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Strandings of Tuna Remains Along Italian Coasts: Insights from Citizen Science into Potential Illegal Fishing

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Abstract

The Atlantic bluefin tuna (*Thunnus thynnus*) is a high-value species subject to strict catch quotas and seasonal closures in the Mediterranean Sea. However, detecting illegal, unreported, and unregulated fishing remains challenging, particularly for small-scale activities. The aim of this study is to investigate whether citizen-reported strandings of tuna remains along Italian coasts can provide potential indirect indications of illegal fishing activities. To address this question, we collected and verified photographic records of stranded tuna remains (e.g., skulls, vertebral elements, complete specimens) reported on social networks. A similar search was conducted for two other conspicuous fishes, the 'dusky grouper' (*Epinephelus marginatus*) and the 'greater amberjack' (*Seriola dumerili*), as controls. Thirty-two strandings of tuna remains were recorded, with no records of amberjacks and only one of dusky grouper. Most strandings involved tuna heads or neurocrania, some of which showed clear mechanical cuts indicating post-capture processing. Several remains were older and degraded, suggesting long-term persistence in the sea. Overall, our results indicate that citizen-reported strandings could provide low-cost, spatially broad potential indications of discards resulting from illegal fishing activities. Wider adoption of standardised public reporting could not only engage the public in marine conservation, but also provide valuable data for policymakers tackling illegal fishing and complement traditional fisheries monitoring.

Keywords: *Thunnus thynnus*; citizen science; tuna fishing; illegal; unreported; unregulated fishing; Mediterranean Sea

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1. Introduction

The Atlantic bluefin tuna (*Thunnus thynnus*) is one of the most valuable and iconic fishes exploited in global fisheries. This species is a long-lived, highly migratory predator with complex population structure, spawning aggregations, and trans-Atlantic movements, making its management particularly challenging [1,2]. The Mediterranean Sea is a primary spawning ground for the eastern stock of the species, with adults migrating from the eastern Atlantic to their natal areas including the Balearic Islands, the Tyrrhenian, the Ionian, and the Levantine seas [2–4]. In the Mediterranean, following decades of overexploitation and catch under-reporting by both professional and recreational fisheries, the fish has been subject to strict conservation and management measures [5].

In Italy, recreational fishing for bluefin tuna (BFT) is regulated under the national implementation of International Commission for the Conservation of Atlantic Tunas (ICCAT) recommendations. The authorised recreational season typically runs from 16 June to 14 October, in accordance with the European Council Regulation (EC) No 302/2009, repealed by Regulation No 2016/1627 and then by Regulation 2023/2053, which established a multiannual recovery plan for BFT in the Eastern Atlantic and Mediterranean [6–8]. Every year, a national decree establishes the quota of BFT assigned to each fishing sector; once this quota is reached, fishing is permitted only under a catch-and-release regime [9–11]. In practice, the recreational quota is usually reached before the official end of the season on 14 October, leading to an early suspension of catches. Notably, in the past five years (2021–2025), the recreational bluefin tuna season has closed in the first half of August [12–16]. Fishing outside the authorized periods is prohibited, and the presence of tuna remains on beaches during closed seasons may indicate illegal, unreported, or unregulated (IUU) fishing activities.

Within this regulatory framework, detecting illegal or unreported fishing is particularly difficult. Therefore, alternative data sources, such as citizen science observations, may provide complementary insights into an otherwise poorly detected phenomenon. Citizen science, the collection of scientific observations by members of the public, is a versatile approach for studying various aspects of environmental sciences. For example, it has been applied to track species distributions and detect invasive species [17,18], document wildlife mortality events [19], and monitor changes in phenology and abundance over large spatial and temporal scales [20,21]. When properly validated, such data can complement formal scientific surveys and expand geographic coverage at a very low cost [22].

This study examines (i) whether beach strandings of bluefin tuna along Italian coasts reported by citizen scientists are more frequent than those of other conspicuous fish species, and (ii) whether their temporal distribution is biased toward closed fishing periods, suggesting discards of illegally fished specimens. First, we outline the dataset of tuna strandings collected via citizen science. Then, we compare these strandings with control species, and examine their temporal distribution relative to open and closed recreational fishing seasons. We then interpret these results in terms of potential illegal fishing activities and discuss the implications and limitations of our approach. The results evidence the potential of involving citizen scientists to provide indirect indicators of possible IUU fishing.

2. Materials and Methods

2.1. Data Collection

To search for records of beached Atlantic bluefin tuna, a targeted search was conducted between July and August 2025 on Facebook, particularly in Italian marine biology and fishing groups. Keywords used for the search: ‘Thunnus’, ‘Thunnus thynnus’, ‘tonno’ (Italian for ‘tuna’). A similar search was performed on iNaturalist, inspecting all observations attributed to the Carangidae family. Each resulting post, photo or observation was carefully examined, and only those clearly showing remains attributable to *T. thynnus* were considered. For each of these, the author of the observation was privately contacted to clarify the date and locality of observation, to gather the best possible photographic material, and to ask for permission to use such data for the research. The photographic material was carefully examined to validate the identity of the species, evaluate which body parts were involved in the stranding (e.g., neurocranium/whole head/whole body), the integrity of the bones, and the presence or absence of soft tissues over the bones. Species identification was based on diagnostic osteological characters of Thunnus thynnus, following comparative anatomical descriptions (e.g., [23,24]) and the authors' direct experience with tuna skeletal material from previous examinations. Overall, 62 observers were contacted, and approximately 52% of them provided additional information and confirmation; only fully validated records were included in the analyses. All records were independently reviewed by two authors to confirm species identity.

A similar approach was used on the same platforms and groups for two control species, the dusky grouper *Epinephelus marginatus* and the amberjack *Seriola dumerili* (Figure 1) for the same period.

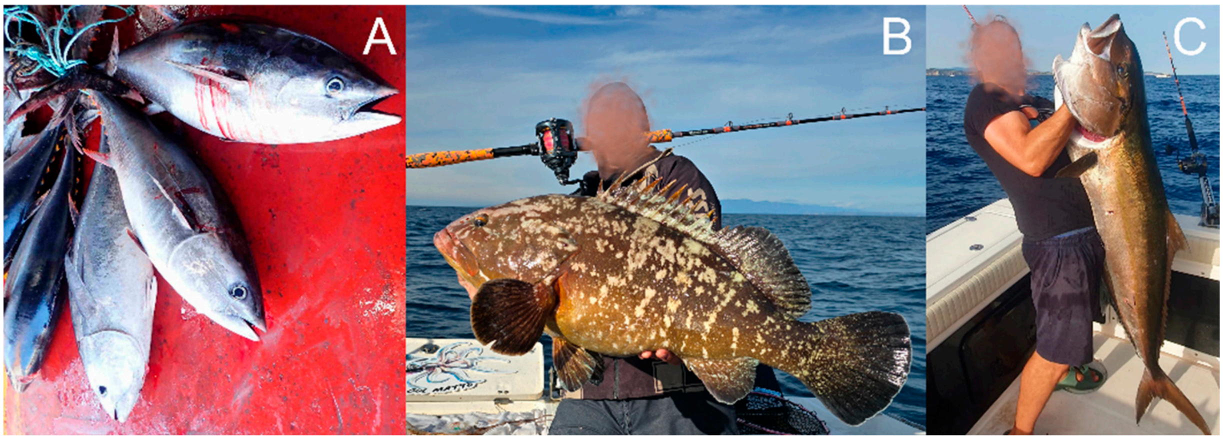

Figure 1. (**A**) *Thunnus thynnus* specimens; (**B**) *Epinephelus marginatus* specimen; (**C**) *Seriola dumerili* specimen. Photo by Francesco Tiralongo (**A**) and Mattia Giovannini (**B**,**C**).

These species were selected because they are large-bodied, common, and easy to recognize; besides, they are commonly targeted by fishermen. The study period considered included records from 1 January 2021 to 19 August 2025.

2.2. Statistical Analyses

To account for the different number of days in the open and closed seasons, a chi square test with an uneven expected distribution was used to compare the frequencies of tuna strandings between open and closed season, with expected values proportional to the number of days in each. To account for the postmortem interval occurring between the death of an individual and its stranding [25], the same analysis was repeated by shifting the open season window forward one week, that is, considering the open season as starting seven days after the official opening date and ending seven days after the official closing date.

Analyses were performed using R v. 4.4.2 (R Core Team, Vienna, Austria).

3. Results

The geographic distribution of *T. thynnus* remains recorded across Italian coasts is shown in Figure 2.

A total of 32 records of beached remains of *T. thynnus* were collected from citizen science sources. The records referred to different body parts: only four involved the complete or quasi-complete body of the fish, while the others concerned other bones, mainly neurocrania (Table 1). Multiple observations display sharp, mechanical cut marks, such as cut fins, vertebral bones, or flesh (Figure 3). Figure 3E shows a complete but filleted individual (cut marks are visible behind the pectoral fin).

Figure 2. Geographic distribution of the collected records of *Thunnus thynnus* and *Epinephelus marginatus* strandings along Italian coasts.

Table 1. Collected records of beached tuna remains along Italian coasts, with information on the date, site, and coordinates of observation (in World Geodetic System 1984, WGS84), bones integrity (intact/slightly damaged/broken), flesh persistence on the remains (no/few/complete), and source of the data (either iNaturalist–iNat or Facebook–Fb).

N	Date	Site	Latitude	Longitude	Element	Bone Status	Flesh Residuals	Source
1	13 May 2021	Marsala	37.792	12.432	Neurocranium, dentary bones, at least 14 vertebrae, cleithra, other unidentified bones	Slightly damaged	No	iNat
2	25 June 2021	Villafranca Tirrena	38.245	15.435	Caudal fin, caudal peduncle	Intact	Complete	Fb
3	13 July 2021	Cala Coticcio (La Maddalena)	41.218	9.486	Neurocranium, ~28 vertebrae	Slightly damaged	Few	Fb

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Table 1. *Cont.*

N	Date	Site	Latitude	Longitude	Element	Bone Status	Flesh Residuals	Source
4	31 July 2021	Lido delle Nazioni	44.735	12.244	Complete or quasi-complete skull	Slightly damaged	Few	iNat
5	27 August 2021	Syracuse	36.748	15.102	Neurocranium	Slightly damaged	No	iNat
6	23 September 2021	Bosa	40.338	8.407	Neurocranium	Broken	No	iNat
7	2 November 2021	Ravenna	44.540	12.280	Complete body without caudal fin	Intact	Complete	iNat
8	27 November 2021	Comacchio	44.695	12.241	Complete head	Intact	Few	iNat
9	5 October 2021	Portoscuso	39.211	8.370	Preopercular, opercular	Slightly damaged	No	Fb
10	11 May 2022	Viareggio	43.866	10.240	Neurocranium, first three vertebrae	Intact	No	Fb
11	21 September 2022	Pachino (SR)	36.678	15.052	Neurocranium and first six vertebrae	Intact	No	Fb
12	6 November 2022	Porto Potenza	43.367	13.696	Neurocranium, first two vertebrae	Slightly damaged	No	Fb
13	22 January 2023	Porto Garibaldi	44.682	12.243	Cleithrum	Broken	No	Fb
14	21 February 2023	Mazara del Vallo	37.650	12.589	Two neurocrania	Slightly damaged	No	Fb
15	4 March 2023	Porto Empedocle	37.290	13.514	Complete, beheaded body	Intact	Complete	Fb
16	6 May 2023	Alghero	40.576	8.314	Complete or quasi-complete head, first ~11 vertebrae	Intact	Few	Fb
17	3 June 2023	Gallipoli	40.060	17.991	Quasi-complete head	Intact	Few	Fb
18	19 July 2023	Villaputzu	39.539	9.640	Neurocranium	Slightly damaged	No	Fb
19	October 2023	Comacchio	44.666	12.252	Dentary bone	Slightly damaged	No	iNat
20	October 2023	Loano	44.125	8.260	Neurocranium	Slightly damaged	No	Fb

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Table 1. *Cont.*

N	Date	Site	Latitude	Longitude	Element	Bone Status	Flesh Residuals	Source
21	1 November 2023	Porto Potenza	43.375	13.692	Dentary right bone	Slightly damaged	No	Fb
22	26 December 2023	Lido di Spina (Comacchio)	44.651	12.256	Neurocranium, posttemporals, other head bones, complete or semi-complete dorsal spine	Intact	Few	Fb
23	1 January 2024	Lido Estensi (FE)	44.669	12.252	Neurocranium, 4 vertebrae, posttemporals, other head bones	Intact	Few	Fb
24	20 February 2024	Minturno	41.241	13.733	Complete or quasi-complete head	Slightly damaged	Few	Fb
25	17 June 2024	Carloforte	39.167	8.308	Complete or quasi-complete body	Intact	Few	iNat
26	October 2024	Mola di Bari	41.068	17.079	Last three vertebrae	Slightly damaged	No	Fb
27	4 December 2024	Minturno	41.224	13.761	Complete head	Intact	Few	Fb
28	10 December 2024	Giulianova	42.758	13.969	Neurocranium, first three vertebral bones	Slightly damaged	No	Fb
29	24 February 2025	Sant'Antioco	39.059	8.477	4 caudal vertebrae	Intact	No	Fb
30	18 April 2025	Cala Moresca (Capo Figari)	40.987	9.647	One vertebral bone	Slightly damaged	No	Fb
31	14 June 2025	Castelvetrano	37.582	12.862	Complete head	Intact	Few	iNat
32	20 June 2025	Capaccio Paestum	40.462	14.957	Complete, filleted body	Intact	Few	iNat

Fifteen of the collected records reported the presence of soft tissues on the remains, while 17 involved bones completely cleaned of flesh. In several cases (16 records), the bones appeared at least partially damaged, potentially indicating a long post-mortem persistence. No records were found for the greater amberjack (*S. dumerili*), and only one was found on iNaturalist for the dusky grouper (*E. marginatus*).

The monthly distribution of BFT records, pooled across the five years (2021–2025), is shown in Figure 4.

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Figure 3. Some of the collected records, numbered in Table 1 as n. 2 (**A**), 8 (**B**), 17 (**C**), 31 (**D**), 32 (**E**). Red arrows indicate cut marks.

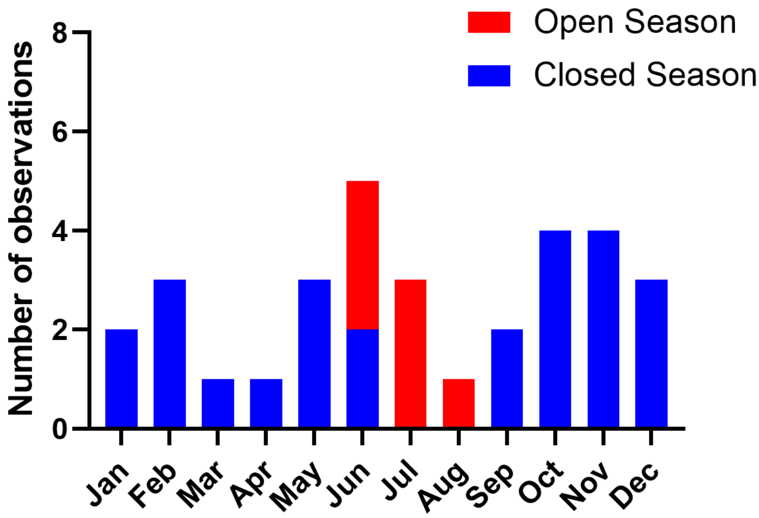

Figure 4. Monthly distribution of tuna strandings observations pooled across the five years 2021–2025, from 1 January 2021 to 19 August 2025.

The chi-square test with uneven expected distribution showed no significant difference between open and closed seasons ($\chi^2 = 0.27$, df = 1, $p = 0.60$). The second test, repeated by shifting the open season forward by one week, also yielded a non-significant result ($\chi^2 = 0.21$, df = 1, $p = 0.65$). Nevertheless, given the limited sample size, the tests had low statistical power, and the analyses should be interpreted as exploratory only.

The complete dataset, including date, location, number of specimens, body parts observed, and presence or absence of soft tissue, is provided in Table 1.

4. Discussion and Conclusions

The presented dataset indicates a clear asymmetry: beach-cast remains attributable to BFT are documented far more often than for the two control, conspicuous, common and commercially relevant coastal species (*E. marginatus* and *S. dumerili*). This pattern is consistent with a species-specific fishing activity and post-capture processing rather than a generic 'big fish' beaching bias. Although strandings can result from natural mortality and predation, the frequent presence of clean cuts and decapitations (Figure 3, Table 1) is difficult to reconcile with purely natural causes. Indeed, this suggests retention of edible portions and subsequent discard of less valuable parts, likely by recreational fishers. However, it is impossible to exclude that some of the records may originate from discards of entire specimens as bycatch from professional activities targeting other fish species.

It is important to recognise that stranded material usually represents only a fraction of what is discarded at sea [26,27]. Carcasses that sink rapidly or drift offshore rarely reach the shore, meaning that the visible strandings are probably only a small portion, the tip of a much larger iceberg. It is reasonable to think that many more tuna carcasses might be lying on the seabed, potentially concentrated near fishing grounds or where underwater currents carry them.

The lack of statistical significance in the results of the two chi-square tests (standard and shifted period) may be due to various factors. First, even during the open season, beach-cast remains might also originate from illegal fishing, for example, when the number of specimens captured exceeds the single one permitted per sea trip [6]. Second, our approach relies on opportunistic, citizen-generated content, where observation effort is uneven across space and time [28,29]. A seasonal bias in coastal use (i.e., more people on beaches in June–August) probably resulted in more records in the open fishing season. Indeed, a large peak in observation is evident in June (Figure 4), as tourists begin to arrive at the beaches. An additional source of uncertainty involves postmortem intervals and carcass persistence that can blur the exact timing of the death and make species-level identification challenging.

Citizen-reported strandings are not intended to replace traditional fisheries monitoring, and direct indicators of illegal fishing, such as vessel monitoring systems and onboard inspections remain essential for fisheries management [30]. Nevertheless, citizen science data provide low-cost indicators that can flag suspicious events and help prioritise patrols or targeted checks, complementing traditional approaches. While citizen data alone does not prove illegality, it can help direct limited enforcement resources. In this case, the preponderance of tuna remains compared to the other two species, along with the mechanical processing marks, suggest discards of illegally retained fish, which can occur in both the open and closed fishing seasons, and which may warrant closer inspection by authorities. Future implementations of standardised public reporting protocols, including minimum photographic requirements and basic metadata, could enhance the applicability and usefulness of citizen-reported strandings.

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Abbreviations

The following abbreviations are used in this manuscript:

BFT	Bluefin tuna

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