New historical data for long-term swordfish ecological studies in the Mediterranean Sea

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15   **Abstract.** Management of marine fisheries and ecosystems is constrained by knowledge based on datasets with limited temporal coverage. Many populations and ecosystems have been perturbed long before scientific investigations have begun. This situation is particularly acute for the largest and commercially most valuable species. We hypothesized that historical trap fishery records for bluefin tuna, *Thunnus thynnus*, could contain catch data and information for other, bycatch species, such as swordfish, *Xiphias gladius*. This species has a long history of exploitation and is presently overexploited, yet indicators

20   of its status (biomass) used in fishery management only start in 1950. Here we examine historical fishery records and logbooks from some of these traps and recovered ca. 110 years of bycatch data (1896-2010). These previously-neglected, but now recovered, data include catch dates and amounts in numbers and/or weights (including individual weights) for the time period before and after major expansion of swordfish fisheries in the Mediterranean Sea. New historical datasets such as these could help understand how human activities and natural variability interact to affect long-term dynamics of this species.

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1 Introduction

Marine populations, species and ecosystems have been exploited for goods and services for long periods of time before scientific records of this exploitation are available. The written scientific record of changes in such populations and systems
30   can, and does in many cases, underestimate the degree to which society has impacted abundances, sizes, diversity or ecosystem functioning (Fortibuoni et al., 2010; Lotze et al., 2014; MacKenzie et al., 2011; Pauly, 1995). Consequently, sustainability objectives and actions based on short contemporary time perspectives (e.g. 2-3 decades, as is typical for many marine ecological time series) may be an insufficient basis on which to make management decisions regarding recovery to former states (Caswell et al., 2020; Engelhard et al., 2016; Jackson et al., 2001).
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Time series length has other implications for ecological understanding and management, aside from those outlined above. Short time series may be insufficient to allow diagnosis and attribution of the causes of changes in their dynamics. Given that many of the changes in marine ecosystems are consequences of multiple drivers operating at multi-annual or multi-decadal time scales (Daskalov et al., 2007; Lotze et al., 2014; Piroddi et al., 2017; Reusch et al., 2018), and that many of these changes
40   can overlap in time, a short time series based on 2-3 decades of observations will make it difficult for scientists to resolve which drivers have led to changes. Consider for example, a system (e. g., population, species, food web, ecosystem) which has experienced increases in fishing effort over most of the 20th century; at the same time the system might also have been perturbed by other drivers such as eutrophication, introduction of non-native species, and increasingly by climate change. A time series lasting 2-3 decades is unlikely to resolve which of these drivers have most influenced the dynamics of the response.
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This situation applies to many fish populations in the Mediterranean Sea, where available time series are generally relatively short (Ferretti et al., 2015; Fortibuoni et al., 2010). Furthermore, many of the stocks are overexploited, even based on the relatively short time series which are available (Cardinale et al., 2017). One such stock is the swordfish, whose available biomass time series starts in 1985 (ICCAT, 2019), and for which officially reported catch data for many countries start only
50   in the 1950s (Spain) or 1960s (e. g., Italy, Greece) (ICCAT, 2020).

This species has however been exploited since antiquity, at least in some parts of the Mediterranean. Harpoon fishermen have been catching swordfish in the central Mediterranean (Strait of Messina) since millennia (Battaglia et al., 2018; Ward et al., 2000), and some swordfish bones dated from the 4th-10th centuries AD have been found in archaeological sites in Istanbul
55   (Yuncu, 2017). Officially reported catch data for some countries are available since 1950, with reporting levels increasing over time (ICCAT, 2020). The exploitation sharply increased during the 1960s-1980s when new gears and deployment strategies were implemented, including longlines and driftnets. Following these changes, reported landings increased from a few 100 t/year in the 1950s to ca. 15,000 t/year in the early 1980s (ICCAT, 2019). Despite the implementation of several technical measures to preserve the resource, the stock is now currently considered to be overexploited and to have a biomass which is
60   72% of the long-term sustainable level of biomass which could support maximum fishery yield (i.e., Bmsy) (ICCAT, 2020).

However, the current time series of biomass estimates (1950-2018) and associated fishery-related reference points are uncertain, particularly before 1985 when fishing effort and other biological data is limited (ICCAT, 2020). As with many other fish stocks, the length of the available biomass and catch time series for Mediterranean swordfish limits understanding of
65   longer-term dynamics and drivers of change (e. g., exploitation, low-frequency climate variations such as the Atlantic Multidecadal Oscillation), which may have initiated before biomass time series begin or which contain too few cycles of variability for detection. New data sources are needed to improve estimates of historical states and ecological understanding of long-term dynamics (Damalas et al., 2015). Such data sources could include information about biomass and lifehistory properties such as sizes, growth rates, distributions and migration behaviour.

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Here we propose that additional catch data for swordfish from earlier time periods than 1950 may be available in presently overlooked or neglected data sources. One such source could be the trap records from the bluefin tuna fishery. This species has been caught in coastally-deployed traps for centuries at many locations around the Mediterranean Sea (Addis et al., 2008; Ambrosio and Xandri, 2015; Ravier and Fromentin, 2001). These traps potentially catch other species as bycatch, and in

75   numbers which could provide new ecological insights. Here we provide new data on catch amounts, fishing effort, and individual size which can be used to derive new understanding of swordfish ecology in the Mediterranean Sea and how it is impacted by multiple drivers over multi-decadal time scales. The data recovered here can be used in statistical analyses and ecological interpretations in new investigations (MacKenzie et al., 2021b).

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2 Methods

2.1 General description of traps and fishing methods:

Coastally-deployed traps have been used for centuries to capture bluefin tuna while migrating to or from spawning areas in

85   the Mediterranean Sea (Addis et al., 2008, 2012; Ambrosio and Xandri, 2015; Ravier and Fromentin, 2001). Most of these traps are no longer in operation; to our knowledge only one is still operational (Addis et al., 2012). Although the traps were designed to target bluefin tuna, they and other similar smaller traps in the Mediterranean do catch other migratory species such as smaller tuna species (e. g., bullet tuna, bonito) and elasmobranchs (Britten et al., 2014; Cattaneo-Vietti et al., 2015; Storai et al., 2011). Some reports also mention bycatches of swordfish (Ambrosio and Xandri, 2015; ICCAT, 2020;

90   Rodríguez-Roda, 1964), but the quantities and sizes have so far not been compiled or analysed; consequently the potential value of the traps for generating new insights to long-term dynamcis of swordfish ecology is unknown. Here we hypothesize that these traps also caught swordfish in amounts that can generate new ecological knowledge.

These artisanal bluefin traps have a similar design, which has changed very little over time (Addis et al., 2008, 2012; Ambrosio and Xandri, 2015; Ravier and Fromentin, 2001). This similarity of gear technology in time and space facilitates

95   comparison of catches over time and among locations. Detailed description of the gear design and operation are available in literature (Addis et al., 2008, 2012; Ambrosio and Xandri, 2015). Because of the stable technology, the traps can be considered to be a standardized sampling device within sites (i. e., over time) and among sites (Addis et al., 2012). The general trap design consists of a long "tail" or fence which guides migrating fish to a series of chambers or rooms, known in Italy as the "castle". The traps were typically deployed by having the long tail portion oriented perpendicular to the shore;

100   the castle portion was at the offshore end of the tail. Water depths at the location of the castle or room portion of the trap were ca. 30-50 m. Differences among areas or over time were generally related to the mouth position of each trap, which was adjusted in relation to several local factors (e. g., bathymetry, and wind and current conditions) and decisions of the trap manager.

Fish swimming alongshore would then be intercepted and met by the tail of the trap, swim along it and eventually enter the

105   rooms of the castle. The tail was ca. 2 km long, and the mesh size (stretched) was 25 cm (Addis et al., 2008). A visual schematic of the usual deployment position relative to the shore and migration pattern is available in the literature (Addis et al., 2008). Details of the sizes and mesh sizes and deployment locations for the specific traps considered in this study are summarized in Table 1.

110   Table 1. Properties and deployment details of bluefin tuna traps considered as sources of swordfish bycatch data in this study.

Property↓	Location				
	Milazzo	Favignana	Formica	Portoscuso	Capo Passero
Latitude; longitude	38 deg., 14 min. N; 15 deg., 13 min. E	37 deg. 56 min. N; 12 deg., 19 min. E	37 deg., 59 min. N; 12 deg., 25 min. E	39 deg., 14 min. N; 8 deg., 22 min. E,	36 deg., 41 min. N; 15 deg., 9 min. E
Number of rooms	5-7	7-8	7-8	5	unknown
Tail length (m)	2000	1450	1200	2500	1600
Depth at rooms (m)	30	29-32	37-41	35	46-50
Cross orientation	NS	variable	variable	NW-SE	EW
Mouth position	SE	variable	variable	SE	variable
Mesh size	25	-	-	25	-
Bottom substrate	sand	rock/sand	rock/sand	sand	sand/rock

Our study is therefore an exploratory data recovery investigation to evaluate the potential that these traps can provide new ecological and fishery-relevant data for a non-target species. This potential has so far not been widely considered or
115   recognized.

2.2 Data recovery and compilation:

Bluefin tuna traps have been deployed at many locations in Italy, as well as other sites in the Mediterranean Sea and northeast Atlantic (Morocco, Portugal, Spain) (Ambrosio and Xandri, 2015; Ravier and Fromentin, 2001). The criteria we used to select trap sites for data recovery included proximity to a major spawning area to which swordfish should migrate
120   annually (thereby increasing the probability that swordfish might be caught), productivity and longevity of the trap deployment for the target species (bluefin tuna), and completeness of the data records (e. g., number of years when records were available, presence of additional data such as dates and sizes of the catch). The spawning time for swordfish in the Mediterranean, and in particular in the Tyrrhenian Sea is June-July (Romeo et al., 2009b), and therefore overlaps with that of bluefin tuna in the same region (June-July; (Mather et al., 1995)). The timing of tuna trap deployment therefore is not only
125   suitable for capturing migratory bluefin tuna, but hypothetically also for swordfish.

The sites chosen for our investigation were on Sicily (Milazzo; Favigna and Formica, hereafter referred to as F+F; Capo Passero; Fig. 1) and Sardinia (Portoscuso). The three Sicilian locations cover the northeast, southeast and western corners of the triangular-shaped island, and trace the potential migration route of swordfish to and from the spawning area. We selected a trap location in Sardinia (Portoscuso) because this is the only bluefin tuna trap still active in the entire

130   Mediterranean Sea and gives us the opportunity to study dynamics of the species in the most recent time period. The four
      traps therefore cover a relatively wide area approaching a major spawning area in the Mediterranean Sea (Abid and Idrissi,
      2006; Romeo et al., 2009b). As a result, the traps and the spawning area are potentially visited by swordfish from a large
      part of the Mediterranean Sea (i. e., immigrating from both within and outside Italian and EU waters towards this spawning
      area).
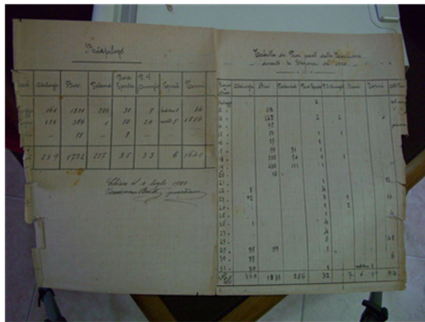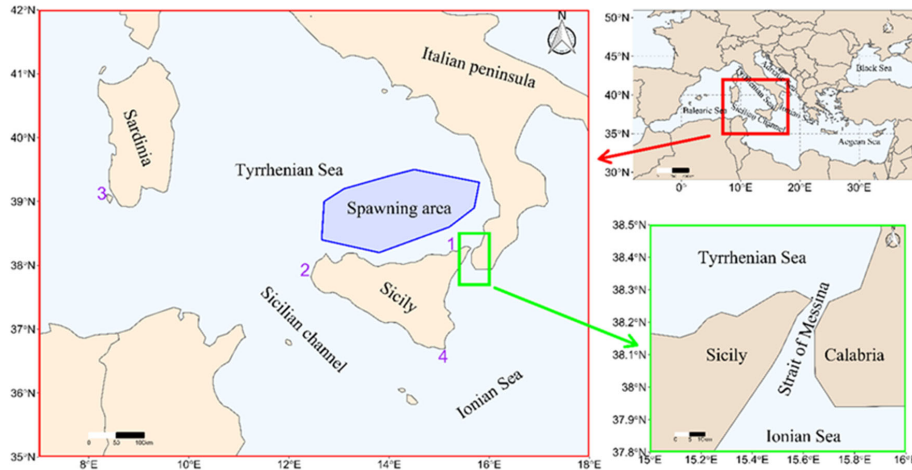
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Figure 1. Map showing locations of bluefin tuna traps whose swordfish bycatch data were retrieved from historical fishing
reports and accounts. Blue area on map indicates the approximate location of the swordfish spawning area. Photos below the
map show examples of pages from the fishing record books for the Milazzo trap.

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      The trap location at Favignana and Formica contains two traps located ca. 10 km from each other. There were separate catch
      records in numbers for each trap for many but not all years; for example during the 1970s, the records do not specify from
      which trap the catches were made but only present the sum caught (in numbers and weight) by the two traps. It is not
      possible to identify which trap caught the swordfish for such years. Inspection of the raw time series of catches for each trap
145   showed that the traps were nearly always checked or emptied on separate days (i. e., there were < 10 days when swordfish
      were reported to have been caught on the same day at both traps; however on those days, only trap-specific catch numbers,
      but not weights, were presented.) The compiled dataset includes the data separated by site where this is possible; in cases
      where the site-specific data is not available, the sum is given under the site name "FavignanaFormica" in the dataset.

We extracted data from historical reports, archives and company accounts for the 4 traps (Fig. 1). The data extracted were
150   the catches in numbers and/or total weights on each day when the trap was emptied during the fishing season. Traps were
usually deployed from approximately April – late August or early September but varied depending on year and location.
Once deployed, traps were usually emptied 1-2 times per week, with frequency increasing during the summer to 2-3 times
per week. The swordfish data we extracted are therefore bycaught individuals.

The traps used in Italy were similar to those deployed in other Mediterranean and east Atlantic tuna trap fisheries (Addis et
155   al., 2008; Ravier and Fromentin, 2001). Those which are the basis for this investigation are similar in size and mesh size
(Table 1); neither of these properties have changed during the period of our study (Addis et al., 2008). When swordfish
were caught as bycatch, the numbers and/or weights were recorded.

2.3 Recovery and compilation of data (catches in numbers and weights; fishing effort; fishing dates):

160   The data were available in company records and logbooks. The data were handwritten for each catch day and we copied and
entered the data into spreadsheet files for subsequent data analysis and interpretation. Examples of the handwritten
documentation from two of the record books are shown in Fig. 1.

We extracted the number and weight of swordfish caught for all days available in these records. This enabled us to produce
a catch time series for each year for each site. An annual time series consisted of the catches in numbers and or weight on
165   each day during a given year's fishing season.

3 Results

The reports and documents contained bycatch data in numbers and/or weights for many years and usually resolved at the daily
time scale (i. e., catches made on single days throughout the fishing season). The temporal coverages (start and end years)
170   only partly overlapped among the four trap sites (Fig. 2). Highest inter-annual overlap was with the Milazzo and F+F traps;
in contrast the Portoscuso trap had little overlap with any other trap. Seasonal coverage was similar for the three traps at
Milazzo, F+F and Portoscuso; the trap at Capo Passero was deployed and operated later in the summer than the three other
traps (Fig. 2).
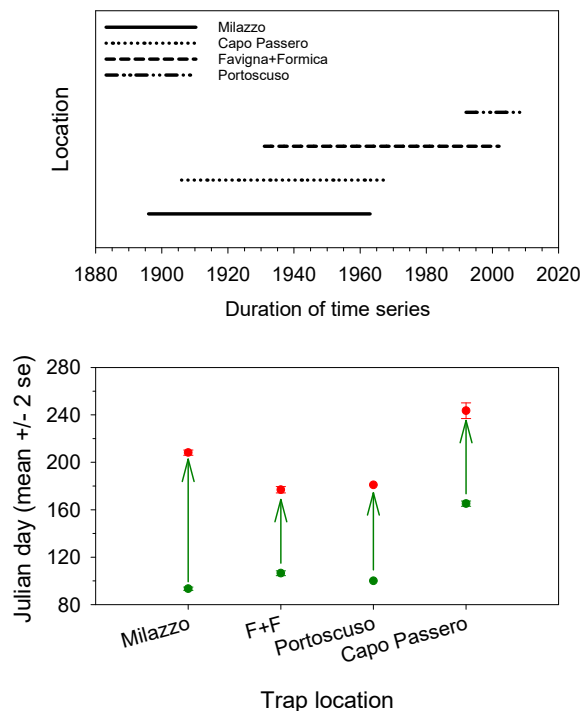
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Figure 2. Summary information for temporal data availability of swordfish caught as bycatch in bluefin tuna traps in Italy. Top panel: years for which data are available (including gaps); lower panel: the mean ($\pm$ 2 standard errors) start and end dates of fishing within a year at each of the four sites where traps were deployed.

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Metadata for the recovered data are presented in Table 2.

Table 2. Summary of swordfish bycatch and size data recovered from 4 bluefin traps in Italy.

| Property	Milazzo	F+F	Portoscuso	Capo Passero	All sites
Time period of data available (including missing years)	1896-1963	1931-2002	1992-2010	1906-1968	1896-2010
Number of years with data available	43	55	14	19	114
Number of daily catch records (nos. and group or individual weights)	4706	1016	743	140	6605
Total number of swordfish caught	5119	1670	744	652	8185

Mean start and end date of fishing season; mean duration in days	98, 208; 115	106, 177; 70	100, 181; 81	165, 244; 78	98, 244; 86
Number of individually-weighed swordfish	0	706	815	71	1592

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Weight data were available for most traps but at various levels of resolution and for differing numbers of years. In one trap (Portoscuso), each individually captured swordfish was weighed. In other locations (e. g., Favignana, Formica, Capo

190   Passero), only group weights with numbers caught for each day were available; we used these data to calculate a daily mean weight. In another site (Milazzo), group weights and group numbers were available by month, and only for a small number of years (1896-1901) (MacKenzie et al., 2021a); no weight data at any level of aggregation was available after 1901 for this site.

The data have been compiled into three datasets (see Section 5). The largest dataset contains the daily-recorded catches in

195   numbers and/or weights for all four trap sites (MacKenzie et al., 2021c). Individual data records in this dataset consist of the trap location and relevant fishing and catch information. This includes the date and location (name and latitude-longitude coordinates) of the catch, how many swordfish were caught and in some instances how much they weighed. In some cases, the individual swordfish was weighed, but in most instances, only a group weight is available on a given fishing day. However, even at sites where only group weights were measured, there were many days when only single swordfish were caught. As a

200   result, it was possible to compile and assemble a data set of 1592 individually-weighed swordfish during the time period covered by these trap data (Table 2); further details of the individual weights and their variability are presented elsewhere (MacKenzie et al., 2021b).

205   Figure 3 shows an example time series of catches during a single year from one of the sites. These can be summed to derive annual total catches. In most locations and for most years, the date of first and last gear deployments were available and have been stored in a separate database (MacKenzie et al., 2021d); these dates can be used to evaluate whether length of fishing season influenced the annual numbers of swordfish caught within each location and across locations throughout the time period of our study (1896-2010). The duration of fishing season and the catch data allows calculation of indices of

210   annual catch-per-unit-effort (CPUE) in the number (or biomass) of individuals caught per day during the fishing season. The inter-annual variability in the cpue can be compared among years and sites. The data among sites can be combined into integrated indicators of abundance (MacKenzie et al., 2021b).
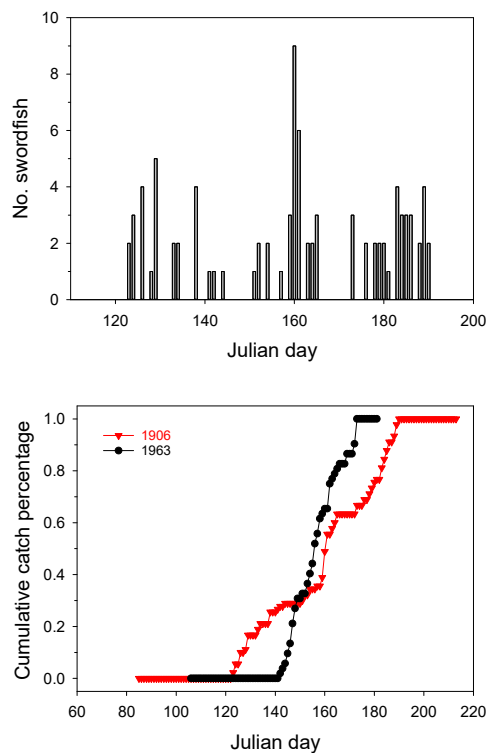
215   Figure 3. Examples of swordfish bycatch data extracted from bluefin tuna trap recrods. These data are from the trap located in Milazzo (Figure 1). Top panel: bycatches on each day during the fishing season of 1906; lower panel: the cumulative catch percentage throughout the fishing season of 1906 and for comparison with 1963.

Most of the swordfish caught in these traps were 20-40 kg, although several larger individuals were commonly caught
220   (MacKenzie et al., 2021b). Some representative sizes of individually-caught swordfish are shown in Fig. 4.
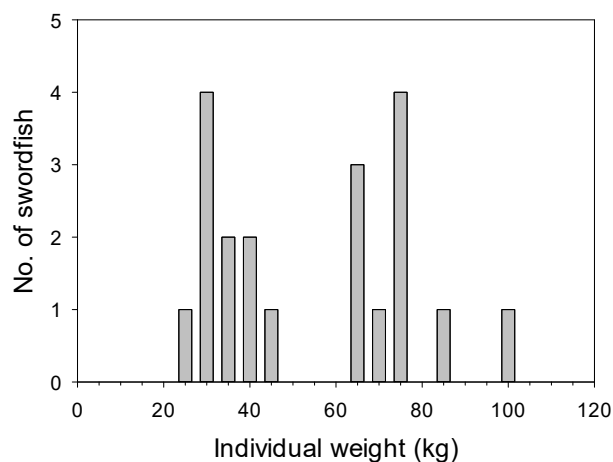
Figure 4. Example of individual weights of swordfish caught as bycatch in bluefin tuna traps located at Favignana + Formica, Italy. These data are for the 20 swordfish caught on 20 separate fishing days in 1946.

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4 Discussion

These newly-recovered historical data represent catches made by the same gear over many years and in different locations. As described above and in literature, the similarity of catch method facilitates comparisons over time and space (Addis et al., 230 2008; Ravier and Fromentin, 2001).

The data we have recovered can potentially be used to address at least three aspects of swordfish ecology: abundance, body size, seasonal occurrence (phenology) in local waters. Here we show some examples of the data for each of these categories and how they could potentially be used in subsequent analyses.

The raw time series of catch as displayed illustrates how many are caught on a single day, and the likelihood that individual 235 or groups of swordfish are caught on single days. As is evident from this example (and in the other years and locations), it is clear that catches often involve single individuals, although there are days when multiple specimens are caught. The incidence of single-capture days reflects the known solitary behaviour of swordfish as they approach spawning time and areas, as also seen from artisanal harpoon fisheries in nearby areas (i. e., Strait of Messina; (Battaglia et al., 2018; Romeo et al., 2009b). Furthermore, it is possible that the sequence of days without catches (i. e., days between catch events) could be 240 indicative of the spatial distribution and inter-fish distances at sea; these issues need further exploration.

The size data from the traps can be used to derive ages from growth relationships in the literature (Abid and Idrissi, 2006; Tserpes and Tsimenedes, 1995), and when compared with the known size- or age-at-maturity schedules for Mediterranean Sea swordfish (Abid and Idrissi, 2006; ICCAT, 2020), indicate the likelihood that the traps capture adults or juveniles.

The size data contained in the fishery records are among the oldest quantitative data available for Mediterranean swordfish 245 and extend into a time period when exploitation was lower than at present. Given that mean body size in exploited fish populations often declines when populations become overexploited (Hilborn and Walters, 2001; Jennings, 2007), new time series of mean body size that extend into low-exploitation periods can also potentially be useful indicators of changes in population status.

The high temporal resolution of the catch data allows derivation and investigation of annual catch phenologies. Although 250 the swordfish catch data reported here are bycatches from gears deployed to catch a different species (bluefin tuna), they may nevertheless reflect the presence of swordfish and its migration behaviour in the region and could be a basis for comparison of phenologies derived from other data sources (e. g, commercial gear such as longlines or harpoons which targets swordfish; tagging data). Examples of catch phenologies from the trap data are shown for illustrative purposes for single years for each of the sites (Fig. 3).

255 The taxonomic identify of species named in historical documents can often be difficult to assess due to multiple names for the same species used in the same and different locations or time periods; furthermore many species can have similar external appearances potentially increasing difficulties for correct species identification. In this study, there is little or no possibility for taxonomic confusion of this species with other species that could have been caught. This species is one of the world's most recognizable and famous fish species (Stergiou, 2017) and because of its unusual appearance, is unlikely to

260 have been mistaken by professional fishermen for other species and vice versa. Another billfish, Mediterranean spearfish, *Tetrapturus belone*, is also present in the area (Romeo et al., 2009a, 2015) but its appearance is sufficiently different from swordfish that the two species are easily distinguishable. Furthermore, there have been no quota or minimum size restrictions for swordfish in the Mediterranean Sea until 2017 and 2011 when regulations on TAC and minimum size respectively were implemented (ICCAT, 2011, 2017). Consequently, there has been little incentive for fishermen to

265 misreport their catches, especially before these years. As a result, the written records are highly likely to be true representations of the amounts of swordfish caught by the traps.

Our finding that the bluefin tuna trap records regularly contain swordfish bycatch in amounts that could increase ecological understanding are consistent with some other data sources. Analysis of the species composition of a smaller trap located on the northern Tyrrhenian Sea coast of Italy indicated that swordfish were sometimes caught as bycatch at this location (Britten

270 et al., 2014). In addition, swordfish have been caught as bycatch in a Spanish bluefin tuna trap at Barbate (Gulf of Cadiz; (Rodríguez-Roda, 1964). The data recovered in our study suggest that there may be potentially many more data in other trap logbooks and accounts for other locations and time periods than we have investigated here. These deserve investigation in future.

275 **5 Data availability**

The data are deposited in three datasets in the Pangaea open-access online repository at the following temporary links (permanent links and DOIs from Pangaea to follow):

https://www.pangaea.de/tok/8d1a24cfe1e5b9f79f61f40eaf8f804e469873f0 (MacKenzie et al., 2021c)

280 https://www.pangaea.de/tok/b7e606c35804776223b2f6f372061ac212458a0d (MacKenzie et al., 2021a)
https://www.pangaea.de/tok/3389e53f767d14bbf5d991985778c6fc871c314c (MacKenzie et al., 2021d)

The first dataset contains the bycatch data in numbers and/or weight on given days during 1896-2010 for the four traps. The second dataset contains monthly-resolved bycatch data in weights for the Milazzo trap for the years 1896-1901. The third

285 dataset contains the estimated start and end dates and durations for the annual fishing seasons in each of the four trap sites.

6 Conclusions

The historical reports and archives we have investigated contain new quantitative information that can be used to make new analyses and discoveries of swordfish ecology in the Mediterranean Sea. The recovered data document swordfish caught as

290 bycatch using similar methods over time and among sites, thereby allowing a high degree of comparability across time and space. The datasets allow investigations of multi-decadal variability in swordfish ecology in the Mediterranean Sea during most of the 20th century, including time periods for which quantitative data are rare or nonexistent, and can potentially establish new baseline knowledge for this population.

295 **7 Code Availability**

No code was used or developed in this study.

8 Author contributions

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BRM and TR designed research. BRM analysed data, prepared figures, wrote first draft of the manuscript and edited later
300 versions. TR, PA, PB, PC, FA and GC assembled data, assisted with interpretations and edited and reviewed the manuscript.

9 Competing interests

The authors declare that they have no conflict of interest.

11 References

Abid, N. and Idrissi, M.: Swordfish, in ICCAT Manual, pp. 1–18., 2006.

315 Addis, P., Dean, J. M., Pesci, P., Locci, I., Cannas, R., Corrias, S. and Cau, A.: Effects of local scale perturbations in the
Atlantic bluefin tuna (Thunnus thynnus L.) trap fishery of Sardinia (W. Mediterranean), Fish. Res., 92(2–3), 242–254,
doi:10.1016/j.fishres.2008.01.021, 2008.

Addis, P., Secci, M., Locci, I., Cau, A. and Sabatini, A.: Analysis of Atlantic bluefin tuna catches from the last Tonnara in the
Mediterranean Sea: 1993–2010, Fish. Res., 127–128, 133–141, doi:10.1016/j.fishres.2012.05.010, 2012.

320 Ambrosio, L. and Xandri, A.: The future of the almadraba sector - traditional tuna fishing methods in the EU, European
Parliament, Directorate-General for Internal Policies, Policy Department B: Structual and Cohesion Policies, Brussels., 2015.

Battaglia, P., Perzia, P., Pedà, C., Esposito, V., Consoli, P., Andaloro, F. and Romeo, T.: Evolution, crisis and new scenarios
of the Italian swordfish harpoon fishery, Reg. Stud. Mar. Sci., 21, 94–101, doi:10.1016/j.rsma.2017.09.006, 2018.

Britten, G. L., Dowd, M., Minto, C., Ferretti, F., Boero, F. and Lotze, H. K.: Predator decline leads to decreased stability in a
325 coastal fish community, edited by G. De Leo, Ecol. Lett., 17(12), 1518–1525, doi:10.1111/ele.12354, 2014.

Cardinale, M., Osio, G. C. and Scarcella, G.: Mediterranean Sea: A Failure of the European Fisheries Management System,
Front. Mar. Sci., 4, doi:10.3389/fmars.2017.00072, 2017.

Caswell, B. A., Klein, E. S., Alleway, H. K., Ball, J. E., Botero, J., Cardinale, M., Eero, M., Engelhard, G. H., Fortibuoni, T.,
Giraldo, A., Hentati-Sundberg, J., Jones, P., Kittinger, J. N., Krause, G., Lajus, D. L., Lajus, J., Lau, S. C. Y., Lescrauwaet,
330 A., MacKenzie, B. R., McKenzie, M., Ojaveer, H., Pandolfi, J. M., Raicevich, S., Russell, B. D., Sundelöf, A., Thorpe, R. B.,
zu Ermgassen, P. S. E. and Thurstan, R. H.: Something old, something new: Historical perspectives provide lessons for blue
growth agendas, Fish Fish., 21(4), 774–796, doi:10.1111/faf.12460, 2020.

Cattaneo-Vietti, R., Cappanera, V., Castellano, M. and Povero, P.: Yield and catch changes in a Mediterranean small tuna trap:
a warming change effect?, Mar. Ecol., 36(2), 155–166, doi:10.1111/maec.12127, 2015.

335 Damalas, D., Maravelias, C. D., Osio, G. C., Maynou, F., Sbrana, M. and Sartor, P.: "Once upon a Time in the Mediterranean" Long Term Trends of Mediterranean Fisheries Resources Based on Fishers' Traditional Ecological Knowledge, edited by M. Gomez-Gesteira, PLoS One, 10(3), e0119330, doi:10.1371/journal.pone.0119330, 2015.

Daskalov, G. M., Grishin, A. N., Rodionov, S. and Mihneva, V.: Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts, Proc. Natl. Acad. Sci. U. S. A., 104(25), 10518–10523, 2007.

340 Engelhard, G. H., Thurstan, R. H., MacKenzie, B. R., Alleway, H. K., Bannister, R. C. A., Cardinale, M., Clarke, M. W., Currie, J. C., Fortibuoni, T., Holm, P., Holt, S. J., Mazzoldi, C., Pinnegar, J. K., Raicevich, S., Volckaert, F. A. M., Klein, E. S. and Lescrauwaet, A.-K.: ICES meets marine historical ecology: Placing the history of fish and fisheries in current policy context, ICES J. Mar. Sci., 73(5), 1386–1403, doi:10.1093/icesjms/fsv219, 2016.

Ferretti, F., Verd, G. M., Seret, B., Sprem, J. S. and Micheli, F.: Falling through the cracks: the fading history of a large iconic
345 predator, Fish Fish. (in Press. DOI 10.1111/faf.12108, x, 1–15, doi:DOI: 10.1111/faf.12108, 2015.

Fortibuoni, T., Libralato, S., Raicevich, S., Giovanardi, O. and Solidoro, C.: Coding early naturalists' accounts into long-term fish community changes in the Adriatic Sea (1800 -2000), PLoS One, 5(11), e15502 [online] Available from: http://dx.doi.org/10.1371%2Fjournal.pone.0015502, 2010.

Hilborn, R. and Walters, C. J.: Quantitative fisheries stock assessment : choice, dynamics and uncertainty, Kluwer Academic
350 Publishers, Dordrecht, Netherlands.

ICCAT: Recommendation for management measures for Mediterranean swordfish in the framework of ICCAT (Rec. 11-03), Madrid, Spain., 2011.

ICCAT: Recommendation [16-05] by ICCAT replacing the recommendation [13-04] and establishing a multi-annual recovery plan for Mediterranean swordfish., 2017.

355 ICCAT: 9.10 - SWO-Med - Mediterranean swordfish (Executive summary of 2018 stock assessment meeting), in ICCAT SCRS Report for the Biennial Period, 2018-19, Part 1 (2018) - Vol. 2, vol. 2, pp. 182–192., 2019.

ICCAT: Report of the 2020 ICCAT Mediterranean swordfish stock assessment meeting (22 May - 6 June, 2020), ICCAT Coll.Vol.Sci.Pap., 77(3), 179–316 [online] Available from: https://www.iccat.int/Documents/Meetings/Docs/2020/REPORTS/2020_SWO_MED_ENG.pdf, 2020.

360 Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., Bradbury, R. H., Cooke, R., Erlandson, J., Estes, J. A., Hughes, T. P., Kidwell, S., Lange, C. B., Lenihan, H. S., Pandolfi, J. M., Peterson, C. H., Steneck, R. S., Tegner, M. J. and Warner, R. W.: Historical overfishing and the recent collapse of coastal ecosystems, Science (80-.)., 293, 629–638, 2001.

Jennings, S.: Reporting and advising on the effects of fishing, Fish Fish., 8(3), 269–276, doi:10.1111/j.1467-
365 2679.2007.00250.x, 2007.

Lotze, H. K., Hoffmann, R. and Erlandson, J. M.: Lessons from historical ecology and management, in The Sea; Vol. 16: Marine ecosystem-based management (568 pp.), edited by M. Fogarty and J. J. McCarthy, pp. 16–55, Harvard University Press, Cambridge, MA., 2014.

MacKenzie, B. R., Ojaveer, H. and Eero, M.: Historical ecology provides new insights for ecosystem management: Eastern
370   Baltic cod case study, Mar. Policy, 35(2), doi:10.1016/j.marpol.2010.10.004, 2011.

MacKenzie, B. R., Romeo, T., Addis, P., Battaglia, P., Consoli, P., Andaloro, F. and Sara, G.: Monthly-resolved swordfish
bycatch data from Milazzo tuna trap, 1896-1901., PANGAEA, 928980 [online] Available from:
https://doi.pangaea.de/10.1594/PANGAEA.928980, 2021a.

MacKenzie, B. R., Addis, P., Battaglia, P., Consoli, P., Andaloro, F., Sara, G., Nielsen, A. and Romeo, T.: Neglected data
375   sources reveal historical declines in ecological properties of a large charismatic Mediterranean top predator, (in prep.), x, x-y,
2021b.

MacKenzie, B. R., Romeo, T., Addis, P., Battaglia, P., Consoli, P., Andaloro, F. and Sara, G.: Swordfish bycatch data from
tuna traps located at four sites in Italy, 1896-2010, PANGAEA, 928996 [online] Available from:
https://doi.pangaea.de/10.1594/PANGAEA.928996, 2021c.

380   MacKenzie, B. R., Romeo, T., Addis, P., Battaglia, P., Consoli, P., Andaloro, F. and Sara, G.: Timing and duration of fishing
seasons for artisanal bluefin tuna traps at four sites in Italy, 1896-2010., PANGAEA, 928981 [online] Available from:
https://doi.pangaea.de/10.1594/PANGAEA.928981, 2021d.

Mather, F. J., Mason, J. M. and Jones, A. C.: Historical document: life history and fisheries of Atlantic bluefin tuna, NOAA
Tech. Memo. NMFS-SEFSC, 370, 1–165, 1995.

385   Pauly, D.: Anecdotes and shifting baseline syndrome of fisheries, Trends Ecol. Evol., 10, 430, 1995.

Piroddi, C., Coll, M., Liquete, C., Macias, D., Greer, K., Buszowski, J., Steenbeek, J., Danovaro, R. and Christensen, V.:
Historical changes of the Mediterranean Sea ecosystem: modelling the role and impact of primary productivity and fisheries
changes over time, Sci. Rep., 7(1), 44491, doi:10.1038/srep44491, 2017.

Ravier, C. and Fromentin, J.-M.: Long-term fluctuations in the eastern Atlantic and Mediterranean bluefin tuna population,
390   ICES J. Mar. Sci. J. du Cons., 58, 1299–1317, 2001.

Reusch, T. B. H., Dierking, J., Andersson, H. C., Bonsdorff, E., Carstensen, J., Casini, M., Czajkowski, M., Hasler, B., Hinsby,
K., Hyytiäinen, K., Johannesson, K., Jomaa, S., Jormalainen, V., Kuosa, H., Kurland, S., Laikre, L., MacKenzie, B. R.,
Margonski, P., Melzner, F., Oesterwind, D., Ojaveer, H., Refsgaard, J. C., Sandström, A., Schwarz, G., Tonderski, K., Winder,
M. and Zandersen, M.: The Baltic Sea as a time machine for the future coastal ocean (10.1126/sciadv.aar8195), Sci. Adv.,
395   4(5), 1–16, doi:10.1126/sciadv.aar8195, 2018.

Rodríguez-Roda, J.: Biologia del atun, Thunnus thynnus (L.), de la costa sudatlantica de Espana, Inv. Pesq, 25, 33–146, 1964.

Romeo, T., Consoli, P., Castriota, L. and Andaloro, F.: An evaluation of resource partitioning between two billfish, Tetrapturus
belone and Xiphias gladius, in the central Mediterranean Sea, J. Mar. Biol. Assoc. United Kingdom, 89(4), 849–857,
doi:10.1017/S0025315408002087, 2009a.

400   Romeo, T., Consoli, P., Greco, S., Canese, S. and Andaloro, F.: Swordfish (Xiphias gladius, Teleostea: Xiphiidae) surface
behaviour during reproductive period in the central Mediterranean Sea (southern Tyrrhenian Sea), Mar. Biodivers. Rec., 2,
e45, doi:10.1017/s1755267209000578, 2009b.

Romeo, T., Battaglia, P., Raicevich, S., Perzia, P. and Andaloro, F.: Swordfish harpoon fishery in the Mediterranean Sea: Recent data to implement the Marine Strategy Framework Directive and the EcAp (Ecosystem Approach) process, Fish. Res.,
405   161, 191–199, doi:10.1016/j.fishres.2014.07.013, 2015.

Stergiou, K.: The most famous fish: human relationships with fish as inferred from the corpus of online English books (1800-2000), Ethics Sci. Environ. Polit., 17(1), 9–18, doi:10.3354/esep00173, 2017.

Storai, T., Zinzula, L., Repetto, S., Zuffa, M., Morgan, A. and Mandelman, J.: Bycatch of large elasmobranchs in the traditional tuna traps (tonnare) of Sardinia from 1990 to 2009, Fish. Res., 109(1), 74–79, doi:10.1016/j.fishres.2011.01.018, 2011.

410   Tserpes, G. and Tsimenedes, N.: Determination of age and grwoth of swordfish, Xiphias gladius L. 1758, in the eastern Mediterranean using anal fin spines, Fish. Bull., 93(3), 1995.

Ward, P., Porter, J. M. and Elscot, S.: Broadbill swordfish: status of established fisheries and lessons for developing fisheries, Fish Fish., 1(4), 317–336, doi:10.1046/j.1467-2979.2000.00026.x, 2000.

Yuncu, E.: Genetic structure of modern and ancient swordfish populations from coasts of Turkey., 2017.

415