

## Article

# Neglected and Underutilized Fish Species: The Potential Loss of Value in the Italian Context

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## Abstract

This study investigates Italian fishery discards through the lens of neglected and underutilized species (NUS). It estimates the potential loss of value (PLoV) to identify pathways for sustainable valorization under the European Union landing obligation (LO). NUS were selected through a stakeholder focus group. Data regarding landings and discards were collected for the period 2020–2022 within the Italian Ministry of Agriculture, Food Sovereignty, and Forestry (MASAF) database. Among the three years, fleets landed roughly 130,400 tons annually, worth about €700 million, while discarding around 6200 tons yearly. This corresponds to an average PLoV of approximately €21.5 million. Most of the discarded quantity and value is concentrated in a few species. Atlantic Horse Mackerel stands out, accounting for nearly one-third of discarded biomass and about one-quarter of total PLoV. In 2020 and 2022, its discards even exceeded reported landings. A conservative valorization scenario for this single species indicates potential revenues of up to €7.5 million per year. Overall, these findings suggest that targeted NUS valorization could represent a way to diversify seafood consumption, alleviate pressure on common stocks, and buffer fishers' incomes. This potential depends on ensuring traceability and safety, supported by pilots in processing, product development, and consumer acceptance.

**Keywords:** landing obligation; NUS; underutilized; market opportunity; circular consumption; policy



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## 1. Introduction

The growing demand for fish products is gradually increasing anthropic pressure on marine ecosystems. This trend is driven by various factors, including population growth, urbanization, demographic shifts, rising income levels, and changes in dietary preferences [1]. If not properly managed, the rising demand for fish products may lead to the overexploitation of aquatic resources, threatening biodiversity and the regeneration of

natural biomes [2–4]. Indeed, overfishing—defined as “when fish are captured at a faster rate than they can be replaced through reproduction, leading to a decline in yearly fish stocks” [5], p. 320—can rapidly disrupt the fragile balance established by millions of years of underwater evolution. This impact is intensified by climate change, alien species invasions, and other anthropogenic activities [6–8].

According to the FAO report “*The State of World Fisheries and Aquaculture*” [1], nearly 38% of global fish stocks are unsustainably exploited, whereas, based on the first recorded data, overfishing accounted for 10% as of 1974. Although the rate of overexploitation in the Mediterranean and Black Sea has shown signs of decline [9], these areas remain among the most overfished globally, with approximately 60% of fish stocks classified as being in critical condition [1].

Beyond species caught for direct human consumption, the issue of bycatch—referred to as “the inadvertent catch of organisms that were not specifically targeted by a fishing operation (for example, non-target fish species, marine mammals, seabirds) that are either discarded or landed for commercial sale” [10]—remains a significant concern, with inevitable negative impacts on marine ecosystems. Moreover, it is estimated that between 7 and 10 million tons of commercially caught fish are discarded each year worldwide [11]. Similarly, Gilman et al. [12] report that 10.8% of the total global catch, approximately 9.1 million tons, is discarded annually. The reason behind discards depends on several factors, including the survival rates of discarded species, the fishing methods employed (e.g., trawling), and the type of gear used (e.g., purse seine nets) [12,13]. At the European Union (EU) level, fish discards may also result from exceeding quota limits, catching undersized fish, failure to meet quality standards (e.g., damaged specimens), low market value, or legal prohibitions on the capture of specific species [11].

To avoid the practice of returning discards directly to the sea, which poses a threat to effective resource management and the sustainability of fisheries [14], the European Parliament and the Council of the EU established the Landing Obligation (LO) as part of the Common Fisheries Policy. The measure was formally introduced in 2015 under Regulation (EU) No. 1380/2013 [15], Article 15. The purpose of the LO is not only to reintegrate discarded resources into the market but also to encourage the adoption of more selective fishing practices that target only species compliant with established fishing regulations [16,17]. This objective also explains why the regulation took nearly four years from its adoption to become fully enforced in 2019 [18]. With limited exceptions, all catches of species subject to catch limits or minimum size requirements must be landed and deducted from the corresponding quotas [11]. Undersized fish that are caught and brought ashore should not be sold for direct human consumption but may instead be processed into pet food, fishmeal, pharmaceuticals, or dietary supplements [11]. Producer organizations have the duty to help fishers find suitable markets for undersized catches, ensuring these do not encourage demand for non-compliant fish [11]. Additionally, EU member states play a role in supporting fishers by facilitating the storage and distribution of undersized catches to appropriate industries [11].

To date, the effectiveness of the LO is still debated among academics. This debate highlights several issues, including the need for high levels of at-sea monitoring and effective control systems [19]. Other concerns include the challenges of adopting new selective fishing gear and the capacity to manage discards once landed [20]. Additional risks include food availability and security, as a reduction in landings for human consumption may occur due to undersized fish being counted against quotas [16]. Non-compliance also arises from the policy’s multilevel governance structure [18,21], as well as potential socio-economic damages resulting from increased costs, particularly for small-scale enterprises [17,21,22]. Indeed, this policy, while aimed at addressing a well-documented issue, could benefit

larger, more structured companies capable of covering the costs associated with adopting new technologies and equipment, to the detriment of smaller enterprises that are limited in their ability to invest in new equipment [23].

Despite this, issues related to the management of landed discards persist and require attention from multiple perspectives. Among the discards generated under the LO are unwanted catches known as neglected and underutilized species (NUS), also referred to as underutilized fish. Although there is no generally accepted definition of NUS [24], they are usually characterized as (i) species included in bycatches [25,26]; (ii) species rarely or never used for human consumption but instead utilized for other purposes such as fertilizer or bait [27]; (iii) species for which quotas and licenses are established but not fully exploited (i.e., quota limits are not reached) [27]; (iv) species not currently included in licensing frameworks but that could be harvested sustainably [27]; and, most importantly, (v) species underutilized due to low market demand [28].

These species, which often have little or no commercial value, could represent an alternative source of food for human consumption. Their valorization could positively impact fisheries sustainability by increasing fishers' incomes and diversifying consumer diets with nutritious, high-value seafood products [29]. Enhancing NUS consumption could help diversify consumer food choices, thereby alleviating pressure on heavily exploited stocks [30] and increasing the value of lesser-known species that are often under-consumed. Indeed, although the fish species available for human consumption far outnumber those of meat, actual consumption is often limited to only a few species. Moreover, the factors potentially underlying the restricted consumption of NUS may be their market availability [31], as these species may be more local than others, and unfamiliarity [32].

In this context, the present study aims to investigate fishery discards in Italy to assess the potential loss of value (PLoV) generated over the three years for which data are available from the Italian Ministry of Agriculture, Food Sovereignty, and Forestry (MASAF). Specifically, considering the growing demand for seafood, the study analyzes the availability of NUS discards and the associated PLoV to provide an overview of the current situation and the potential valorization by transforming these resources. Based on the findings, the study presents a set of considerations aimed at enhancing current LO implementation and discards management at both national and European levels.

## 2. Materials and Methods

### 2.1. Materials

#### 2.1.1. Definition Used

Given the various existing definitions of landings and discards (Table 1), this study acknowledges the diversity of interpretations among institutions. However, to ensure consistency with the data sources used, the definitions provided by MASAF have been adopted for both landings and discards. Specifically, the MASAF definition of landings was chosen because the dataset originates from this institution, ensuring coherence between data and terminology. The definition of discards refers to the portion of the catch that would generally have been returned to the sea prior to the regulation introducing the LO. Additionally, since one of the objectives of this study is to determine the annual PLoV generated by discards, the table also includes the definition considered most appropriate for this specific purpose.

Table 1. Definitions.

| Term                           | Definition   | Source  |
|--------------------------------|--|---|
|                                | Eurostat’s landings statistics relate to fishery products (product weight and value) landed by EU/EAA vessels on EU/EAA territory. Landings from non-EU/EAA vessels or landings outside the EU/EAA territory are excluded. Landlocked EU countries without a marine fishing fleet are not included.  | [33]  |
| Landings                       | Landings mean the initial unloading of any quantity of fisheries products from on board a fishing vessel to land in a given country, regardless of the nationality of the vessel making the landings, but also fishery products landed by the country’s vessels in non-EU countries. Landings are reported in net weight (tons) and in euros (€).  | [34]  |
|                                | According to Regulation 1224/2009 (EC) [35] and Regulation 2023/2842 (EU) [36], “landing” refers to the initial unloading of any quantity of fishery products from a fishing vessel to shore. Sampling is conducted for vessels under 10 m; for vessels over 10 m, data is obtained directly from logbooks completed by the fishermen and verified for accuracy by technical experts.  | Italian Ministry of Agriculture, Food Sovereignty, and Forestry (MASAF) (attached to the dataset) |
|                                | Discards, or discarded catch, is that portion of the total organic material of animal origin in the catch, which is thrown away, or dumped at sea for whatever reason. It does not include plant materials and post-harvest waste such as offal. The discards may be dead or alive.  | [37]  |
| Discards                       | Discarding is a term specifically used for catches of species that are not kept but returned to the sea.   | [10]  |
|                                | Discards are the quantities of fish thrown back and estimated based on biological sampling conducted following the Data Collection Framework (DCF). The reported discards refer exclusively to those related to fishing activities.  | MASAF (attached to the dataset)   |
| Potential loss of value (PLoV) | In this case, the loss of value is an economic indicator that quantifies the value (€) of potential losses generated by discards. It is calculated as the ratio between the number of discards (tons) multiplied by the annual market value per ton (€/ton), expressed in euros (€), for each species. This value reflects the potential economic loss due to the lack of commercial utilization of discards. It is essential to note that this estimate of loss of value assumes that the destination of the fish discards was not reported in the available data. Other methods of valorization, such as non-food uses (e.g., feed or fertilizers), have not been addressed. | Own elaboration   |

### 2.1.2. Dataset Used

The data used for this analysis were obtained from the public official secondary sources provided by MASAF. Access to these data can be requested directly from the Fisheries Directorate of the Ministry. The dataset (Table 2) includes information on the landing quantities (in tons) and commercial value (in euros) of 244 fish species caught in Italian waters, as well as the number of discards (in tons) recorded for 38 species. The analysis covers the three years for which MASAF data were available (2020, 2021, and 2022) as the LO entered fully into force in 2019, making 2020 the first year with complete recorded data. The MASAF database compiles the official landings and discard records collected under the EU Data Collection Framework (DCF), which integrates logbook data from vessels exceeding 10 m with biological sampling from vessels under this threshold. As such, it offers national-level coverage and aims to be representative of fishing activity in Italian waters.

**Table 2.** MASAF dataset variable overview.

| Column | Variable           | Description                             |
|--------|--------------------|---|
| 1°     | Year               | 2020, or 2021, or 2022                  |
| 2°     | FAO 3-alpha code   | Univocal code made of 3 capital letters |
| 3°     | Scientific name    | <i>Genus species</i>                    |
| 4°     | Commercial name    | 244 species listed                      |
| 5°     | Landing quantity   | Value in tons                           |
| 6°     | Commercial value   | Value in Euros (€)                      |
| 7°     | Discarded quantity | Value in tons                           |

## 2.2. Methods

### 2.2.1. Focus Group

After reviewing the literature and considering the lack of a unified definition of NUS [24], a focus group was organized with key stakeholders to define criteria for identifying potentially neglected and underutilized species. The focus group was selected as an effective approach for discussing concepts and terminology, illustrating scenarios, and determining the information participants needed to answer the assessment questions [38]. The focus group was held at the end of January 2024 and involved academic actors and other stakeholders, including processors and fishermen. Participants were selected as a convenience sample (non-probabilistic) based on their direct involvement with the topic under discussion. This approach enabled the inclusion of a diverse range of perspectives from various contexts, aligning with the focus group's objective of gathering a representative sample of stakeholder opinions and viewpoints [39]. The group size was determined based on literature recommendations, aiming for 6 to 10 participants, which is small enough to allow for a meaningful exchange of insights while being large enough to capture a diverse range of perspectives [40].

In the absence of sensitive topics or issues requiring individual exploration, this method was deemed more suitable than cognitive interviews. The selection criteria considered were the quantity of landings and seasonality, determined by the HelloFish database [41], and commercial value based on data from BMTI S.c.p.A. [42].

### 2.2.2. The Potential Loss of Value

As previously mentioned, the PLoV is an estimate of the value of discarded species, without considering their actual destination or end use. Therefore, this value does not account for how much of this discarded biomass is actually recovered or valorized for purposes other than food. To calculate the PLoV (€) of an individual species in a given year, the following equation was used:

$$\text{PLoV}_{i,x} = D_{i,x} \times V_{i,x} \quad (1)$$

where  $i$  represents the individual species,  $x$  the year,  $D$  the quantity of discards (in tons), and  $V$  the market value (€/ton). To determine the annual PLoV (€) for all species:

$$\text{PLoV}_x = \sum_{i \in S}^N (D_{i,x} \times V_{i,x}) \quad (2)$$

where  $N$  is the set of all fish species caught in Italy,  $i$  belongs to the group of fish species, and  $x$  indicates the specific year. The variables  $D$  and  $V$  refer, respectively, to the discarded quantity (tons) and unit value (€/ton). Finally, to calculate the total PLoV:

$$\text{TPLoV} = \sum_{x=1}^M \sum_{i \in S}^N (D_{i,x} \times V_{i,x}) \quad (3)$$

where  $M$  represents the total number of years for which data are available (in this case, from 2020 to 2022), and the other variables follow the same definitions as in the previous equations.

### 3. Results

#### 3.1. Focus Group Results: Species Identified as NUS

Based on the previously mentioned criteria in the methodology (quantity of landings, seasonality, and commercial value), seven species were identified as meeting the requirements in the Italian context: Bogue (BOG), Thinlip Mullet (MGC), Red Mullet (MUT), Common Pandora (PAC), Greater Forkbeard (GFB), Atlantic Horse Mackerel (HOM), and Stargazer (UUC) (Table 3).

**Table 3.** List of the neglected and underutilized species (NUS) involved in the study with their FAO 3-alpha codes and scientific names.

| Commercial Name         | FAO 3-Alpha Codes | Scientific Name            |
|-------------------------|-------------------|----------------------------|
| Bogue                   | BOG               | <i>Boops boops</i>         |
| Thinlip Mullet          | MGC               | <i>Liza ramada</i>         |
| Red Mullet              | MUT               | <i>Mullus barbatus</i>     |
| Common Pandora          | PAC               | <i>Pagellus erythrinus</i> |
| Greater Forkbeard       | GFB               | <i>Phycis blennoides</i>   |
| Atlantic Horse Mackerel | HOM               | <i>Trachurus trachurus</i> |
| Stargazer               | UUC               | <i>Uranoscopus scaber</i>  |

#### 3.2. Total Potential Loss of Value Results

Over the three years analyzed (see Table 4), the average quantity of landings in Italy was approximately 130,400 tons, corresponding to an average commercial value of around €700 million. During the same period, the average quantity of discards amounted to approximately 6200 tons, resulting in an average PLoV of €21.5 million. The year 2020 recorded the highest levels of both discards and PLoV, with nearly 7800 tons discarded, equivalent to just over €27.6 million in potential value lost. In contrast, 2021 reported the lowest number of discards, totaling 4076 tons.

**Table 4.** Total discards (tons) and potential loss of value (€) compared with total landings (tons) and value of landings (€) (Source: own elaboration on MASAF's data).

| Variable                               | Unit of Measurement | Year        |             |             |
|--|---------------------|-------------|-------------|-------------|
|  |                     | 2020        | 2021        | 2022        |
| Total landings quantity                | tons                | 130,087     | 136,380     | 124,670     |
| Total discarded quantity               | tons                | 7796        | 4076        | 6748        |
| Top 10 species discarded quantity      | tons                | 7211        | 3768        | 6672        |
| Total landings value                   | €                   | 642,450,657 | 736,071,856 | 719,650,989 |
| Total potential loss of value          | €                   | 27,622,430  | 14,747,383  | 22,060,876  |
| Top 10 species potential loss of value | €                   | 24,951,944  | 13,333,577  | 22,060,876  |

Focusing on the top ten discarded species (Table 4), their contribution to the total PLoV was 90.3% in 2020. This percentage increased slightly in 2021 (+0.1%) and rose significantly in 2022, reaching 98.4%. In terms of quantity, the top ten discarded species consistently accounted for more than 90% of total discards across all three years, with a peak of nearly 99% in 2022.

Only five out of the seven NUS appeared in the top ten rankings: HOM, PAC, BOG, GFB, and MUT. These species consistently ranked among the top ten both in terms of discard quantity and PLoV, confirming their significant impact relative to the 38 recorded species (see Table 5). HOM showed a dominant role, ranking first for both discard volume and PLoV in 2020 and 2022, and maintaining a top position in 2021. Although it dropped to eighth place in discard quantity that year, it remained among the top ten in terms of PLoV. In 2020, PAC ranked second for PLoV and fourth for the amount discarded. While its ranking dropped in both categories in 2021, it remained within the top ten. In 2022, ranked sixth in PLoV and eighth in discarded quantity. BOG demonstrated notable stability in discard quantities, maintaining third place in both 2020 and 2022, although it did not appear in the top ten in 2021. GFB emerged only in the last two years of the analysis, ranking sixth in PLoV and seventh in discarded quantity in 2021, and maintaining sixth place in PLoV again in 2022. MUT showed an increasing trend in discard importance. Starting from lower positions in 2020 (tenth in both discarded quantity and PLoV), it rose to fifth place in discard quantity and sixth in PLoV by 2022.

**Table 5.** Placings of the seven NUS based on the discarded quantity and potential loss of value.

| FAO 3-Alpha Codes | Placing 2020              |                             | Placing 2021              |                             | Placing 2022              |                             |
|-------------------|---------------------------|-----------------------------|---------------------------|-----------------------------|---------------------------|-----------------------------|
|                   | Discarded Quantity (tons) | Potential Loss of Value (€) | Discarded Quantity (tons) | Potential Loss of Value (€) | Discarded Quantity (tons) | Potential Loss of Value (€) |
| BOG               | 3°                        | 3°                          | NP *                      | NP *                        | 7°                        | 9°                          |
| MGC               | NP *                      | NP *                        | NP *                      | NP *                        | NP *                      | NP *                        |
| MUT               | 10°                       | 10°                         | 9°                        | 9°                          | 6°                        | 5°                          |
| PAC               | 4°                        | 2°                          | 10°                       | 7°                          | 8°                        | 6°                          |
| GFB               | NP *                      | NP *                        | 7°                        | 6°                          | NP *                      | NP *                        |
| HOM               | 1°                        | 1°                          | 8°                        | 10°                         | 1°                        | 1°                          |
| UUC               | NP *                      | NP *                        | NP *                      | NP *                        | NP *                      | NP *                        |

\* Not placed in the top ten.

In addition to the five highlighted NUS, other recurrently discarded species, such as European Anchovy (*Engraulis encrasicolus*), Mediterranean Horse Mackerel (*Trachurus mediterraneus*), European Hake (*Merluccius merluccius*), Deepwater Rose Shrimp (*Parape-naeus longirostris*), Shortfin Squid (*Illex coindetii*), European Pilchard (*Sardina pilchardus*), and Mantis Shrimp (*Squilla mantis*), were also observed. Still, they fall outside the scope of the present study.

### 3.3. NUS Potential Loss of Value

On average, the seven NUS investigated landed approximately 5870 tons per year, with a total annual commercial value of around €25.4 million (Table 6).

**Table 6.** NUS landings quantity and value per year (Source: own elaboration on MASAF's data).

| FAO 3-Alpha Codes | Landed Quantity (tons) |      |      | Value Landed (€) |            |            |
|-------------------|------------------------|------|------|------------------|------------|------------|
|                   | 2020                   | 2021 | 2022 | 2020             | 2021       | 2022       |
| BOG               | 791                    | 839  | 776  | 2,359,073        | 2,406,877  | 2,661,445  |
| MGC               | 1                      | ND * | ND * | 887              | ND *       | ND *       |
| MUT               | 3143                   | 3910 | 3020 | 14,022,747       | 17,711,154 | 14,781,226 |
| PAC               | 410                    | 535  | 410  | 2,847,556        | 4,060,396  | 3,649,571  |
| GFB               | 154                    | 254  | 282  | 787,070          | 1,272,155  | 1,350,030  |
| HOM               | 680                    | 1093 | 1012 | 1,540,184        | 2,520,450  | 2,439,627  |
| UUC               | 105                    | 109  | 86   | 591,489          | 725,864    | 561,681    |

\* Not defined.

Among them, MUT was the most landed species and the one generating the highest value over the three years, with an annual average of about 3400 tons and €15.5 million, representing more than 57% of the total landings and around 61% of the total value of the seven NUS. HOM followed with an average of 928 tons and €2.2 million, while BOG recorded an average of 802 tons and €2.5 million. Although PAC ranked fourth in landing volume (452 tons/year), it was the second highest in commercial value, averaging €3.5 million per year due to its relatively high unit price. GFB contributed an average of 230 tons and €1.1 million annually, while UUC accounted for 100 tons and just over €0.5 million. The presence of MGC was marginal, as only one ton was recorded in 2020, with no data available for the remaining years.

Overall (Table 7), HOM stands out as the most discarded species, accounting for the majority of the rejected biomass and over half of the total PLoV, with annual peaks significantly exceeding those of all other species. PAC ranks second in terms of total economic loss, despite its lower discard volumes, due to its considerably higher unit price (€/ton). BOG holds second place in terms of discarded quantity but drops to third in PLoV, indicating a relatively lower economic impact despite substantial volumes. MUT follows, showing intermediate levels in both discard quantity and potential value loss. GFB ranks last among the five, with considerably lower discard volumes and PLoV, as well as marked fluctuations across the years. No discards were reported for MGC or UUC during the period under consideration.

**Table 7.** Discards and potential loss of value per year (Source: own elaboration on MASAF's data).

| FAO 3-Alpha Code | Discarded Quantity (tons) |      |      | Potential Loss of Value (€) |         |           |
|------------------|---------------------------|------|------|-----------------------------|---------|-----------|
|                  | 2020                      | 2021 | 2022 | 2020                        | 2021    | 2022      |
| BOG              | 811                       | 80   | 68   | 2,420,211                   | 229,299 | 234,980   |
| MGC              | ND *                      | ND * | ND * | ND *                        | ND *    | ND *      |
| MUT              | 191                       | 119  | 154  | 854,227                     | 537,982 | 755,158   |
| PAC              | 435                       | 84   | 68   | 3,022,309                   | 639,908 | 604,505   |
| GFB              | 65                        | 146  | 12   | 333,093                     | 734,258 | 56,151    |
| HOM              | 3083                      | 136  | 3295 | 6,986,663                   | 312,891 | 7,941,093 |
| UUC              | ND *                      | ND * | ND * | ND *                        | ND *    | ND *      |

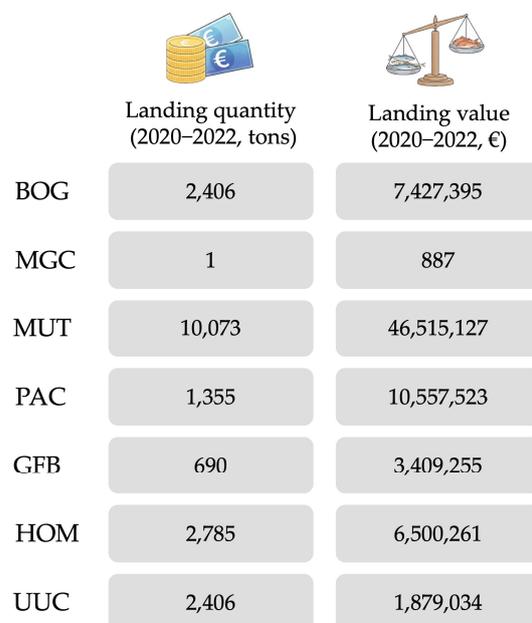
\* Not defined.

#### 4. Discussion

As of 2023, Italy ranks fourth in Europe in terms of value per quantity (€/ton) of fish landed [43]. The total value generated from landings amounted to approximately €642 million in 2020, €736 million in 2021, and €720 million in 2022 (Table 4). Of this total, the PLoV associated with discards was estimated at €27.6 million in 2020, €14.5 million in

2021, and €22.1 million in 2022, corresponding to 4.3%, 2%, and 3.1% of the annual landing values, respectively. In terms of quantity, discards were estimated to represent 6% of total landings in 2020, 3% in 2021, and 5% in 2022.

Regarding NUS, the total landings over the three-year period amounted to approximately 17,600 tons, with a value exceeding €76 million (Figure 1). Only five of the seven species were recorded among the landed discards, with HOM ranking first in two of the three years.



|     |  Landing quantity<br>(2020–2022, tons) |  Landing value<br>(2020–2022, €) |
|-----|---|---|
| BOG | 2,406   | 7,427,395   |
| MGC | 1   | 887   |
| MUT | 10,073  | 46,515,127  |
| PAC | 1,355   | 10,557,523  |
| GFB | 690   | 3,409,255   |
| HOM | 2,785   | 6,500,261   |
| UUC | 2,406   | 1,879,034   |

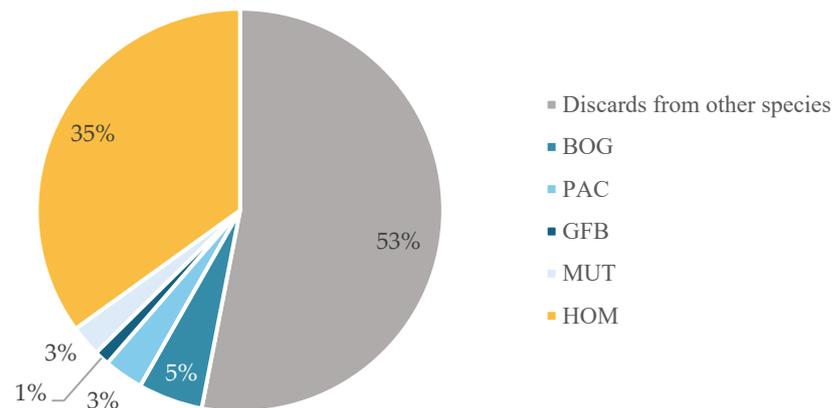
**Figure 1.** Total amount of landing quantity and value of the 7 NUS over the three years.

The combined PLoV of these five species was €25.7 million, corresponding to 8765 tons of discards. Of this, 60% of the total PLoV and 74% of the discarded quantity were attributed to HOM. Notably, the difference between the landed value and the PLoV generated by HOM was negative, amounting to €8.8 million. HOM landings generally exceed the consumption demand for this species [44]. The data from 2020 and 2022 highlight that discards exceeded landings by 450% and 325%, respectively, resulting in a cumulative PLoV of approximately €15 million. In 2020, the discarded volumes of BOG and PAC were 100% higher than their respective landings, leading to estimated losses of €2.9 million and €4.3 million, respectively. As for MUT, which ranked among the top ten most-landed species by quantity in Italy during all three years analyzed, discards over the same period resulted in a PLoV of €2.2 million. GFB appeared among the top ten most discarded species (by both quantity and PLoV) only in 2021. In 2020 and 2021, on average, discarded volumes were equivalent to about half of the landings, resulting in a PLoV of over €1 million across the two years. Among the five NUS with recorded discards, GFB generated the lowest cumulative PLoV over the three years. No discards were reported for MGC and UUC, making the valorization of these species through discards currently unfeasible. In the case of MGC, due to the morphological variability of “mulletts” along the Italian coastline, it is possible that data for this species were aggregated under other genera or collective categories. Accordingly, available records in the dataset were examined for related entries, including Mugilidae, *Mugil cephalus*, *Chelon labrosus*, *Liza aurata*, *Liza saliens*, and *Liza* spp.; however, no discard quantities could be attributed to any of these categories.

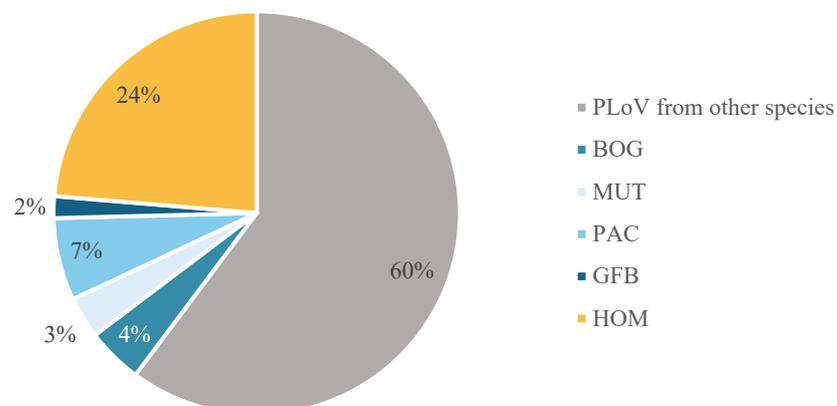
Overall, these five species play a significant role in the context of fishery discards in Italy, suggesting potential avenues for valorization strategies. In particular, they could be

reintroduced into the food system through direct human consumption, contributing to the diversification of seafood offerings and reducing market reliance on a narrow set of commonly consumed species. Moreover, their consistent presence among the top-ranking species (both in terms of discarded volumes and PLoV) underscores their relevance.

Figures 2 and 3 represent the aggregated data generated by the three analyzed years concerning the discarded quantity and PLoV (reported in Table 7). From the representation, it is possible to observe how the five NUS accounted for nearly half of the total amount of discards and 40% of the total PLoV. HOM alone represented a substantial portion, contributing 35% of the discarded biomass and 24% of the PLoV (Figures 2 and 3).



**Figure 2.** Discarded fish quantity (tons) in Italy and the share of the 7 NUS (total amount of the three years).



**Figure 3.** Potential loss of value (€) in Italy and the share of the 7 NUS (total amount of the three years).

#### 4.1. The Atlantic Horse Mackerel Case

Maximizing the recovery of discards generated by LO represents a key strategy for a sustainable fisheries sector and for reducing waste within the seafood value chain. Among the seven species analyzed in this study, the HOM emerged as the one with the highest discard volume and was therefore selected as a case for simulating the potential valorization of these discards.

Based on the average annual discard quantity recorded over the three years (2171 tons) and an average gross value of €2315 per ton, hypothetical scenarios were developed (Table 8) assuming recovery rates of 100%, 75%, 50%, and 25% of discards. Considering that the edible yield for direct human consumption can vary due to factors such as fish size and physical condition, three yield levels were assumed: 75%, 50%, and 25% of the recovered discards. Additionally, five price scenarios were defined: one corresponding to the average

gross value and four with incremental increases of 25%, 50%, 75%, and 100% above that value. The simulation indicates that, in the best-case scenario—where the entire average discard quantity is recovered, processed at a 75% yield, and sold at twice the average gross value—the potential annual revenue from HOM discards could exceed €7.5 million. Conversely, in the worst-case scenario, with only 25% of discards recovered, a yield of 25%, and a selling price equal to the gross value, the estimated annual valorization would be approximately €315,000.

**Table 8.** Valorization simulation for the Atlantic Horse Mackerel discards (shading intensity increases with value).

| Value                          | Quantity of Discards | Fillet Yields |           |           |
|--------------------------------|----------------------|---------------|-----------|-----------|
|                                |                      | 75% Yield     | 50% Yield | 25% Yield |
| Gross value (€)                | Total discards       | 3,786,805     | 2,524,537 | 1,262,268 |
|                                | 75% discards         | 2,840,104     | 1,893,403 | 946,701   |
|                                | 50% discards         | 1,893,403     | 1,262,268 | 631,134   |
|                                | 25% discards         | 946,701       | 631,134   | 315,567   |
| 25% more than gross value (€)  | Total discards       | 4,733,507     | 3,155,671 | 1,577,836 |
|                                | 75% discards         | 3,550,130     | 2,366,753 | 1,183,377 |
|                                | 50% discards         | 2,366,753     | 1,577,836 | 788,918   |
|                                | 25% discards         | 1,183,377     | 788,918   | 394,459   |
| 50% more than gross value (€)  | Total discards       | 5,680,208     | 3,786,805 | 1,893,403 |
|                                | 75% discards         | 4,260,156     | 2,840,104 | 1,420,052 |
|                                | 50% discards         | 2,840,104     | 1,893,403 | 946,701   |
|                                | 25% discards         | 1,420,052     | 946,701   | 473,351   |
| 75% more than gross value (€)  | Total discards       | 6,626,909     | 4,417,940 | 2,208,970 |
|                                | 75% discards         | 4,970,182     | 3,313,455 | 1,656,727 |
|                                | 50% discards         | 3,313,455     | 2,208,970 | 1,104,485 |
|                                | 25% discards         | 1,656,727     | 1,104,485 | 552,242   |
| 100% more than gross value (€) | Total discards       | 7,573,611     | 5,049,074 | 2,524,537 |
|                                | 75% discards         | 5,680,208     | 3,786,805 | 1,893,403 |
|                                | 50% discards         | 3,786,805     | 2,524,537 | 1,262,268 |
|                                | 25% discards         | 1,893,403     | 1,262,268 | 631,134   |

#### 4.2. The Need for a Valorization

Based on these findings, the need to valorize the potential losses associated with discarded fishery products has become evident. If not properly valorized, these discards not only represent a waste of natural resources but may also generate adverse socio-economic effects on fishing activities, particularly for small-scale fishers, due to the additional management costs incurred once the discards are landed [12].

In this regard, following the introduction of the European LO regulation, the literature highlights various potential applications for fishery discards, often framed within circular economy models. Among these, several bio-conversion and bio-refinery approaches have been explored to obtain raw materials for food and feed purposes [45]. These include the extraction of fish oils [46,47], fishmeal, minerals [47], hydrolysates [46], gelatin and collagen [47,48], as well as bioactive peptides and peptones [46]. A noteworthy example of an integrated food-and-feed chain is presented by Pérez-Martín et al. [49], who describe a pilot plant designed to first separate the edible parts from whole fish and produce a mince suitable for direct food use. The remaining biomass is then processed to extract and refine bio-compounds not intended for direct human consumption.

The products obtained through the studies mentioned above typically require industrial processing and technological investment, resulting in end products often in the form of minced fish suitable for items such as burgers or nuggets [49,50]. However, an alternative

approach could be the development of ready-to-eat products, such as dry-cured fish, which is raising market interest, especially among restaurants and small enterprises [51]. The term “dry-cured fish” refers to preservation methods that include drying, smoking (either hot or cold), brining or dry salting, grinding, and fermentation, either individually or in combination, excluding refrigeration and canning [52]. In this case, fish products can be placed in dedicated cabinets that allow for constant monitoring and regulation of the maturation environmental parameters [53], enabling processing without the need for industrial-scale operations and enhancing the value of the product in its natural form. Moreover, these types of products may facilitate consumer exposure to NUS, which may be overlooked due to their limited market appeal [28]. This could represent a win-win strategy, enabling fishers to add value to discards while offering consumers the opportunity to diversify their diets with high-nutritional-value seafood. By adopting this approach, fishing pressure on the small number of species that currently dominate diets in Europe [30] would be reduced, while also mitigating the risks associated with overly concentrated production and consumption systems [29].

Although studies specifically aimed at increasing the consumption and commercialization of underexploited fish species as well as the development of innovative products remain limited [29], some authors have highlighted concrete opportunities to expand the market for NUS, particularly among younger generations [24]. Further research is certainly needed to explore the potential for valorizing the five NUS identified with recorded discards, as these species may possess the necessary characteristics to become viable food products. More importantly, consumer studies should be conducted to assess acceptance and perceptions of such products, as demonstrated in the work by [50]. Additionally, when considering the consumption phase, benefiting from the principles of circular economy models [54,55], the valuation of NUS goes beyond the supply side and enters the realm of consumer behavior. Diversifying consumers’ current seafood diets to include NUS is a demand-side action that supports the closure of resource loops by ensuring the full utilization of marine biomass for human nutrition. Introducing new species to our tables will contribute to a more equitable distribution of fishing pressure and increased food system resilience by reducing reliance on a relatively narrow range of familiar species [56,57]. Awareness campaigns, transparent labeling, and the integration of NUS products into public food supplies (e.g., school and institutional catering) can act as pull factors, stimulating demand for these species and creating a feedback loop that encourages both sustainable fishing practices and innovative product development.

Finally, cooperation between fishers and industry is essential to facilitate the effective valorization of these discards, as also emphasized by [58]. Even when available in small quantities, discard management is crucial to improving the overall sustainability of the fisheries sector. In particular, small-scale fishing vessels and ports that may generate limited amounts of discards should have access to dedicated storage centers that comply with hygiene and food safety regulations. These facilities would enable the proper preservation of discards while awaiting collection and transport to processing or sorting centers, where they could be valorized. Without such infrastructure, these discards risk becoming waste material, resulting in unnecessary loss of valuable resources and increased disposal costs.

#### *4.3. Limits of the Study*

The first limitation of this study lies in the lack of information on the current destination or end use of these discards. This was not due to an omission by the authors, but rather to the absence, as far as our knowledge, of any available data source that tracks how these products are utilized. As such, it was not possible to determine to what extent these resources have been effectively valorized. Therefore, even if PLoV assumptions yield the

total economic loss estimation generated by the LO discards, the reported results may be overestimated. Additionally, inconsistencies were observed for particular species, such as MGC, which showed no landing data for 2021/2022, despite first sales data being available from the EUMOFA database [34]. This discrepancy may indicate incomplete datasets or inconsistencies in recording criteria. These gaps limit the ability to accurately analyze market dynamics, particularly for lesser-known species where precise identification can be challenging. These limitations further reinforce the concerns already raised by [58], as they call into question the quality and completeness of data, even when sourced from official secondary government repositories such as MASAF. This highlights the critical importance of robust data collection and its implications for subsequent interpretation and policy development, as current EMFAF policies emphasize as a key challenge across the different priorities for the period 2021–2027.

In addition to the limitations related to quantitative data, some considerations should be made regarding the focus group methodology adopted for identifying NUS [59]. As is typical with this qualitative approach, certain methodological constraints may have influenced the outcomes. These include limited time for in-depth discussion, potential conformity effects arising from group dynamics, and the influence of recording equipment or varying communication styles among participants. While these are well-known limitations inherent to focus group techniques, they should be taken into account when interpreting the prioritization of species, which is strongly based on the gathered perspectives of stakeholders.

## 5. Conclusions

This study provided an overview of the fishery discards generated across Italian territory. It offered a monetary quantification of the PLoV to highlight the market potential of landed discards under the LO. The results of this study provide an opportunity to enrich the discussion on underutilized species and represent a foundation for developing not only a structured database but also benchmarks for species that are still poorly tracked today. Moreover, a valorization simulation scenario for HOM species has been reported to highlight the potential of this NUS.

This study quantified the scale of landed discards in Italy and the associated PLoV, showing an average of €21.5 million per year from 2020 to 2022, with a disproportionate contribution from a small set of NUS. Among them, HOM alone accounted for roughly a quarter of total PLoV, and scenario analysis suggests that targeted recovery and processing could generate up to €7.5 million in annual valorization under favorable assumptions. Translating these findings into EU action aligns with the European Maritime, Fisheries and Aquaculture Fund (EMFAF) priorities, specifically the blue transition, the digital transition, and resilience. On the supply side, EMFAF co-finances remote electronic monitoring, digital traceability, and micro-cold chain in small ports, enabling safe valorization of landed discards and NUS, and encourages a supply chain approach as the valorization of these discards requires a multi-stakeholder flow capable of generating added value from natural resources that would otherwise risk becoming waste. On the demand side, to catalyze circular consumption, EU Member States and Producer Organizations should deploy co-funded market measures, such as standardized NUS definitions and labeling, pilot projects that introduce NUS to school canteens and a broader public, and retailer shelf-space commitments, to familiarize consumers with these species. Together, these instruments can reduce market concentration on a few species, unlock PLoV, and buffer fishers' incomes while monitoring safeguards ensure compliance with the LO and food-law boundaries.

Assessing NUS through targeted recovery and market integration should be viewed as both a production-focused strategy for a circular economy and a consumption-focused measure for a circular food system. In this way, the use of NUS aligns with the principles of Sustainable Development Goal 12, which addresses sustainable production and consumption in fisheries, closing nutrient and value loops in the seafood supply chain. By combining supply-side interventions, such as secure handling and processing infrastructure, with demand-side reactions that normalize NUS in consumer diets, fisheries can simultaneously reduce waste, deflate environmental pressure, and deliver socio-economic benefits [60]. This understanding renders the NUS evaluation a concrete example of circular food consumption in practice.

For future research, considering the PLoV identified, it will be crucial to investigate consumer perspectives, as the final actors in the valorization chain, and to assess the economic feasibility of processing discarded NUS for different uses [61]. To further explore this aspect, future studies need to investigate consumers' knowledge, attitudes, and willingness to try underutilized fish species, as well as their preferences regarding product types, preparation methods, and labeling information. Suitable methodologies for exploring consumer perceptions and preferences regarding these species may include stated preference techniques, pricing models, and sensory analysis models. These approaches enable the identification of the attributes considered most relevant, the definition of acceptable price ranges, and the estimation of consumers' willingness to pay.

Finally, and no less importantly, it is worth noting that NUS still lacks a clear and generally accepted definition. As previously highlighted by Davis et al. [24], the arbitrary use of the terms "NUS" or "underutilized" based solely on limited market visibility may lead seafood suppliers and advocacy groups to stimulate demand in an uncoordinated manner. This can ignore best management practices and ecological context, ultimately increasing fishing pressure on species that may already be overexploited or vulnerable to overfishing.

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## Abbreviations

The following abbreviations are used in this manuscript:

|       |   |
|-------|---|
| BOG   | Bogue   |
| EU    | European Union  |
| GFB   | Greater Forkbeard   |
| HOM   | Atlantic Horse Mackerel   |
| LO    | Landing obligation  |
| MASAF | Italian Ministry of Agriculture, Food Sovereignty, and Forestry |
| MGC   | Thinlip Mullet  |
| MUT   | Red Mullet  |
| NUS   | Neglected and underutilized species                             |
| PAC   | Common Pandora  |
| PLoV  | Potential loss of value   |
| UUC   | Stargazer   |

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