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**Deliverable 2.5.1
Report on recycling
process**

**Activity 2.5 – Feasibility Study for
Nylon gillnets recycling cycle
(Version 1.0 – August 2025)**

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BlueDiversity

Shared BLUE knowledge and skills to sustain BIODIVERSITY in mariculture

Project Details

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DISCLAIMER NOTE

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ABOUT THE **BlueDiversity** PROJECT

The **BlueDiversity** project is part of the Interreg Italy-Croatia 2021-2027 Programme, co-funded by the European Union. The **BlueDiversity** project's priority is priority 2 (Green and resilient shared environment). The Specific Objective is SO2.2: improve the protection and preservation of nature, biodiversity and green infrastructure, including in urban areas, and reduce all forms of pollution. In light of this, the **BlueDiversity** project aims at enhancing the ecosystem services-based practices, which allow the sustainment of local ecosystems' preservation through reducing human activities' impacts on biodiversity, while enhancing and developing economic and territorial opportunities.

To achieve the project's objectives, the Project Partners have the need to assess the State of the Art about the main biodiversity threats identified in the pilot areas, by analysing biodiversity, non-indigenous species, marine litter, and lagoon litter. The State of the Art analysis will also target, experiment and screen existing practices, innovations, resources available and attitudes of the ecosystem services end users in the context of the Adriatic Sea.

The Adriatic socio-eco-cultural features represent the common thread for the project actions, bringing relevant stakeholders of the blue economy and blue research to work together towards best and innovative practices with the common scope to develop a green and sustainable transition in the blue sector. In particular, the **BlueDiversity** project targets small and medium enterprises aiming to establish "living laboratories", providing institutional support on the one hand, and placing them as didactic examples at the much-needed interface with schools and younger generations, enhancing the framework of the blue economy with a multilateral approach that includes institutional actors and citizens.

The Adriatic Sea, shared by Italy and Croatia, represents one of the best examples of natural backgrounds in ecological terms, where the dynamics of co-creation, based on an intertwinement of tradition and innovation, can be established. The project aims to develop pilot activities that will experiment with innovative fishing gear to tackle the presence of non-indigenous species that seriously threaten the Adriatic coasts' aquatic ecosystems.

The **BlueDiversity** project is modular, aiming at fully replicable successful experiences, representing the actions' legacy and the core of a shift towards the blue economy. Such elements will be strategically disseminated targeting different institutional and non-institutional entities focusing on the capitalization of the knowledge, know-how and innovative instruments developed throughout the project and aimed at building a sound ground for future major innovative developments.



D 2.5.1 - EXECUTIVE SUMMARY

This document summarises the findings about nylon 6 gill-nets, their composition and possible way of disposal, as well as common procedures of their recovery and storage thanks to the identification of storage sites. Moreover, the document contains indications about costs and normative framework.

D 2.5.1 - LINKS WITH OTHER PROJECT ACTIVITIES

The activities of Working Package 2 - Activity 2.5 is part of the broader topic of marine litter reduction, also covered in Activity 2.6, “Market analysis for sustainable alternatives to plastic materials in aquaculture sites”. The activities are also linked with the implementation of WP 3 “Blue Education, Training and Culture” and WP 4 “Blue Capitalization”.



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1. DELIVERABLE 2.5.1 - INTRODUCTION

1.1. DELIVERABLE OVERVIEW

1.1.1. OBJECTIVES

Deliverable 2.5.1 - Report on recycling process aims to examine the feasibility of recycling Nylon 6 fishing nets in the pilot areas defined by the **BlueDiversity** Project. The primary objective is to assess the technical and economic feasibility of collecting, treating, and recycling discarded nets, no longer used and treated as unsorted waste. The study also aims to identify operational and logistical challenges, identifying common procedures for their recovery and storage by identifying storage sites. The report also provides information on costs and the regulatory framework.

1.1.2. KEY FINDINGS

The analysis aims to achieve the following specific objectives:

- Assessment of the current situation of discarded nylon 6 fishing nets:
- Analyze the quantity and distribution of discarded fishing nets in the project's six pilot areas.
- Examination of available recycling technologies:
Identify and evaluate existing technologies for recycling fishing nets, including collection and treatment methods.
- Cost-benefit analysis:
Evaluate the costs associated with the collection, treatment, and recycling of fishing nets, comparing them with the environmental and economic benefits resulting from sustainable management of these materials.
- Identification of barriers and opportunities:
Identify the main technical, economic, and regulatory barriers hindering the recycling of fishing nets, as well as opportunities for development and innovation.
- Proposals for action:
Develop practical recommendations to improve the management of discarded fishing nets, promoting effective and sustainable recycling practices, with particular attention to cross-border collaboration between Italy and Croatia.

1.1.3. LIMITATIONS

The feasibility analysis focuses on the recycling of a type of material from which fishing nets are made (Nylon 6) from the Adriatic fishing sector. The sites where the assessments were carried out were chosen independently by the project partners (PPs) and can be included within the project pilot areas or in the immediate vicinity.



1.2. MATERIALS AND METHODS

The data collection methodology for this feasibility study involved the following steps:

- **Collection of existing data:**
Reports, studies, and publications regarding fishing net recycling were examined, with a particular focus on initiatives in the Adriatic Sea basin, including scientific articles, reports from non-governmental organizations (NGOs), and data provided by Italian and Croatian government agencies.
- **Surveys and interviews:**
Surveys and interviews were conducted with local fishermen, waste management experts, recovery and recycling companies, and other stakeholders to gather first-hand information on current practices, challenges, and opportunities related to fishing net recycling.
- **Site visits - Direct observations:**
Field visits to coastal communities and ports to directly observe the management of discarded fishing nets and identify potential collection and treatment points from a logistical and management perspective.
- **Tools:**
Questionnaire and Pilot Area report.

Each project partner conducted a specific analysis for the project pilot areas, producing a detailed report. The reports vary in detail depending on the specificity of the areas considered. To facilitate the analysis, a questionnaire summarizing the key information was developed. This tool, combined with meetings and on-site surveys, allowed for precise and timely feasibility assessments.



2. PROBLEM ANALYSIS

2.1 CONTEXT AND RATIONALE

In recent decades, marine pollution has become one of the most pressing environmental challenges, globally. Among the various types of marine debris, fishing nets abandoned in the environment, lost, or discarded, pose a significant threat to marine life, ecosystems, and navigational safety. These **ghost nets**, if abandoned at sea, can continue to catch fish and other marine life for many years; if abandoned on land, they can cause ecological damage and become a source of coastal pollution for fishing communities. Furthermore, many fishing nets no longer used by fishermen are commonly discarded and treated as unsorted waste, ending up in landfills along with other waste and exacerbating the problem of solid waste management. In the Adriatic Sea basin, shared between Italy and Croatia, only few projects for the recovery and recycling of discarded nets have been launched. These pilot projects, while partially successful, have not led to the radical change needed to reduce the impact of fishing on the marine ecosystem. Clearly, to mitigate marine pollution and promote sustainable fishing, a more decisive and systematic commitment to recycling discarded fishing nets is essential. The Adriatic Sea basin, shared between Italy and Croatia, is particularly vulnerable to these problems. Its geological composition, combined with intense fishing activity, makes ghost and discarded nets a significant problem. The management and recycling of discarded fishing nets can significantly contribute to reducing marine pollution and promoting a circular economy. On a cultural level, a coastal community committed to recycling and reusing fishing nets can make a significant difference in safeguarding the marine ecosystem. Promoting a culture of recycling not only helps reduce waste and pollution, but also raises awareness of the importance of environmental protection. Communities that adopt sustainable practices become positive examples, demonstrating that human commitment can lead to real change and lasting benefits. Humans have a responsibility to care for their environment; Without conscious and collective action, the condition of marine ecosystems will continue to deteriorate. Only through cooperation and concrete action can we hope to reverse this negative trend and protect the seas for future generations.

2.2 ENVIRONMENTAL IMPACT OF DISUSED FISHING NETS

Disused fishing nets, mostly containing nylon and polyethylene, can take hundreds of years to degrade in the environment. The lack of national recovery chains for these materials leads to fragmented management policies, which vary across regions and ports.

In most of the areas examined, the current management of disused nets involves the disposal of the material as unsorted waste, destined for landfill. Plastic materials, theoretically recoverable, are therefore sent to landfill, with disposal costs borne by coastal communities and a flow of highly resistant materials that contributes to the filling of waste storage sites. The lack of common rules for the disposal of disused nets and the absence of recovery and initial storage centers for the nets



indirectly encourages the abandonment of nets in the environment, precluding the possibility of implementing recovery and recycling initiatives within a circular economy framework.

2.3 TECHNICAL FEASIBILITY OF NET RECYCLING

Recycling discarded fishing nets presents several technical challenges, but it is also, and above all, an opportunity for innovation. Nets are often made from strong and durable synthetic materials, such as nylon and polypropylene, which can be recovered and transformed into new products. Fishing nets are mainly made of the following materials and/or combinations thereof:

- 1. High-density polyethylene (HDPE)**
- 2. Polyester (PET)**
- 3. Nylon (PA6, PA66)**

All of these thermoplastic materials are technically recyclable.

Nylon 6, in particular, appears to be the most attractive from a recycling perspective, as the recycled material can have commercial value for the production of various new products. This report aims to assess the feasibility of recycling discarded Nylon 6 nets, the recycling of which is currently feasible and conceivable. For the remaining materials, however, the recovery chain in Italy and Croatia is currently more challenging due to the low value of the recycled material and the poor quality of the recycled material.

However, the recycling process requires specific technologies for treating and cleaning the materials, which are often contaminated with organic and inorganic substances. Some advanced technologies for recycling fishing nets already exist, such as depolymerization and mechanical regeneration. These techniques yield high-quality recycled materials, which can be used to produce new products, from technical textiles to industrial components. However, the technical feasibility of recycling also depends on the availability of adequate infrastructure for the collection and treatment of discarded nets. In the Adriatic basin, it is necessary to develop an efficient collection network, developing synergies with specialized recycling plants to ensure a sustainable and effective process or with companies in the sector that are attentive to the issue.

Summarizing the main requirements for implementing decommissioned network recovery activities, we have:

- Aspects related to the minimum quantities of materials to be recovered, which can optimize transportation and management costs (the minimum quantity per single recovery site is estimated at 2 tons per year).
- Logistical aspects regarding the availability of adequate space for sorting, selection, and storage of the networks prior to recovery by specialized companies.



- Management aspects regarding the management rules and the legal entity to be identified for the management of the initial storage center.
- Regulatory aspects regarding traceability requirements for the transport of recovered materials to recovery/recycling centers.



Figure 1. Abandoned Nylon Gillnets

2.4 ECONOMIC AND FINANCIAL ASPECTS

The economic analysis of recycling discarded fishing nets must consider several factors. First, the costs associated with the collection, transport, and treatment of discarded nets can be high if not organized synergistically with other components of the supply chain. An initial investment is required to develop the collection infrastructure and to acquire or improve recycling technologies. However, these costs can be mitigated through incentive policies and collaboration between public and private entities.

Second, the market for recycled materials offers revenue opportunities. Products obtained from recycled fishing nets, such as technical textiles, sports equipment, and industrial components, can have high added value. Furthermore, the adoption of sustainable practices can improve the image of companies and attract environmentally conscious consumers.

It is also important to consider the indirect economic benefits resulting from reducing marine pollution. A healthier marine environment can support vital economic activities for coastal communities, such as tourism and fishing, reducing the costs associated with beach cleanups and restoring damaged habitats. Investing in the recycling of discarded fishing nets can therefore represent not only an environmentally sustainable choice but also a long-term economic opportunity.



In this context, attention was focused on the feasibility of recycling Nylon 6, a polymer with high technical performance that retains a certain market value even when used. Nylon 6 recovery/recycling companies can cover the costs of transporting it from the initial recovery center to the recycling facility. This reduces the transportation costs that would otherwise be borne by fishermen/waste producers, facilitating the recovery of these materials within a circular economy framework.

2.5. APPLICABLE LEGISLATION

2.5.1. ITALIAN LEGISLATION

Legislative Decree No. 197 of November 8, 2021, implements Directive 2019/883/EU (MARPOL Update). It defines waste generated by ships (including fishing vessels), including waste accidentally caught, such as nets remaining at sea. This legislation requires every port to have port waste reception facilities capable of accepting even accidentally caught waste. Legislative Decree No. 46 of April 8, 2024, clarified and improved the division of responsibilities between the Maritime Authority, port managers, and shipowners; it introduced the possibility for facilities to agree on special waste management methods and strengthened workplace health and safety aspects in facilities. The Decree of the Ministry of the Environment and Energy Security of October 27, 2023, published in the Official Journal on December 7, 2023, establishes that for the years 2024–2025, a minimum collection rate of 15% by weight is mandatory for fishing gear containing plastic placed on the market in Italy. This collection includes nets, netting, buoys, floats, ropes, and monofilaments present in the sea or accidentally caught. Producers, through individual or collective systems, must report to ISPRA by April 30 both the quantities placed on the market and those collected. Port authorities, management systems, and municipalities also declare data via the MUD (Registration of Environmental Data).

Extended Producer Responsibility (EPR): The 2023 decree extends the EPR to plastic fishing gear: producers must finance collection, transport, treatment, recycling, and awareness campaigns. Effective January 1, 2024, ARERA has established a fee of € 0.10 per user to cover the costs of collecting accidentally caught waste (the "Salvamare Law").

Traceability and Collection Incentives: Legislative Decree No. 152 of April 3, 2006 (Environmental Code) mandates the traceability of hazardous waste (including fishing nets) through the RENTRI system in ports lacking a port facility. The same law promotes incentives, e.g., penalty discounts for those who regularly dispose of hazardous waste, for fishing vessels participating in organized systems.

In summary, Italian Legislation:

1. Classifies plastic fishing nets and gear as hazardous waste;
2. Imposes a minimum collection rate of 15%;
3. Places financial responsibility for collection, treatment, and awareness-raising on producers;



4. Provides traceability tools (RENTRI, MUD, ISPRA reports);
5. Introduces a preferential rate (ARERA) for the recovery of accidental waste;
6. Promotes pilot projects for the circular economy in ports.

2.5.2 CROATIAN LEGISLATION

Pursuant to the European Parliament and Council Directive 94/62/EC on packaging and packaging waste and the Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment, the Croatian Ministry of Economy and Sustainable Development adopted the “Ordinance on packaging and waste packaging, single-use plastic products and fishing gear containing plastic”. The Ordinance was adopted at the end of 2023 (Official gazette 137/23). It was derived from the Waste management act adopted in 2021 (Official gazette 84/21). It lays down the guidelines and recommendations on the collection, management, transport and treatment of end-of-life fishing gear containing plastic. The Ordinance defines that the fishing gear containing plastic should be handed over to the port waste reception facilities (if available) or handed over to the private or legal entity owning a concession contract for waste collection. It also sets a minimum annual collection rate of waste fishing gear containing plastic for recycling.

2.6. ANALYSIS OF AVAILABLE MATERIALS AND TECHNOLOGIES

To assess the technical feasibility of recycling discarded fishing nets, the following aspects were analyzed:

Material Characteristics: Study of the physical and chemical properties of fishing nets, focusing primarily on Nylon 6. Identification of net types and components composed of Nylon 6.

Recycling Technologies: Identification and evaluation of currently available technologies for recycling fishing nets. These include depolymerization, mechanical regeneration, and other innovative techniques.

Case Studies: Analysis of successful pilot projects and initiatives in other regions or countries. These case studies provided valuable insights into best practices, lessons learned, and potential solutions applicable to the Adriatic Sea context.

2.7 EVALUATION OF POTENTIAL PARTNERS AND STAKEHOLDERS

This phase of the methodology included:

Stakeholder mapping: Identification of all stakeholders involved or interested in the fishing net recycling process, including fishermen, recycling companies, local authorities, NGOs, and research institutions. The stakeholders identified in the specific analysis of the six **BlueDiversity** project pilot areas are summarized in the referenced database D 2.5.2.



Capacity and resource assessment: Analysis of the technical, financial, and operational capabilities of potential partners. This activity included examining existing infrastructure, human resources, and available expertise.

Engagement and collaboration: Development of strategies to actively involve stakeholders in the project. This activity included engaging all key stakeholders during the feasibility analysis phase to share the solutions proposed in the specific feasibility studies.

Partnership proposals: Formulation of collaboration proposals, highlighting mutual benefits and operational modalities for each partner. The implementation strategies of the pilot actions in the project pilot areas are defined in Output 2.1 of the project.

Table 1. Main stakeholders categories

| Actors/stakeholders | Role |
|---|--|
| Fishermen/Shipowners/Networkers/Net Manufacturers | Waste producers deliver discarded nets to the center, checking the homogeneity of the material. |
| Fishermen's Associations | They offer various services to their members. |
| First Storage Point Management Body | Body that manages the storage of discarded nets, performs pre-storage inspections, and manages disposal by contacting recycling companies. |
| Recycling Companies | Companies specializing in the collection and treatment of discarded nets to transform them into useful materials for reintroduction into plastics production cycles. Companies with all required authorizations. |
| Discarded Net Transport Companies | These are transport companies specialized in waste transportation, registered in the register of environmental managers and holding all required authorizations. |
| Local – Territorial Authorities | These are control and guidance bodies with responsibility for port organization. |
| Environmental associations | These are organizations present in local areas with an interest in the health of ecosystems and could be involved in awareness-raising and motivational activities. |

2.8. INDUSTRY ANALYSIS

Materials recycled from nylon 6 fishing nets can be transformed into a variety of products, including technical textiles, sports equipment such as shoes and bags, and various industrial components. Demand for these products has been growing in recent years, driven by growing consumer environmental awareness and the trend toward sustainable production processes. This creates a potential market for materials derived from recycled fishing nets. Numerous companies, some of which are well-established in the textile sector, have been occupying a significant market share for years, such as in the apparel sector.



2.8.1. INDUSTRIES USING RECYCLED MATERIALS

Recycled fishing nets offer materials such as nylon and polyethylene that are highly sought after in various industries. The textile sector, for example, uses recycled nylon to produce technical and sportswear. The automotive industry also uses recycled plastic materials for interior components. Analyzing the needs of these industries reveals a growing demand for sustainable materials that can replace virgin raw materials.

2.8.2. RECYCLED PRODUCTS

A growing number of consumers are willing to pay a premium for eco-friendly products. This trend is supported by market studies showing that consumers are increasingly oriented toward purchasing sustainable products. Awareness campaigns and environmental certifications can further increase demand for products made from recycled fishing net materials.

2.8.3. RECYCLING TECHNOLOGIES.

Technologies for recycling fishing nets primarily include depolymerization, which breaks down polymers into reusable monomers, and mechanical regeneration, which allows the reuse of synthetic fibers.

Mechanical recycling processes are divided into primary and secondary recycling processes.

Primary recycling is the process of mechanically reintroducing clean monopolymer plastic into the extrusion cycle to generate products made from similar materials with properties nearly equivalent to the original product. This is often referred to as "closed-loop recycling." Due to the requirement for clean (uncontaminated) monopolymer input materials, primary recycling is often used for waste materials generated in the manufacturing process (Hillier et al., 2022). Unused waste generated in the manufacturing process can be ground and reintroduced into the extruder, a process known as re-extrusion. Fishing gear waste from the manufacturing process could be a useful source of such materials, provided it is clean and made from a single polymer.

In **secondary recycling**, solid plastic waste materials are mechanically fed into the extrusion loop and reduced in size to more acceptable shapes and formats, such as pellets, flakes, or powders, depending on the quality of the input material and the polymer composition. The resulting materials are of overall lower quality than those introduced into the recycling process and are sometimes referred to as "downcycling" or "downgrading" processes (Dorigato, 2021; Ragaert et al., 2017). A combination of primary and secondary recycling may also be appropriate for fishing net recovery. For example, pieces of unwanted new material used in net repair may be suitable for primary recycling, while scraps recovered from repaired nets may be suitable for secondary recycling.



Successful mechanical recycling is more likely if the recycled polymers are isolated single polymers or known, compatible polymer blends, rather than unknown or incompatible polymer blends. For example, while PA is generally limited to compatibility with PS blends, it is also compatible with PET in small quantities for further processing in the melting process. However, PA is incompatible with PE and PP because they melt at much lower temperatures (Bertling and Nühlen, 2019). Given these requirements for often high-quality and sometimes pure polymer inputs, plastic recyclers use integrated or separate melt filtration technologies to remove polymer contaminants (Bertling and Nühlen et al., 2022).

In the case of depolymerization, also called chemical recycling, fishing nets are broken down into smaller molecules using chemicals and then reused to produce new nylon products. This process requires specialized equipment and can only be performed in several steps at an industrial level:

- **Depolymerization:**
The nylon 6 present in the net is broken down into monomer units using hydrochloric acid or hydrogen sulfide.
- **Neutralization:**
The acidic solutions produced during depolymerization are neutralized using bases.
- **Removal of impurities:**
Impurities present in the solution are removed through filtration or decantation processes.
- **Polymerization:**
The monomer units are reunited to form long chains of Nylon 6, which can be used to produce new products.

The chemical recycling of nylon 6 can only be done on an industrial scale, as it requires specialized equipment and the use of hazardous chemicals. However, this recycling process allows for 100% reuse of Nylon 6, without losing any of the material's important properties.

In both cases, recycling Nylon 6 fishing nets can help reduce the environmental impact caused by their disposal in landfills or abandonment at sea, reducing the amount of waste produced and protecting the marine environment. However, recycling Nylon 6 fishing nets presents some challenges, such as the need to separate the nylon from other materials in the net, such as the presence of other plastic polymers in the nets and the presence of materials such as lead or steel. The benefits of chemically recycling nylon 6 include:

- **Reduction in waste:**
Recycling nylon 6 fishing nets reduces the amount of waste produced, preventing the nets from ending up in landfills or in the sea and becoming a threat to the environment.
- **Reduction in environmental impact:**
Recycling nylon 6 reduces the environmental impact of virgin nylon production, which requires oil extraction and energy consumption.



- **Reuse of resources:**

Recycling nylon 6 allows existing resources to be reused and reduces dependence on virgin raw materials.

However, the chemical recycling process for Nylon 6 also presents some sustainability challenges and limitations:

- **Hazardous chemicals:**

The chemical recycling process for Nylon 6 requires the use of hazardous chemicals, such as hydrochloric acid or hydrogen sulfide, which can have a negative impact on the environment and human health if not managed properly.

- **Greenhouse gas emissions:**

The chemical recycling process for nylon 6 requires the use of energy, which can produce greenhouse gas emissions.

- **Process efficiency:**

The chemical recycling process for nylon 6 may be less efficient than the production of virgin nylon, as recycled nylon may lose some of its original properties during the recycling process.

In general, the chemical recycling of Nylon 6 can only be considered a sustainable process if it is managed correctly and responsibly, minimizing negative impacts on the environment and human health and maximizing the benefits of reusing existing resources. According to the study, the most effective process for recycling discarded fishing nets **is mechanical recycling**, as it is less costly and more suitable for the type of industry from which the nets to be recycled originate. The mechanical recycling process is described in the following paragraphs.



3. THE NYLON 6

3.1 CHARACTERISTICS OF THE MATERIAL

Nylon 6 is a thermoplastic polymer used to manufacture certain types of fishing nets. Its strength, elasticity, and durability make it an extremely suitable material for use in the fishing industry. However, there is no specific data on the exact amount of Nylon 6 used to produce fishing nets at the national or European level. According to a study published in the scientific journal "Marine Pollution Bulletin" in 2018, it is estimated that nylon makes up approximately 20% of the material used to manufacture fishing gear worldwide, including nets, traps, and fishing lines.



Figure 2. Fishing net in Nylon



Figure 3. Fishing Net Components in plastic



Its main characteristics are:

1. **High mechanical strength:** Nylon 6 is known for its strength and durability. It has a good ability to withstand heavy loads and resist wear.
2. **High toughness:** Nylon 6 is a very tough material, meaning it can absorb energy during deformation without breaking.
3. **High tensile strength:** Nylon 6 is a very tensile material, meaning it can resist deformation and breakage when subjected to a tensile force.
4. **High fatigue resistance:** Nylon 6 has good fatigue resistance, meaning it can withstand repeated cyclic loads without breaking.
5. **Good chemical resistance:** Nylon 6 has good chemical resistance, although it can be attacked by some organic solvents.
6. **Good abrasion resistance:** Nylon 6 is known for its good abrasion resistance, meaning its ability to resist wear and tear caused by rubbing.
7. **Good processability:** Nylon 6 can be easily processed using extrusion, injection molding, and blow molding, making it a very versatile material suitable for many applications.
8. **Low hygroscopicity:** Nylon 6 has low hygroscopicity, meaning it has a limited ability to absorb water from its surroundings.
9. **Low resistance to high temperatures:** Nylon 6 has low resistance to high temperatures compared to other thermoplastic polymers such as polypropylene and high-density polyethylene.
10. **High density:** Nylon 6 has a relatively high density compared to other thermoplastic polymers such as polypropylene and high-density polyethylene.

3.2 NYLON 6 AND FISHING NETS

Nylon 6 is commonly used for the production of fishing nets due to its mechanical strength, toughness, and abrasion resistance. Furthermore, it has low hygroscopicity, meaning it does not absorb much water and does not become heavy when used in water. This property makes Nylon 6 ideal for the production of fishing nets, as the additional weight of water can affect the buoyancy of nets. Furthermore, Nylon 6 is also easily workable and can be produced in threads of different thicknesses, making it suitable for the production of fishing nets with different mesh sizes and strengths. However, it is important to note that Nylon 6 can be negatively affected by sunlight and UV rays, which can reduce its strength and durability over time.



3.2.1 WHERE IS NYLON 6 FOUND IN FISHING NETS

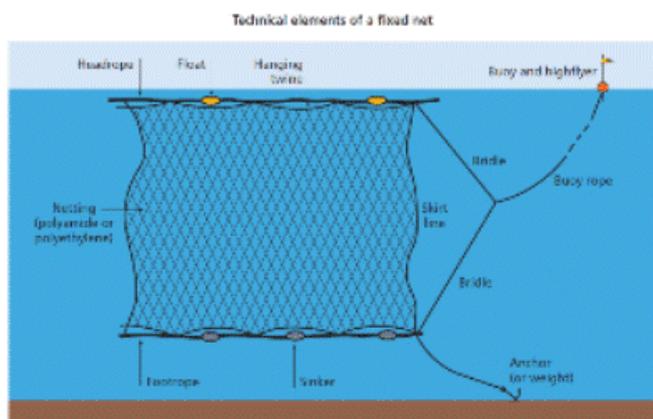


Figure 4. Nylon part in gillnets

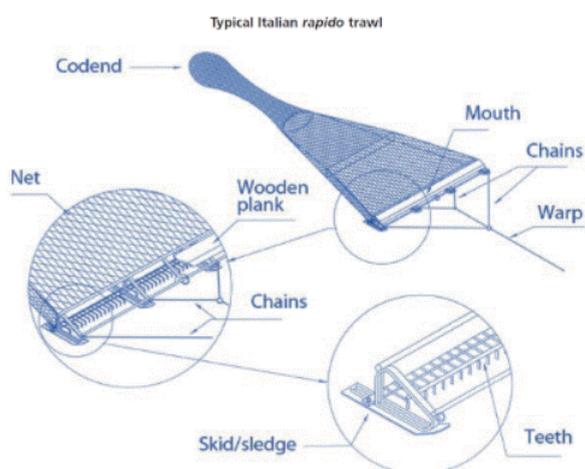


Figure 5. Nylon part in rapid net



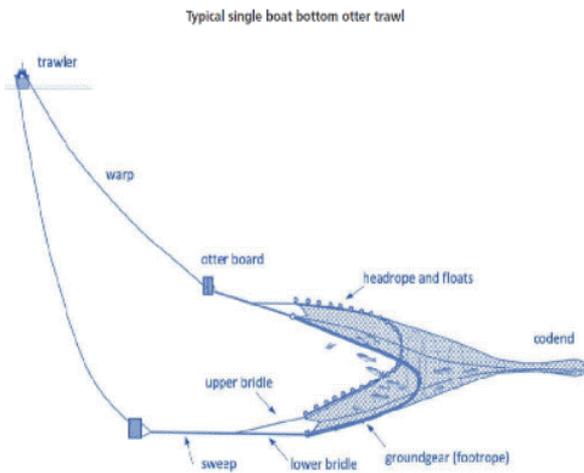


Figure 6. Nylon part in trawlers net

3.3 RECOVERY/RECYCLING SUPPLY CHAIN FOR NYLON 6 FROM DISUSED NETS

As described in the previous section, there are two main methods for recycling Nylon 6: mechanical recycling and chemical recycling.

Mechanical recycling: Nylon 6 is ground into small pieces and then melted to produce new products. This process can be carried out on an industrial or artisanal scale, using special machinery or shredders.

Chemical recycling: Nylon 6 is broken down into smaller molecules using chemicals and then reused to produce new products.

A third route for disposing of Nylon can be added to this list: **energy recovery**; Nylon 6 can be used as fuel to produce energy.

From analyses conducted in collaboration with nylon recovery companies, mechanical recycling appears to be the most cost-effective, although it yields recycled materials of lower quality than the final product from chemical nylon recycling.



4. NET RECOVERY AND RECYCLING ACTIVITIES

4.1 ORGANIZATIONAL MANAGEMENT

Managing a temporary net storage center requires a legal entity that organizes, monitors, and manages the recovery, storage, and disposal activities. Ports where fishing associations or similar entities already exist are able to organize a storage center for discarded nets.

The entity responsible for managing the collection and recovery of discarded nets has important responsibilities, the main ones being:

- sorting and storage activities;
- coordinating waste disposal activities by producers;
- defining incentive and reward systems for those who dispose of discarded nets;
- managing relationships with recovery/recycling companies;
- managing documentation for waste collection and disposal;
- training operators for proper disposal.

Other Possible Management Models.

Other management models that could be used for a potential storage and recovery center include:

- **Consortium model:** managed by cooperatives or consortia in the fishing industry.
- **Contracted management:** entrusted to specialized firms.

Direct management by a public entity: Port Authority, Land Management Agencies, Regions, Municipalities.

4.2 LOGISTICS MANAGEMENT

A hypothetical recovery and storage center for disused networks must provide adequate storage space and well-defined and organized technical transport and storage methods.

The hypothetical storage area should have the following minimum requirements:

- **Minimum required surface area: 200 m²**
- **Surface characteristics:** perimetered and paved; if an outdoor area, roofs are required to protect the material from the elements (especially sunlight); if covered, a small office is preferable. Access to the area should be supervised at all times and kept secure.
- **Necessary utilities:** Water, electricity.
- **Skills:** The personnel involved should have precise knowledge of the various materials in order to deliver the disused material with an adequate level of homogeneity. Training of the



personnel involved (including waste producers) is therefore a necessary and essential element for the activation of a hypothetical recovery center for disused networks.

- **Storage characteristics:** The best solution for storage and subsequent delivery for recycling should involve the use of dedicated containers or, better yet, big bags. Big bags, also known as FIBCs (Flexible Intermediate Bulk Containers), are primarily made of woven polypropylene (PP) fabric. This material makes them flexible, durable, and suitable for the transport and storage of loose materials such as powders, granules, and flakes.

Commercially available big bags come in various sizes with different characteristics and represent the best storage method for nets, allowing for easy movement by forklift or other lifting equipment. The characteristics of the big bags to be used in a hypothetical recovery center should be chosen considering the load capacity of the lifting and transport equipment required for loading and unloading operations. When choosing the various types of big bags, nylon ones should be preferred, so that the big bag can be combined with the rest of the container's contents (nylon nets) during recycling.

4.3 MATERIAL CONTROL TECHNIQUES

Plastic materials can often be confusing because visual inspection can lead to errors in judgment by untrained personnel. For this reason, recycling companies often have technologies capable of identifying the type of polymer in the network with a high degree of certainty. These controls may include laboratory analysis or the use of NIRS Near-Infrared Spectroscopy technology.

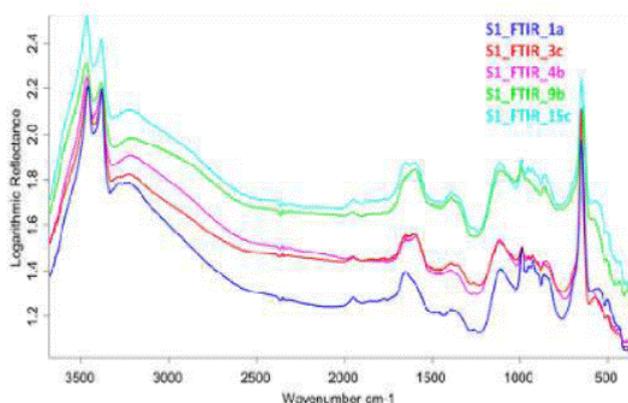


Figure 7. Spectroscopic analysis graphs

Near-infrared spectroscopy (NIRS) has been a well-established method for rapid and reliable quality control in the polyamide industry for over 30 years. There are several advantages to using NIRS over other conventional analytical technologies. NIRS can measure multiple parameters in just 30 seconds without any sample preparation; the non-invasive light-matter interaction used by NIRS,



influenced by the physical and chemical properties of the sample, makes it an excellent method for determining both types of properties. NIR spectroscopy analyzes the interaction between light and matter to generate a spectrum. In spectroscopic methods, light is typically described not by the applied energy, but by its wavelength. NIR spectroscopy operates in the near-infrared region of the electromagnetic spectrum, i.e., the wavelength range between 780 and 2500 nm. In other words, an NIR spectrometer measures the absorption of light by the sample at different wavelengths in the NIR region. NIRS is a secondary technique; this means that it is first necessary to create a prediction model and it is therefore necessary to “train” the instrument by preparing and using standard samples of the substance and measuring them to create a reliable calibration curve.

FTIR, or Fourier Transform Infrared Spectroscopy, is an analytical technique used to identify the chemical composition of materials by measuring their absorption of infrared (IR) light. It works by passing infrared radiation through a sample and analyzing the absorbed and transmitted light, revealing a unique spectral “fingerprint” that identifies the material's molecular structure.

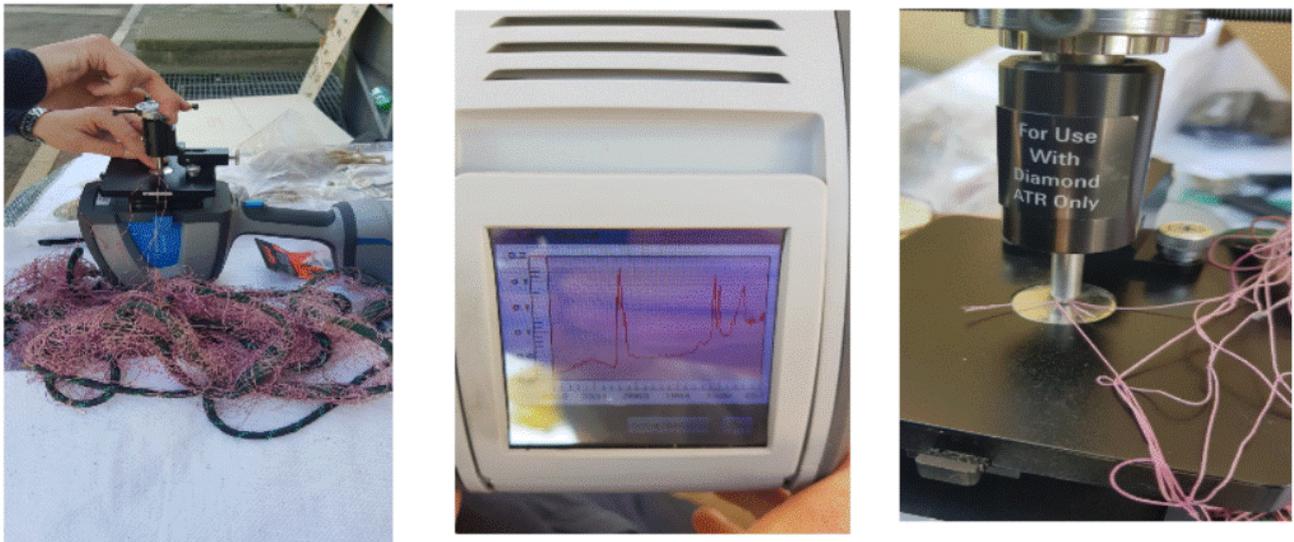


Figure 8. Use of FTIR technologies in net material inspection carried out during the project activities.

This precision technology is not affected by the color of the raw material, despite its higher costs compared to other technologies. This technology is used in the nylon recycling sector to identify and remove contamination from polymers such as PE (polyethylene), PP (polypropylene), and PET (polyethylene terephthalate). This technique allows for characteristic infrared spectra for each material, facilitating the identification of the various components.



FTIR technology is also used to verify the type of materials and is therefore a useful and necessary tool for on-site inspections and checks, as it allows the type of plastic fibers to be verified and the material's composition to be confirmed.

4.4 DESCRIPTION OF NYLON 6 RECOVERY SUPPLY CHAIN ACTIVITIES

The following flowchart illustrates the phases of the recovery and storage process for disused nets to be implemented in a hypothetical recovery center to be established.



Figure 9. Example of a work flow for recovery and temporary storage of nylon nets

Step 1: Selection of material for recycling (net cutting)

The first important step in implementing an initial recovery and storage center for discarded nets is to establish a waste management process for recovered materials that can handle mixed polymers, biological substances, marine debris, and metal objects. The waste management process should set operative instructions and procedures in order to train the staff involved.

However, the variety of materials and polymer mixtures present in fishing gear often complicates recycling efforts due to the need to separate different types of material, particularly the different plastic polymers that comprise a single gear component. Preparing fishing gear for recycling requires manual sorting and processing operations and facilities to prepare them for recycling (Stolte et al., 2019); this is especially true for nets, ropes, and traps, which often have many attached parts and components.

The first important step in implementing a disposal center for discarded nets is to establish rules and instructions for properly cutting the nets to be disposed of, taking care to maintain the homogeneity of the material (nylon only or plastic only).



Step 2: Incoming inspection at the initial storage center

Before loading the material to be stored at the initial recovery center, a check must be performed to ensure the material is homogeneous and clean. If any anomalies are found, the material cannot be collected.

Step 3: Storage

The discarded material must then be placed in designated areas within the center. The material will then be identified and recorded, possibly keeping an updated loading log book.

Step 4: Nylon recycling

Once the minimum quantity to justify the collection of the material for recycling is available, the collection is organized in collaboration with the recycling company.

The following flowchart of activities refers to the **mechanical recycling process** of Nylon 6.

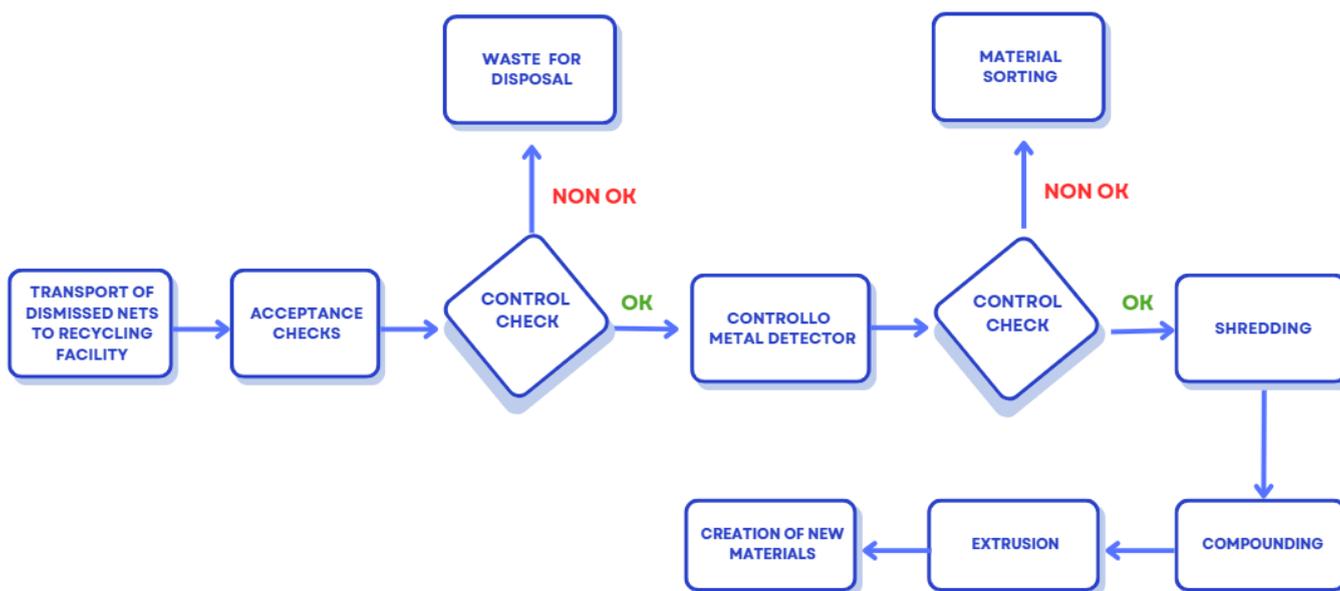


Figure 10. Example of Nylon 6 Recycling Activity Flow

Step 1: Selection and inspection at the recycling plant

The materials arriving at the recycling center are again inspected visually or using FTIR technology. If other polymers are present, the material is discarded and segregated in a dedicated area.

It should be noted that the recycling company, which bears the costs of transport from the initial storage facility (port) to the recycling center, must be certain of the homogeneity of the material to be recycled, as non-compliant material must be disposed of as waste, with the associated costs borne by the company. Furthermore, if impurities in the supply of disused nets are not identified



before entry into the production cycle, this could create problems in subsequent phases, making it impossible to use the recycled material due to technical issues. This would generate additional material disposal costs. It is therefore crucial that the initial storage facility for the nets correctly sorts the material to avoid compromising the quality of the entire supply.



Figure 11. Shredding and compounding plant

Step 2: Shredding

The first mechanical process the material undergoes is shredding, carried out with industrial shredders capable of reducing the size of the polymers to be recycled, facilitating subsequent processing steps.

Step 3: Metal Removal

The material is then passed through a metal detector to eliminate any residual metal contamination, ensuring the purity of the final product.

Step 4: Compounding

The material resulting from shredding is then subjected to a compounding process to obtain various products intended for molding, such as modified polyamides for improved impact resistance and glass fibers for increased strength. Compounding is a process that involves mixing polymers with additives to obtain plastic materials with specific properties. It is a crucial step in plastics processing, allowing the characteristics of the final product to be customized based on industrial needs and improving the quality of the polymers in the recycled material. Compounding involves mixing polymers with additives such as lubricants, heat stabilizers, antioxidants, fillers, reinforcements, colorants, etc. This process is carried out using extruders or compounders: specialized machines that melt and mix materials homogeneously. This phase allows for the



production of materials with desired properties, such as strength, flexibility, chemical resistance, thermal properties, etc.

Step 5: Injection Molding

After the compounding phase, products undergo the injection molding process, a technique that allows for the production of components with complex geometries and optimal mechanical properties. The injection molding process is a manufacturing technique that involves injecting molten material (typically plastic polymers) into a mold, where it cools and solidifies into the desired shape. This process is widely used for the mass production of identical parts due to its efficiency and precision. The granules resulting from the compounding process are fed into a hopper and then heated until they become molten.

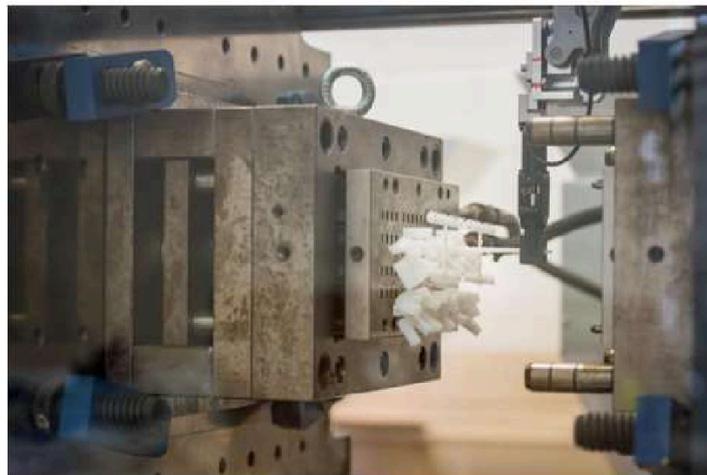


Figure 12. Injection Molding process

The molten material is injected into the mold at high pressure. The molten material inside the mold begins to cool, solidifying and taking the shape of the mold cavity. Once the material has completely solidified, the mold opens and the finished piece is ejected.

4.5. THE VALUE OF THE RECYCLED MATERIAL

Products made from recycled nylon are actually used in numerous sectors, such as automotive, household appliances, and sportswear, contributing to the circular economy and environmental sustainability. The recycled nylon cannot however be reused to create new fishing nets, as the characteristics of the recycled material do not allow it to meet the technical requirements of a fishing net.

4.6. CASE STUDY: COOPERATIVE PESCATORI MOTOPESCHERECCI ANCONA

The **Cooperative Pescatori Motopescherecci** of Ancona (Marche Region, Italy) has implemented and operationalized a project ("Nets in Circle") that has led to the creation of an integrated system



for the recovery and recycling of discarded Nylon 6 fishing nets at the port of Ancona. The overall goal is to reduce the environmental impact of plastic waste generated by local fishing, transforming a problem into a resource through a circular economy approach. The project was promoted and coordinated by Legambiente Marche, part of the national Legambiente network, the most widespread Italian environmental association. It works for environmental sustainability, land protection, and the dissemination of an ecological culture in the Marche region. It is committed to environmental education projects, sustainable development, the enhancement of local economies, and the promotion of activities such as sustainable tourism and renewable energy.

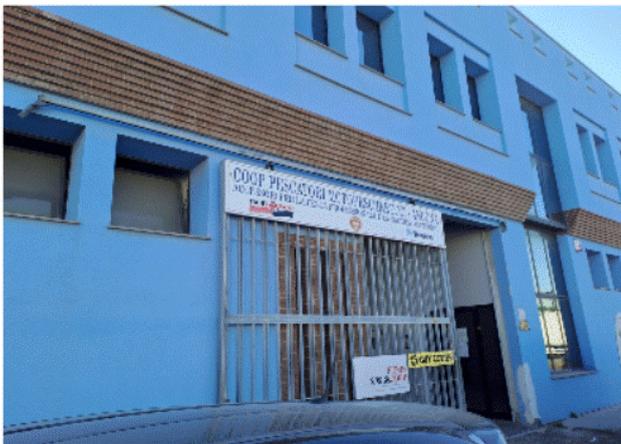


Figure 13. Headquarters of the Cooperativa Pescatori Motopescherecci Ancona

The activities included:

- the creation of a storage and recovery center for decommissioned nets;
- the training of marine operators and local stakeholders;
- the activation of a recycling chain with specialized companies;
- communication and environmental awareness campaigns.

In 2024, approximately 30 tons of nylon from decommissioned nets from small-scale coastal fishing, trawling, and rapid trawlers were sent for recycling. The project was structured to be economically sustainable even after the funding expires, thanks to the commercial value of the recycled Nylon 6 and agreements with companies in the sector.

The Cooperativa Pescatori Motopescherecci Ancona availability to share their best practices in collection, storage and recycling of fishing nets allowed **BlueDiversity** project consortium to acquire essential information on the organizational and logistical methods of the temporary storage center established in Ancona.





Figure 14. Loading operations of Nylon 6 nets at the Cooperativa Pescatori Motopescherecci Ancona to be sent for recycling.



5. COST-BENEFIT ANALYSIS

5.1 ESTIMATION OF STARTUP AND OPERATION COSTS FOR A POTENTIAL TEMPORARY STORAGE CENTER

The main lever that can be used to make a temporary storage center sustainable and ensure its long-term continuity is the costs of landfilling the discarded nets. Waste producers (given their volume and weight) must pay specialized suppliers for the collection and disposal of these materials. However, given that recycled Nylon 6 retains a certain market value, recycling companies are willing to pay the costs of transporting and recycling these materials from the temporary storage centers to the recycling site. This approach reduces the disposal costs of nylon nets, making recovery and storage activities sustainable over time. Another possible source of funding for the implementation of a temporary storage center is offered by funds linked to the European Maritime, Fisheries and Aquaculture Fund (EMFAF) <https://www.feampa.it/>; https://euribarstvo.hr/home/?utm_source=chatgpt.com.

Table 2. EMFAF Priority

| EMFAF Priority | Main purpose | Type of eligible intervention |
|---|--|---|
| Priority 1 – Sustainable Fisheries and Biodiversity | Improve fishing waste management to protect ecosystems | Temporary storage centers for discarded fishing nets; selective disposal system in ports |
| Priority 3 – Blue Economy and Community Development | Support coastal infrastructure and fishing communities | Local projects for exceptional marine waste management, collaboration between ports and fishermen |

Startup costs:

1. Infrastructure and equipment:

- Acquisition and/or improvement of infrastructure for the collection and treatment of fishing nets.
- Purchase of equipment necessary for the handling, transport, and treatment of nets (e.g., recycling machinery, specialized containers).

2. Personnel and training:

- Costs for training personnel involved in the collection, treatment, and management of the project.
- Costs for hiring personnel dedicated to the daily management of net collection and treatment operations.

3. Administrative and legal costs:

- Legal fees for compliance with environmental and local regulations.
- Registration and authorization costs required to initiate fishing net recycling activities.



Recurring operating costs:**1. Collection and transportation:**

Operating costs for the collection of discarded fishing nets from ports and coastal areas. Transport costs of collected nets to treatment and recycling centers.

2. Treatment and Recycling:

Costs for the treatment of fishing nets, including washing and cleaning processes, material separation, and actual recycling. Expenses for energy and other resources required during the recycling process.

3. Maintenance and Operation of Facilities:

Costs for preventive and corrective maintenance of treatment equipment and infrastructure. Overheads for the daily management of net collection and recycling operations.

5.2 ANALYSIS OF ENVIRONMENTAL AND ECONOMIC BENEFITS

Environmental Benefits:

1. Reduction of Marine Pollution: Minimization of the negative impact of abandoned fishing nets on the marine ecosystem, contributing to the protection of biodiversity. Reduction of microplastics and other waste resulting from the degradation of nets, improving the quality of the marine environment.

2. Conservation of Natural Resources: Saving virgin resources through the recycling of plastic materials, such as nylon and polypropylene, used for the production of new products.

3. Public health benefits: Reduction of the risk associated with plastic and microplastic contamination in the marine food chain, indirectly improving human health.

Economic benefits:

1. Growth of the recycled materials market: Opportunity to enter new markets for recycled materials derived from fishing nets, such as technical textiles, industrial components, and sports products.

2. Reduction of waste management costs: Minimization of costs associated with marine litter management, including those related to beach cleanups and the restoration of damaged marine habitats.

3. Enhanced corporate image: Improvement of the image of companies and organizations that adopt sustainable practices, increasing consumer confidence and investment attractiveness.



Italy – Croatia



The cost-benefit analysis emphasizes the importance of considering both financial and environmental aspects. Accurately calculating initial and ongoing costs, coupled with an assessment of the benefits resulting from improved marine environments and economic opportunities, will provide a solid basis for informed decision-making and promote net recycling towards long-term sustainability.



6. RECOMMENDATIONS FOR THE IMPLEMENTATION OF A STRATEGIC PLAN FOR THE RECOVERY AND DISPOSAL OF DISCARDED FISHING NETS

Currently, the collection and treatment capacity for discarded fishing nets in the Adriatic Sea is limited and operated in a fragmented manner across various regions. The lack of adequate infrastructure, such as storage centers and an innovative organization of the recycling chain, represents a significant barrier. However, growing attention to environmental issues and the circular economy has created a favorable environment for the adoption of net recovery systems that could be developed on the Italian and Croatian coasts. The fishing net recycling sector involves various stakeholders, including fishermen, recycling companies, local authorities, and NGOs. Collaboration between these actors is crucial to creating a sustainable value chain. Initiatives such as municipal collection networks and public-private partnerships can facilitate the development of the sector and improve marine litter management. Finally, a factor that can facilitate the adoption of recycling and recovery policies for fishing materials is the implementation of the priorities of the European Fisheries and Maritime Fund, which encourages local communities to address the recycling and recovery of decommissioned/abandoned gear. The development strategy for the implementation of the project's pilot actions is fully outlined in the document Output 2.1 Marine litter reduction strategy.

6.1 SUMMARY TABLES

Table 3. Summary of the Pilot area Analysis

| Item | Pilot Area LP1 | Pilot Area PP2 | Pilot Area PP4 | Pilot Area PP5 | Pilot Area PP6 | Pilot Area PP7 |
|------------------|--|--|-----------------------------|--|---|------------------------|
| Pilot Area | Italy Acquatina di Frigole and Ionian Sea mariculture | Croatia Cetina river Croatia Split | Croatia Neretva river | Croatia Mali ston bay Dubrovnik – Neretva County | Italy San Benedetto del Tronto – Riserva Naturale della Sentina (AP) | Italy Venice Lagoon |
| Harbour analysed | Acquatina di Frigole (LE) | Brižine Fishing Port | Gradac; Trpanj; Klek; Blace | Luka port Blaževo port Brijesta port | San Benedetto del Tronto (AP) | Chioggia (VE) |



Table 4. Available quantities of dismissed net per year

| Available quantities of dismissed net in Nylon 6 (kg) | Pilot Area LP1 | Pilot Area PP2 | Pilot Area PP4 | Pilot Area PP5 | Pilot Area PP6 | Pilot Area PP7 |
|---|----------------|----------------|----------------|----------------|----------------|----------------|
| Nylon 6 Small scale fishery nylon gillnets | 1500-2500 | 800 | 880 | 53 | 400 | 450 |
| Nylon 6 Trawl Nets | // | 40 | // | // | 6500 | 20000 |
| Other Nylon Net Types | // | // | // | // | 600 | // |
| Total | | | | | | |
| | 2500 | 840 | 880 | 53 | 7500 | 20450 |

Table 5. Logistic management

| Characteristic | Pilot Area LP1 | Pilot Area PP2 | Pilot Area PP4 | Pilot Area PP5 | Pilot Area PP6 | Pilot Area PP7 |
|----------------------------------|-------------------|----------------|-------------------|----------------|----------------|----------------|
| Temporary storage area available | No suitable areas | Detected | No suitable areas | Detected | Detected | Detected |
| Access to the storage site | // | Granted | // | Granted | Granted | Granted |

Table 6. Organizational structure

| Characteristic | Pilot Area LP1 | Pilot Area PP2 | Pilot Area PP4 | Pilot Area PP5 | Pilot Area PP6 | Pilot Area PP7 |
|---|----------------|----------------|----------------|----------------|----------------|----------------|
| Presence of fishing associations/cooperatives | No | Yes | no | no | Yes | Yes |
| Nylon recycling companies operating in the area | Yes | Yes | no | no | Yes | Yes |



Table 7. Costs and sources of funding

| Characteristic | Pilot Area LP1 | Pilot Area PP2 | Pilot Area PP4 | Pilot Area PP5 | Pilot Area PP6 | Pilot Area PP7 |
|--|----------------|----------------|----------------|----------------|----------------|----------------|
| Access to EMFAF funds | Yes | Yes | Yes | Yes | Yes | Yes |
| Presence of local Flag (Fishery local action group) | Yes | Yes | Yes | Yes | Yes | Yes |
| Required human resources | 1 | 1 | 1 | 1 | 2 | 3 |
| Hours per month required to manage the collection center | 40 | 40 | 40 | 40 | 40 | 60 |

