	0,59 (0,51)	0,83 (0,38)	0,94 (0,25)	0,70 (0,46)
n. of family members	2,88 (0,99)	2,89 (1,13)	3,06 (1,06)	3,19 (1,11)
Average income	8,47 (5,73)	7,06 (3,81)	11,00 (4,34)	7,41 (2,78)

Tab. 3 - The members' main socio-demographic characteristics (SD in brackets).

The final questionnaire was made up of 40 questions (excluding socio-demographic questions) divided into 9 sections. We submitted the questionnaire in December 2015 through the CAWI method (Computer Assisted Web Interviewing) and collected 4000 interviews, 1000 of which in the Veneto Region. Table 4 summarises the main socio-demographic characteristics of the sample.

Variables	Average	Stand. Deviation
Males	0,52	0,50
Age	40,39	13,53
Diploma	0,23	0,50
Degree	0,23	0,42
Family members	3,14	1,17
Children < 15 years	0,15	0,42
Average income (€/year)	27,432	16,843

Tab. 4 - Socio demographic characteristics of the sample (N=4000).

In particular, section 8 was the core of our work, and provided respondents with a valuation scenario. Based on the knowledge and insight gathered in previous sections, on the respondents' opinions and preferences elicited by the information provided, and on their acknowledgement of specific issues gradually presented, we introduced the valuation scenario, collected people's preferences and their WTP for improvement and conservation interventions.

Specifically, 4 different valuation scenarios were introduced:

- removal of fishing nets (partial or total intervention);
- removal of different types of fishing gear (lobster pots, rakes, anchors, fish traps, etc.);
- removal of fishing litter (cordage, mussel socks and lures);
- Continuous monitoring through a new Regulation containing measures to prevent dangerous behaviour towards biodiversity.

For each scenario, respondents had to choose if they were willing to pay a randomly selected one-time amount (€2; 5; 10; 15; 20; 30; 40; 50; 70; 100) to help removal interventions in the coralligenous habitats of the North Adriatic sea. Figure 15 shows the WTP estimates for each scenario.

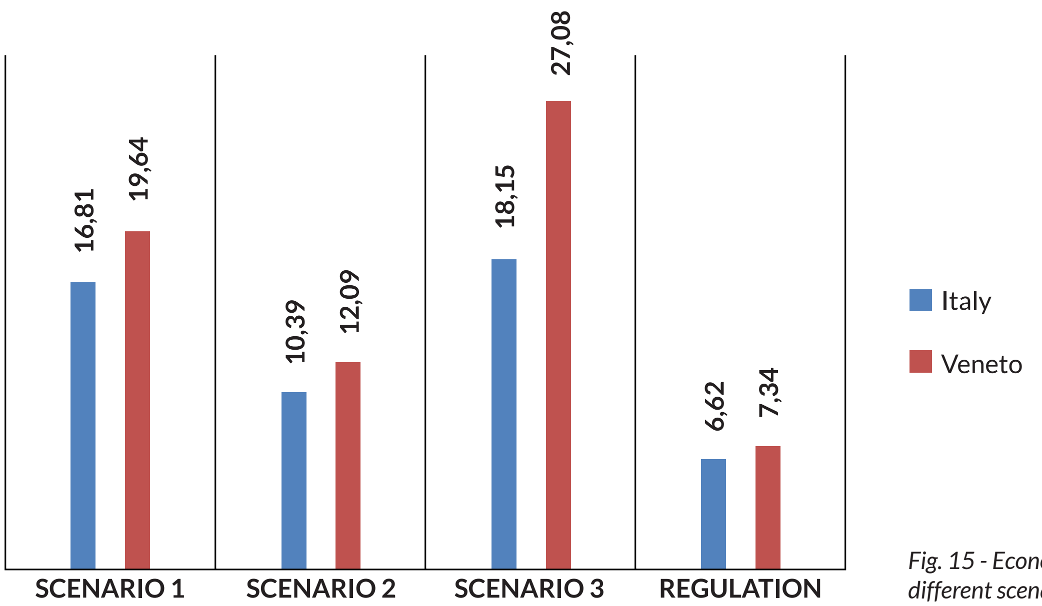


Fig. 15 - Economic valuation of the different scenarios.

The complete model, without specifying the removal scenario and without covariates, provided a WTP of €15.34 for the national sample and €19.90 for the Veneto sample. These WTP figures were then used to calculate the total benefits of ALDFG removal and biodiversity restoration in the *tegnùe*. They are also input values for cost-benefit analysis, which calculated the expenditure of inspection, removal and disposal operations within the project against the estimated benefits. Table 5 shows the estimated values.

COSTS	COST ITEMS	AMOUNT IN €
Inspection costs	Specialised personnel	20680
	Vessel crew (helmsman)	7520
	Equipment (scuba tanks)	21800
	Means of transport/vessel	45872
	Fuel	4700
	Scanning sonar	29483
	Total inspection costs	**130055**
Removal costs	Scuba divers	15400
	Vessel crew (helmsman)	5600
	Additional equipment	1600
	Means of transport/vessel	34160
	Fuel	3500
	Total Removal costs	**60260**
Disposal costs	Hooklift rent	122
	Forms	6
	Transport to landfill	732
	Total disposal costs	**860**
	GRAND TOTAL	**191175**

Tab. 5 - Costs of project (gross value including VAT) divided into inspection, removal and disposal activities in the tegnùe.

Cost-benefit analyses require information, such as discount rates, the beneficiaries of removal interventions, the period of cost-benefit enjoyment, etc. To keep things simple, and taking into account only the Veneto Region population as beneficiary, a 5% discount rate (as suggested by the EU, 2014), 2,057,227 Veneto families and 3 years of project duration, the intervention is extremely cost-effective. Table 6 shows the results.

	Year 0	Year 1	Year 2	Year 3	Total
Benefits (family groups)	41.309.118	15.058.902	15.058.902	15.058.902	
Benefits (family groups) actualized with r=5%	41.309.118	14.341.811	13.658.868	13.008.445	82.318.242
Costs	191.174	50.646	50.646	50.646	
Costs actualized with r=5%	191.174	48.234	45.937	43.750	329.096
Benefits (family groups)/costs ratio	216,1				250,1

Tab. 6 - Cost-effectiveness for the Veneto families.

In conclusion, the cost-benefit analysis showed the economic efficiency and the social opportunity of ALDFG removal and restoration activities like those of the LIFE-GHOST project, with a cost-benefit ratio higher than 1. Moreover, in the same action D2, the effectiveness of ALDFG removal was demonstrated by a cost-effectiveness study using the costs in table 5 and biodiversity improvement measurements like the Margalef's and Shannon's indices.

3.7 Dissemination to the general public, stakeholders and the scientific community

In a 'hyper-communication' era, the main hurdle in a project is to reach specific targets, and the tools we use to communicate affect the efficiency of our strategy. An effective communication strategy must use different communication channels and tools, and integrate them to create a long-lasting relationship with stakeholders.

The communication strategy adopted by the LIFE-GHOST project had these objectives:

- to disseminate information both about project activities and about products developed within it by emphasising their innovative aspects;
- to inform and to create a bond with stakeholders since the early stages of the project, aiming at marketing results;
- to reduce the gap between the research world and citizens by enhancing the joint work done by researchers and institutions;
- to make potential sponsors (both public and private) aware of the project results to prompt new funding;
- to attract potential partners for future projects;
- to stimulate the creation of products and / or services through experiments.

3.7.1 The Communication Plan

The first step in "impact-oriented" communication is to draw up a communication plan (CP) that will ensure the greatest dissemination of project activities and results to specific targets identified in the first phase of the project. The CP then summarises the overall communication strategy (objectives, content, message, corporate identity) and adapts it to all the media, tools and actions used to achieve the different targets (Fig. 16).

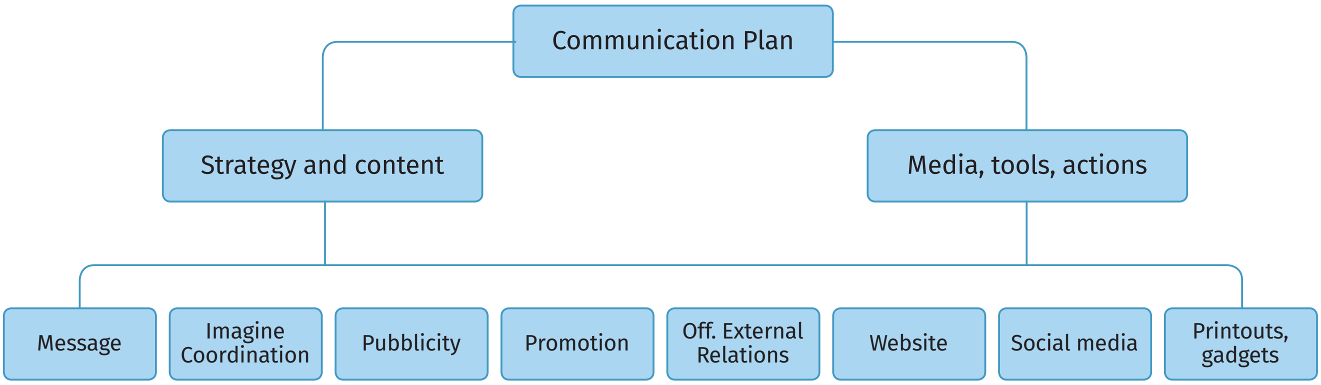


Fig. 16 - Contents of the Communication Plan.

The Communication Plan of the LIFE-GHOST project developed an effective communication strategy based on the following requirements:

- to keep communication and information flow constant throughout the project;
- to remember that internal communication is just as important as the external one because it ensures scheduled and shared communication;
- to use different tools and languages for external communication towards three target groups - the scientific community, stakeholders and civil society;
- to use a concise communication strategy on social media.

The CP was drafted in the first six months of the project. We met all the milestones identified in the document, the schedule of the event organisation and the production of deliverables.

3.7.2 Monitoring communication activities

All communication activities should be monitored, as established by the Communication Plan. Monitoring helps to understand if the adopted communication strategy is working well and if communication results and effectiveness to the targeted audience are appropriate. Corrective measures may be taken if feedback is negative. Throughout the project, monitoring was carried out for all means of communication used, for instance, for the website we used Google Analytics to track the number of visits and their duration (Fig. 17). For Facebook and YouTube indications came from numbers of likes and views.

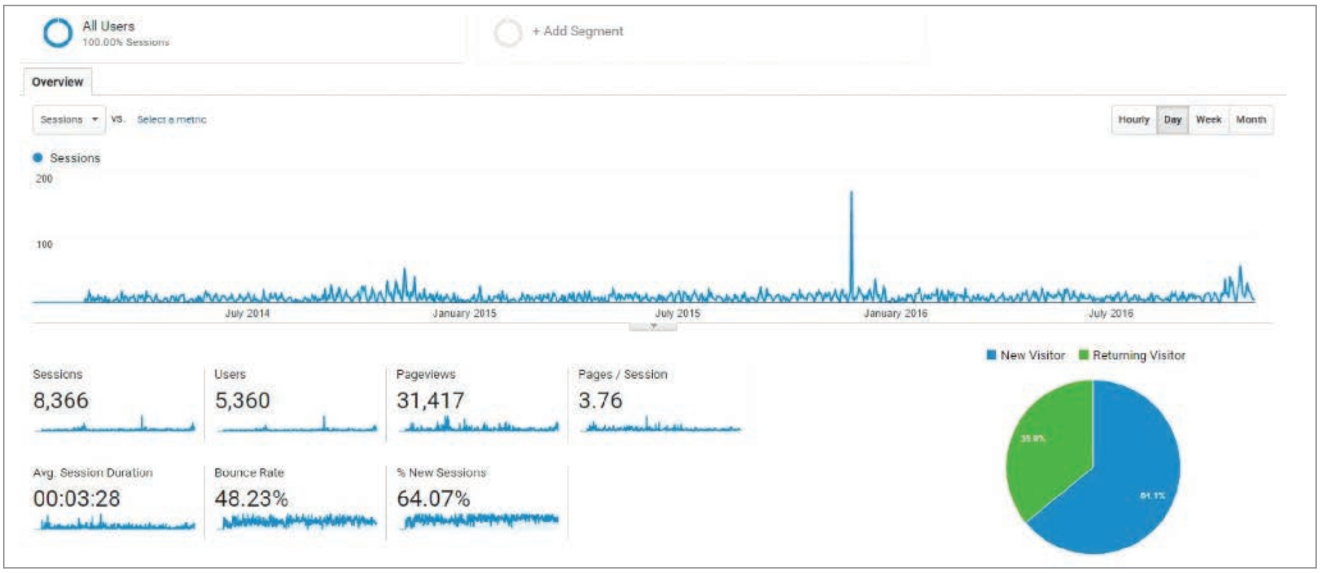


Fig. 17 - Website stats from 1 January 2014 to 31 October 2016.

3.7.3 Choosing the best communication tools

To day, we are spoilt for choice in terms of communication tools, and it is challenging to find which best suits your target. Table 7 lists the numerous communication tools used during the project, and the number of people they reached.

Judging by the feedback we received, it is clear that the most effective communication tool is Facebook, both in terms of number of people reached and of impact derived from news published therein. This shows that constant, fast communication is highly efficient. Further proof came from the number of views of our two 3-minute video clips, which used an appealing infographic technique. We took the right decision when we decided to produce two 8-minute videos instead of the 20-minute long one initially planned by the project (3798 views on Facebook and YouTube).

Despite its good results, the website proved to be a communication tool for insider experts rather than for the general public. Similarly, people showed little interest in the printed products offered at several project events. In this regard, participation was satisfactory if events addressed a broad audience (e.g. stakeholders' meetings, info points), less so if they were technical. Judging by the press, we can conclude that at least 470,000 people read the articles published by the Italian newspaper "La Repubblica" (455,672 issues) on the final project conference and one by the regional newspaper "La Nuova Venezia" (10,220 issues). 20,000 more readers were reached through several scientific and informative publications.

N.	Communication tools	People reached
4	Questionnaires	5.000
13	Focus Groups	107
18	Conferences	1670
6	Seminars	180
4	School visits (seminars for children)	99
9	Exhibitions/trade shows	7.300
22	Workshops	554
17	Articles in the press	490.000
2	Scientific papers	2.000
2	Press releases	1.200
5	Newsletters	5.500
3	Brochures + Layman	7.000
1	Manual	800
3	Videos-Video clips	12.550
11	Posters/Factsheets	1.180
1	Photography contests	300
6	Banners-Roll-ups	6.000
1	Facebook	43.598
1	YouTube	1.179
1	Website	5.360
1	Roundtable discussions	50

Tab.7 - Communication tools used and people reached December 2013 - October 2016.

3.8 Communication tools

3.8.1 Project website

The project website is a national and international dissemination channel and a tool to facilitate and support interactions with and between project participants. The bilingual (Italian and English) website was designed as a "web portal" with sections for the dissemination and publication of news and products (Fig. 18).

The website has several sections about specific project issues, the most important of which are:

– **Homepage**: the main page includes a brief description of the project, a newsbox and a section called "Recycling corner" which lists companies that recycle recovered fishing nets. From the Homepage, you can connect to social media such as Facebook and YouTube (Fig. 19);

– **The project**: detailed description of the background, objectives, actions and expected results;

– **Partners**: presentation of the project team with short CVs of the people involved in the project, their role and contact information;

– **Downloads**: section divided into technical products (technical reports, surveys, photographic atlas, database) and dissemination products (brochures, posters, press releases, newsletters, factsheets, video clips, Layman report, etc.);

– **News and Events**: news and events organised by the project and those attended by the project team;

– **Gallery**: photo gallery divided into three sections - meeting photos, project team photos and photos submitted by the public;

– **Networking**: short descriptions of other projects or initiatives that address the same issue as the LIFE-GHOST project and with which contacts or developed joint initiatives have been established;

- **Links**: list of international, European and Italian projects that may be of interest to website visitors.

Fig. 18 – Project website.

Fig. 19 – Project Social networks (Facebook, YouTube).

We also created a special area for project partners, divided into Actions, which is a sort of archive so that all documents are always available.

3.8.2 Notice Boards

The LIFE+ Programme requires each project to create notice boards describing the project and to place them in strategic positions accessible to the public (Fig. 20).

We made 6 project notice boards (roll-up format):

- 2 General Roll-ups, explaining the aims and activities of the project
- 1 Roll-up for partners presenting the project activities of each partner
- 1 Roll-up with the project results

The general notice boards were displayed at different events organised and attended by the project team, while those containing the activities of individual partners were exhibited at their headquarters.

Fig. 20 – Project Notice Boards.

3.8.3 Layman's report

According to the Life + Programme, at the end of project beneficiaries should draw up a short report for non-experts to inform them about the aims, activities and results achieved.

The report was distributed:

- on the project website;
- by email through a mailing list;
- at events organised by the project or other institutions (trade shows, workshops, etc.).

The Layman report is in English and Italian and is the most commonly used paper document to spread the knowledge of the project activities and results.

3.8.4 After-Life Communication Plan

The aim of the After-Life Communication Plan is to show how the LIFE-GHOST partners will follow up with the dissemination and communication activities developed during the project, and how they intend to disseminate results in the 5 years following the end of the project.

The document contains descriptions of future activities, tools and products that will be produced by the project partners and focuses on 8 steps:

- to distribute dissemination material;
- to upkeep the project website and social media;
- to maintain the project email;
- to attend networking meetings with other Italian and European projects;
- to continue the collaboration between partners and stakeholders;
- to update the biodiversity databases;
- to distribute the Code of Conduct;
- to exploit the project results.

3.9 The stakeholders' involvement

Showing stakeholders the activities and results of the project meant sharing their values. This sharing process has produced a virtuous cycle as stakeholders and citizens have passed on important information by word-of-mouth which will certainly help to develop the right behaviours to keep the sea clean.

Good communication about the project aims and objectives and good dissemination of results have considerably increased the chances of success as well as the early engagement of stakeholders, ensuring the work done has positive future effects.

Engaging stakeholders allowed us to interact as much as possible with people and organisations interested in the project issues.

The groups of stakeholders identified and involved in the project are:

- Fishermen;
- Cooperatives of Fishing and Aquaculture;
- Divers;
- Environmental Associations;
- The Italian Coast Guard;
- Port Authorities;
- Recycling Companies;
- Local authorities (municipalities, the Veneto Region, the Province);
- Representatives of projects dealing with similar topics;
- Universities and research institutions;
- Companies dealing in waste treatment;
- Students and teachers
- Citizens.

In the initial phase of the project we drew up a list of stakeholders we should contact and inform about project activities. We then created and continuously updated a database of about 500 people, who were grouped by type, geographic area and expertise. To involve them, we used the tools described in Table 7 .
As the project area is rather small and the numbers of stakeholders limited, their participation was more than satisfactory especially in terms of local authority representatives and fishermen's associations. Less satisfactory was the participation of fishermen and divers, despite our use of spot-on tools and meetings organised at their convenience. There may be many reasons for this, like lack of time, similar activities promoted by similar projects running at the same time in the area, changes of institutional representatives, etc.

Fig. 21 – Participation of the stakeholders in various events organised by the project.

3.10 Networking with other projects

The aim of this action is to identify Italian and European projects in similar fields to the LIFE-GHOST, funded within different programmes and initiatives, to create a network of all relevant projects dealing with the reduction of marine litter in general and with ghost fishing in particular. Networking activities helped the project in communication and information campaigns thanks to information exchanges and transfer of good practices identified by other projects or initiatives, such as DEFISHGEAR, MERMAIDS, GIOCONDA, TARTALIFE, LIFE-SMILE, MARLISCO, REEF CHECK ITALY, BLUE LINE SYSTEM and SOSREDES (Fig. 22).

Fig. 22 – Networking events.

The activity developed by:

- identifying and contacting other Italian and EU projects dealing with similar issues;
- attending meetings and workshops organised by other projects and events organised by LIFE-GHOST;
- creating a project website section (Networking) where various EU-funded projects on marine litter, ghost fishing and restoration of biodiversity in the marine environment share information.

One of the most significant networking actions is our cooperation with the Global Ghost Gear Initiative (GGGI), which started in November 2014. The LIFE-GHOST project is now a member of the Initiative like other international organisations dealing with global ghost fishing (FAO, UNEP, CSIRO, Ghostfishing etc.). The GGGI has created three working areas: 1) Build evidence, 2) Define best practices and information policies and 3) Catalyse and replicate solutions. The LIFE-GHOST project is part of the first working area and must collect data on Mediterranean ALDFG for a database now under construction, which will later be uploaded in an open-access portal by CSIRO-Australia. Data on the recovery of nets and other fishing gear were collected from several projects and were added to a database together with a report on types of fishing and their equipment in the Adriatic.

The networking activity also included projects that do not strictly focus on the same topic as the LIFE-GHOST project, but share the same intervention area (Venice lagoon) and aim at restoring the lagoon ecosystem, like LIFE-SERESTO and LIFE-VIMINE projects.
Cooperation agreements (TARTALIFE, VIMINE, SERESTO, GGGI, INSTITUTE OF FISHERIES OF SAO PAULO (BRAZIL), POLICE DIVERS GROUP) were signed with some projects/initiatives to organise joint activities, publications, data and information exchanges, etc.

4. RESULTS

The results we obtained with the project are the following:

- drawing up of a database with all the information available on the biological communities of rocky outcrops (*tegnùe*) in coastal areas of the Veneto region;

- total removal of ghost nets and fishing waste materials from 9 impacted coastal areas. Overall, 12 km2 of seabed were monitored, from which 514 Kg of materials were removed;

- biodiversity enhancement in cleared areas through the functional recovery of their habitats;

- gradual biodiversity increase monitored over 18 months in 5 areas cleared from ALDFG. Their diversity indexes were assessed at the end of the survey and showed improvements comparable with those of unaffected reference sites;

- analysis of the economic value of biodiversity improvement in marine environments (rocky outcrops in particular) and identification of policy guidelines to calculate the economic value of removal of this type of waste;

- cost-benefit analysis to assess feasibility and cost-effectiveness of waste removal and disposal from sea-beds using alternative management options;

- drafting of a Code of conduct for the adoption of responsible behaviour and fishing practices, shared with fishermen operating in the project area, and showing best practices to limit loss and abandonment of fishing nets and other fishing equipment at sea;

- issue of operational recommendations for effective ALDFG management;

- publication of a technical protocol to manage ALDFG in marine coastal areas that identifies tools, procedures and instructions to minimise the most severe environmental effects;

- awareness-raising among stakeholders, concerned institutions and all citizens on the broad issue of marine litter and ghost nets in particular, through training and information activities on this topic and ALDFG-related environmental effects.

5. LESSONS LEARNED

Throughout the three years of the project, our activities aimed at achieving specific results in terms of environmental improvement by adopting definite measures in a specific marine coastal area particularly rich in biodiversity. However, we have achieved many other goals that exceed the territorial boundaries of the project area. For instance, we have developed technical procedures of general value, analysed the legislative framework that showed specific gaps and management difficulties in coordinating the onshore collection and disposal of marine plastic litter, especially waste produced by fishing activities. The project's undoubted success is also due to the commitment and helpfulness of participants, who shared their experience and knowledge and acquired new specific know-how. This may support us in future projects.

In developing the *tegnùe* biodiversity database, we had methodological difficulties in giving each species found in literature an updated name, since the scientific nomenclature and classification of many species has changed over time, and we might have overestimated the numbers of reviewed species. We used the latest classification found in the zoological catalogue WoRMs, available at http://www.marinespecies.org. The data on the abundance of different taxa were extremely variable, and depended not only on the type of *tegnùa* (due to the micro-environmental conditions of the specific habitat), but also on the sampling method used. As a consequence, any future comparisons between sites or repeated measures over time within the same site will necessarily have to take this variability into account.

As regards mapping activities, although the High Resolution Side Scan Sonar (HRSS) is a high-precision instrument, which can detect even small objects such as cables and net parts on sandy bottoms, it is not completely effective in locating ALDFG that lie on sub-tidal rocky substrates. In those cases, divers are essential for detailed analyses of seabed conditions.

In scheduling ALDFG removal activities with divers, the rapid changes in weather conditions at sea had to be assessed carefully, which suggests using more divers at once, rather than fewer over longer periods. In addition, we strongly recommend using appropriate cutting tools (e.g. cutters of medium/large size, longer than 60 cm).

Raising awareness among fishermen was particularly hard. Involving them was more difficult than expected, as we had to overcome their initial suspicion towards the true necessity of such a project. Participation grew when we involved people who the fishermen trusted, such as facilitators and professional organisation and cooperative leaders. Moreover, to encourage their participation, we organised meetings locally, so that they did not need to travel and were therefore more collaborative.

As regards the management of fishing and aquaculture nets and gear to be disposed of at the end of their lifecycle and the application of new treatment and recycling technologies, we believe that the virtuous cycle could start at industrial level.
However, in order to do this we should:

- involve stakeholders (namely fishing and aquaculture operators, local governments and plastic production and recycling businesses);
- take action to reduce the risks deriving from discarded fishing gear, both by taking advantage of technological developments, and by raising awareness among fishing and aquaculture operators. The project results provide the necessary information to implement a virtuous management system to reduce the effects of plastics in the sea;
- significantly improve the information about fishing and aquaculture gear on the market, so as to dispose of it in the best way (mechanical or chemical recycling, landfill);
- find out if other plastic items, not only fishing and aquaculture nets, recovered from the sea may be chemically recycled;
- improve the material cleaning process and establish specific recycling lines for each polymer type.

Although analysis of the encrusting community issued significant results regarding its horizontal growth, it was nearly useless in assessing vertical growth. This was mainly due to very short observation periods. Since encrusting communities develop in height very slowly, longer observation periods are required to evaluate the effects of ALDFG removal correctly. The non-destructive visual census technique may be used to monitor the effects of ALDFG removal solely on the cryptic members of fish populations.

The economic value of the *tegnùe* biodiversity improvement in the North Adriatic may be adapted to similar subtidal rocky outcrops along the Italian coasts. It was the most effective and suitable method to assess the existence value of environmental goods, although better results could be obtained in future research if the economic value of biodiversity improvement were combined with an ecosystem function approach, i.e. not by assessing biodiversity *per se*, but the interdependence of different ecosystem services that are beneficial to man.

As regards communication and the changes recently occurred in this field, we suggest focusing on social networks, digital publications, and short videos produced with different techniques. They reach a wider audience and are all more environmentally sustainable (less paper for publications and less metal and plastic for DVDs). Fewer printed products are also more inexpensive. As acknowledged in the original project proposal, we reduced printing and favoured different, less environmentally impacting dissemination means, which were also more attractive to the public and more effective communication-wise.

6. REFERENCES

ARPAV (Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto), 2010. Le *tegnùe* dell'Alto Adriatico: valorizzazione della risorsa marina attraverso lo studio di aree di pregio ambientale. Volume realizzato nell'ambito di: INTERREG III A / Phare CBC Italia – Slovenia VI Piano Nazionale Triennale della Pesca e dell'Acquacoltura LEADER PLUS "Interventi per la salvaguardia e la valorizzazione di un'oasi marina di ripopolamento denominata *Tegnùa* di Porto Falconera", 206 pp.

Arthur, C., Sutton-Grier, A. E., Murphy, P., Bamford, H., 2014. Out of sight but not out of mind: Harmful effects of derelict traps in selected U.S. coastal waters. Marine Pollution Bulletin 86(1-2), 19-28.

Braga, G., Stefanon, A., 1969. Beachrock ed Alto Adriatico: aspetti paleogeografici, climatici, morfologici ed ecologici del problema. Atti Ist. Veneto Sc. Lettere ed Arti, 127, 351-366.

FAO, 2013-2015. Statistical Office of the European Communities (EUROSTAT). EU Fishery economic report 2012. European Union Mediterranean and Black Sea fishing fleet, 2010. FIRMS Reports. In: Fishery Resources Monitoring System (FIRMS) [online]. Rome. Updated 11 January 2013. [Cited 14 January 2015].

Francour, P., 1999. A critical review of adult and juvenile fish sampling techniques in Posidonia oceanica seagrasses beds. Naturalista Siciliano, 23 (Suppl.), 33-57.

Garrabou, J., Zabala, M., 2001. Growth dynamics in four Mediterranean Demosponges. Estuarine, Coastal and Shelf Science, 52, 293-303.

Good, T.P., June, J.A., Etnier, M., Broadhurst, G., 2010. Derelict fishing nets in Puget Sound and the Northwest Straits: patterns and threats to marine fauna. Marine Pollution Bulletin, 60, 39–50.

Gordini, E., Ciriaco, S., Borme, D., Cibic, T., Falace, A., Faresi, L., Marocco, R., Odorico, R., 2010. Trezze o "grebeni": biotopi e geotopi dell'alto Adriatico. In: Le "trezze dell'alto Adriatico: Studio di alcune aree di particolare pregio ambientale ai fini della valorizzazione delle risorse alieutiche locali. Regione Autonoma del Friuli Venezia Giulia, OGS, 241pp.

Large, P. A., Graham, N. G., Hareide, N-R., Misund, R., Rihan, D. J., Mulligan, M. C., Randall, P. J., et al., 2009. Lost and abandoned nets in deep-water gillnet fisheries in the Northeast Atlantic: retrieval exercises and outcomes. ICES Journal of Marine Science, 66, 323–333.

Lopez-Legentil, S., Ruchty, M., Domenech, A., Turon, X., 2005. Life cycles and growth rates of two morphotypes of Cystodytes (Ascidiacea) in the western Mediterranean. Marine Ecology Progress Series, 296, 219-228.

Macfadyen, G., Huntington T., Cappel R., 2009. Abandoned, lost or otherwise discarded fishing gear. UNEP Regional Seas Reportsand Studies, N° 185; FAO Fisheries and Aquaculture Technical Paper, N° 523. Rome, UNEP/FAO, 115 pp.

Mizzan, L., 1995. Substrati solidi naturali del litorale veneziano: potenzialità e prospettive. ASAP Azienda Sviluppo Acquacoltura Pesca, Venezia. 46 pp.

Mizzan, L., 2010. Introduzione sul contesto territoriale. In: Le *tegnùe* dell'Alto Adriatico: valorizzazione della risorsa marina attraverso lo studio di aree di pregio ambientale. Volume realizzato nell'ambito di: INTERREG III A / Phare CBC Italia – Slovenia VI Piano Nazionale Triennale della Pesca e dell'Acquacoltura LEADER PLUS "Interventi per la salvaguardia e la valorizzazione di un'oasi marina di ripopolamento denominata *Tegnùa* di Porto Falconera", 10-13.

Molin, E., Bocci, M., Picone, M., Penna, G., Zanovello, G., 2008. Analisi fotografica del megabenthos in tre affioramenti rocciosi (tegnúe) del Golfo di Venezia (Nord Adriatico). Biologia Marina Mediterranea, 15, 276-277.

Pansini, M., Monconi, R., Pronzato, R., 2011. Fauna d'Italia. Porifera I – Calcarea, Demospongiae (partim), Hexactinellida, Homoscleromorpha. Calderini Editore, pp. 1 -554.

Ponti, M., Fava, F., Abbiati, M., 2011. Spatial-temporal variability of epibenthic assemblages on subtidal biogenic reefs in the northern Adriatic Sea. Marine Biology, 158, 1447/1459.

Stefanon, A., 1967. Formazioni rocciose del bacino dell'Alto Adriatico. Atti Ist . Veneto Sc. Lettere ed Arti, 125, 79-89.

Stefanon, A., 1970. The role of beachrock in the study of the evolution of the North Adriatic Sea. Mem. Biogeogr. Adriat., 8, 79-99.

Stefanon, A., Boldrin, A., 1979. Gli affioramenti rocciosi dell'Alto Adriatico: considerazioni sulla loro distribuzione, struttura ed evoluzione, nel contesto della problematica del bacino. Atti del Convegno Scientifico Nazionale P.F. oceanografia e fondi marini, Roma, 5-7 marzo 1979, 1233-1242.

Stefanon, A., Mozzi, C., 1972. Esistenza di rocce organogene nell'Alto Adriatico al largo di Chioggia. Atti dell'Istituto di Scienze, Lettere ed Arti, 130,495-499.

Sundt, P., Schulze P-E., Syversen, F., 2014. Sources of microplastics-pollution to the marine environment. Mepex for the Norwegian Environment Agency.

Thresher, R. E., Gunn, J. S., 1986. Comparative analysis of visual census techniques for highly mobile, reef- associated piscivores (Carangidae). Environmental Biology of Fishes, 17: 93-116.

Turon, X, Tarjuelo, I, Uriz, MJ., 1998. Growth dynamics and mortality of the encrusting sponge Crambe crambe (Poecilosclerida) in contrasting habitats: correlation with population structure and investment in defence. Functional Ecology, 12, 631-639.

UNEP, 2005. UNEP Regional Seas Programme, Marine Litter and Abandoned Fishing Gear. Report to the Division of Ocean Affairs and the Law of the Sea, Office of Legal Affairs, Nairobi, 30 pp.

PARTNERS

CNR-ISMAR
Arsenale, Tesa 104 - Castello 2737/F - 30122 Venezia
www.ismar.cnr.it

IUAV
Santa Croce, Tolentini 191 - 30135 Venezia
www.iuav.it

LAGUNA PROJECT
Sestiere di Castello 6411 - 30122 Venezia
www.lagunaproject.it

OBSERVERS:

- Regione Veneto -Direzione Difesa del Suolo - Tutela delle acque e difesa idraulica
- Provincia di Venezia - Ufficio Caccia Pesca
- Comando Generale delle Capitanerie di Porto
- Rari Nantes Venezia
- Club Sommozzatori Mestre
- Società Cooperativa San Marco - Pescatori di Burano
- Coopesca - Organizzazione Produttori e Lavoratori della Pesca S.r.l. Chioggia

www.life-ghost.eu
info@life-ghost.eu