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FACTORS TO BE TAKEN INTO ACCOUNT FOR A CORRECT READING OF TUNA TRAP CATCH SERIES

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SUMMARY

*The long history of the trap fishery for bluefin tuna (*Thunnus thynnus*), which is the longest among the world's fishery industry, is finally providing important data series. These huge amounts of data, going back to more than five centuries, are also the mirror of many events, either natural or caused by human factors. In some cases, going through the analysis of historical chronicles, it is possible to precisely identify the factors which might affect trap catches, while in other cases more advanced studies on natural cycles might be able to explain peaks in yields. The sole purpose of this work is to propose a list of factors to be taken into account or to be checked when analysing these long historical series, considering that only in a very few cases these factors can be easily detected, while in most cases they should be investigated in the huge amount of literature concerning this fishery.*

RÉSUMÉ

*La longue histoire de la pêcherie des madragues de thon rouge (*Thunnus thynnus*), la plus ancienne industrie halieutique du monde, fournit finalement d'importants jeux de données. Ces grands volumes de données, datant de plus de cinq siècles, sont également le reflet de nombreux événements, naturels ou causés par des facteurs humains. Dans certains cas, l'analyse des chroniques historiques permet d'identifier avec précision les facteurs susceptibles d'influencer les prises des madragues, alors que dans d'autres cas, des études plus approfondies sur les cycles naturels peuvent expliquer les pics de production. Le présent travail a pour seul but de proposer une liste de facteurs à prendre en considération ou à vérifier lors de l'analyse de ces longues séries historiques, étant donné que ces facteurs ne peuvent être détectés facilement que dans des cas très limités, alors que dans la plupart des cas ils doivent être étudiés dans le grand volume de publications se rapportant à cette pêcherie.*

RESUMEN

*La larga historia de la pesquería de almadrabas de atún rojo (*Thunnus thynnus*), que es la industria pesquera más antigua del mundo, está facilitando finalmente series de datos importantes. Estas grandes cantidades de datos, que se remontan a hace más de cinco siglos, son también el reflejo de muchos sucesos, tanto naturales como producidos por el factor humano. En algunos casos, al analizar las crónicas históricas, es posible identificar de forma precisa los factores que podrían haber afectado a las capturas de las almadrabas, mientras que en otros casos, estudios más avanzados sobre los ciclos naturales podrían explicar los picos del rendimiento. El propósito de este trabajo es proponer una lista de factores a tener en cuenta o a comprobar al analizar estas largas series históricas, considerando que sólo en algunos casos pueden detectarse con facilidad estos factores, y que en la mayoría de los casos deberían ser investigados en la enorme bibliografía que existe sobre esta pesquería.*

KEYWORDS

Trap fishery, ancient industry, bluefin tuna, Atlantic, Mediterranean Sea, CPUE, catches, biology, impacts, conflicts, cycles

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1. Foreword

The tuna trap fishery is the most ancient industrial activity in the fishery sector, because it is well known that "tuna traps" were operating in ancient times in several countries during Phoenician times, while tuna traps were also known to be active since Greek and Roman times, in many coastal areas (Adams, 1883; Aubet, 1987, Azcoytia, 207a, 2007b, 2007c, 2008, 2009, 2011; Bacci, 1982; Baskett, 1899; Bekker-Nielsen, 2005; Bekker-Nielsen & Casasola, 2010; Ben Lazreg *et al*., 1995; Bernard Casasola, 2009; Campos *et al*., 1999; Consolo, 1987; Curtis, 1988, 2005; Doumenge, 1998, 1999a; Dumont, 1976-1977, 1981; Edmondson, 1987; Eschilo, 472 b.C.; Esopo, 1592; Fernández-Duro, 1866; Fernandez Gómez *et al*., 2007; García Vargas, 2001, Herodotus, V b.C., Levine, 2006; Mastromarco, 1998; Merino, 1991; Mila y Pinell, 1902; Morales-Muñiz & Roselló-Izquierdo, 2007, 2008; Moreno Páramo & Abad Casal, 1972; Muñoz Vincente & de Frutos Reyes, 1999, 2004 ; Omerus, VII b.C.; Oppianus, 177 b.C. ; Pepe, 2006; Pérez Gomez *et Al*., 2007; Plinius, 65 a.D.; Powell, 1996, Radclife, 1921; Strabonis I b.C.; Vargas *et Al*., 2010). More ancient data are not very well defined.

Even though this fishery dates back at least 26 centuries ago, detailed data on catches were recorded in various ways from the XVI century on. The peak of literature production on subject areas related to the tuna traps was between the XIX and the XX century, but many papers were also available in the XVIII century (Corwin, 1929; Di Natale, 2012a). Currently, the World Wide Web is a further opportunity for publishing scientific papers on traps.

Since several years, many scientists have been trying to standardise the data of tuna trap series (Abid and Idrissi, 2006 a, 2006c, 2008a, 2009a, 2009c; Abid et al., 2008, in press, Addis et al., 1997, in press, Fonteneau A., 2009, Fromentin, 2002c, 2009, Idrissi and Ortiz de Urbina, 2008; Ortiz de Urbina et al., 2006a, 2006b, 2010, Ravier and Fromentin, 2001, 2003, 2004) and these works have been usually carried out using GLM models and daily, monthly or yearly catch statistics by trap.

These time series only consider the fishery effort variables, mostly in terms of days at sea of the trap or in terms of individual fishing operations ("matanza" in Spanish or "mattanza" in Italian). A few papers also consider the importance of environmental variables, such as the North Atlanti Oscillation (NAO), in trying to explain long-term fluctuations.

As usually occurs while studying and analysing human activities carried out over long periods of time on natural resources, the reality is much more complex and there are many factors which should be possibly explored and investigated, in order to take them into account when analysing this ancient fishery in depth and for a better understanding of the natural fluctuations, which are still almost unknown for most of the marine species.

The ICCAT-GBYP has been recovering a huge amount of historical data sets and the bulk of this activity so far concerns the data mining of the tuna trap fishery. Most of the data are coming from the owners' registers, while in some cases official catch declarations are also available. All these data are now in the ICCAT bluefin tuna database and they are available for further analysis.

2. The limiting factors for the trap fishery

Since the first record of this ancient fishery, it was clear that the trap owners were facing various problems apart from the fishing activity itself. Many old and recent papers on the trap fishery report various events able to affect the fishing activity and subsequently the yields (Avolio Di Paola, 1805; D'Amico, 1816; De Bragança, 1899; Delefosse, 1999; Fage, 1924; Fonteneau, 2009; García del Hojo, 2002; García García, 2012; Li Greci *et Al*., 1991; Lippi Guidi, 1993; López Capont & Armesto, 1991; Lopez Linage & Arbex, 1991; Neuparth, 1924, 1925 ; Parona, 1919; Ruiz-Acevedo & Lópéz-González, 2005, Sarà, 1983, 1998; Sarmiento, 1757a, 1757b), sometimes in a very serious manner, showing a list of limiting factors.

In some cases, the events can be found not necessarely in scientific papers related to this fishery but from legal acts witnessing disputes or in historical books reporting various important events. As a matter of fact, many of these events were never considered in any of the most recent papers analysing this fishery.

The history of each tuna trap and a broader view of the nearest traps, along with the historical facts in each location are important elements for refining the study of each data series.

With this paper, we would like to provide an extensive, but not exhaustive, list of factors possibly with some examples or references, which may help in searching them when dealing with some historical series of tuna data.

2.1 Environmental factors and natural variables

Some of these factors are, at the moment, the only ones taken into account in the standardisation methods. In particular, the North Atlantic Obscillation (NAO) was the factor considered by some authors in recent times, trying to find explanations for long-term variations in yields (Caballero-Alfonso, 2011; Caballero-Alfonso *et Al.*, 2012; Anon., 2009a; Fonteneau, 2009; Fromentin, 2002a, 2002b, 2002c, 2003, 2009, Fromentin *et al*., 2000; Ravier-Mailly C., 2003; Ravier & Fromentin, 2001a, 2001b, 2002c, 2002, 2003, 2004).

Going through the available literature on tuna traps, it is very clear that the list of factors is longer and it includes several events which were thought to affect the yields in a significant way. The list is the following:

- *Oceanographic abnormalities*, including the afore-mentioned NAO (Fromentin, 2002a, 2002b, 2002c, 2003, 2009, Fromentin *et al*., 2000; Ravier-Mailly C., 2003; Ravier & Fromentin, 2001a, 2001b, 2002c, 2002, 2003, 2004), but even the Eastern Mediterranean Transient (EMT) (Di Natale, 2007), or other oceanographical factors (Sarà, 1983), or changes in sea current circulations, either at a large-scale or at the local scale (i.e., the construction of a port close to a trap was able to change both the local currents and the coastal environment, including some pelagic components). The oceanographic abnormalities events are important either in terms of the changes in the throphic chains or in general circulation of the water masses.

- *Climate changes,* which are able to modify the large-scale distribution of bluefin tuna (Di Natale, 2007), with multi-year or single-year effects on yields of fixed gears, like the tuna trap. The aerial survey on bluefin tuna spawning aggregations conducted by the ICCAT-GBYP confirms the inter-annual variability of bluefin tuna abundance in some Mediterranean areas, showing that yearly variability in climate factors (also inducing changes in the oceanography of upper marine strata) may cause considerable variations in yields.

- *Meteorological and hydrography factors,* particularly winds, either at a vaste or local scale, which are able to delay the stabilisations of some important oceanographic factors relevant for bluefin tunas or to induce movement of surface water masses. Most of the experienced "Rais" (the experienced tuna-trap fisherman in charge of conducting and managing the activities at sea) decided the setting of the the different components of the trap or the fishing events according to the dominant winds in the area of the trap. Local environmental factors are known to affect yields in tuna traps (Lemos & Gomes, 2004, Scordia, 1925, 1929), or on migratory movements (Rey, 1982, 1983, 1999; Rodiguez Roda, 1965, 1966, 1970a, 1970b; Roule, 1921), while even micro-changes in the surface oceanography are known to induce changes in the presence or concentration of bluefin tunas in some areas (Li Greci, 1981). The influence of climatic factors on tuna traps yields or on bluefin tuna spawning is studies since centuries (Marion, 1894, 1897; Mather *et Al*, 1955).

- *Dramatic changes in the marine environment.* This event is mostly related to the situation that occurred in the Black Sea at the beginning of the second half of the XX century, when the global marine environment underwent a dramatic change, due to a chain of events (pollution, alterated chemichal conditions, modification of the marine food network, etc.), which caused serious problems to several marine species, including the bluefin tuna. In this case, the bluefin tuna, originally present in the Black Sea since historical times (Deveryian, 1915, 1926; Ninni, 1923; Karakulak & Oray, 2009; Lagona, 1990), suddenly disappeared (Kideys, 2004; Zaitsev & Mamaiev, 1997), possibly moving to the Mediterranean Sea and preventing the further existence of any tuna trap fishery in the area.

- *Changes in the food web*, which may be induced by many factors and which are able to drive tuna schools in some areas instead of the usual ones in some years. This factor is sometimes linked to natural fluctuations of small pelegics in some areas and may also induce quantitative varibility in those areas.

- *Attacks by top predators*. The story of the attacks on migrating bluefin tunas by herds of killer whales in the area of the Strait of Gibraltar is well documented since more than four centuries (Garcia Garcia, 2012) and these attacks are reported to induce the schools of tunas under attack to modify their courses or may have an unknown effect on bluefin tunas whenever they occur in traps or close to traps (Rodiguez-Rota, 1978; Cañadas and De Stephanis, 2006; de La Serna et al., 2010; Di Natale and Mangano, 1983, Di

Natale & Notarbartolo di Sciara, 1994). Whenever attacks occur close to a trap, the yields can be affected. Severe attacks by false-killer whales on bluefin tunas were also reported, even if the predator species was wrongly classified as killer-whale and the attacks affected migrating tunas that were not close to any trap (Scordia, 1939). Interctions and predations by sperm whales are also reported (Di Natale, 1990), but it is not clear if these could affect the migratory courses of bluefin tuna. It is not very clear if the contemporary presence of large sharks in traps, such as the great white shark, *Carcharodon carcharias* (Cristo *et al*., 2006; Mojetta *et Al*., 1997, Storai et Al., 2006, 2007, 2011; Vacchi et Al., 2002) or other large sharks (Fergusson & Compagno, 2000; Sarà, 1983), might affect yields.

- *Natural turbidity*, which may affect some traps when they are within the plume range of large rivers and whenever floods or heavy rains affect the area close to or during the tuna fishing season (Garcia Garcia, 2012; Rodriguez Roda, 1970b). In these cases, turbidity higher than normal may induce tunas to avoid that area, swimming more offshore.

- *Strong hearthquakes in marine or coastal areas,* which were reported to considerably and negatively affect the yields of the tuna traps within the range of the earthquake. This was reported in many old papers for some Portuguese and Spanish traps (the earthquake in Cadiz in 1731, IX on the Mercalli scale, followed by a sort of tsunami; the great earthquake in Lisbon in 1755, 8.7-9 on the Richter scale, with the following tsunami event) (García Garcia, 2012), and for the Sicilian and Calabrian tuna traps (the heavy earthquakes in Messina in 1613, 1638, 1693, the series of great hearthquakes in Messina and south Calabria in 1783, with a magnitude of more than 7.2 on the Richter scale, and the great earthquake of Messina and Reggio Calabria in 1908, 7.2 or more on the Richter scale, with the associated tsunami event) (Reina, 1658).

- *Underwater eruptions*, such as the new formation of the Isle Ferdinandea along the southern Sicilian coast in July 1831[2](Mazzarella, 1984; Prevóst, 1831), or the several underwater eruptions of the many submerged volcanos in the central-eastern part of the Mediterranean basin, are considered capable of inducing temporary variability in migration courses or in the local food network.

- *Epidemies*, such as the bubonic plague or malaria, were able to seriously affect tuna trap workers (Ingrassia, 1576); sometimes, experienced workers were replaced by unexperienced ones and this fact negatively affected the trap yealds, as was reported in the XVI and XVIII centuries in Spain (Garcia García, 2012).

- *Effects of changes or alterations of electromagnetic fields:* As highly migratory species, tunas possibly use both the sun and the moon as compasses, and are possibly capable of understanding and percepting magnetic fields which allow them to navigate in the oceans. Even if this hypothesis is still to be studied and demonstrated, it is possible that any changes in the electromagnetic fields in areas crossed by bluefin tuna courses may have considerable effects on the migration patterns.

- *Unforecastable events*, such as local storms or strong waves are able to cause damage to the traps or even to destroy them. These events are not uncommon and may have serious impacts on the yields of a single trap or on a series of traps, because of the very limited fishing season. In some cases, it is possible to have records of these events in some Rais's logbooks.

Some of the above listed variables were and are able to create negative or positive yield variability in the traps, depending on the geographical position and other conditions or situations.

The actual tremendous improvement of information on the web is providing additional tools for these correlations with tuna trap catch series which were not available before or which required long and difficult bibliographic studies.

2.2 Human-induced variables

A long list of anthropogenic variables is coming out from the literature related to tuna trap activities in the last eight centuries because, in this case, some tracks exist well before the data were recorded. Of course, some of the

[2] This small isle is known to appear at the surface from time to time at least since a couple of centuries b.C. After the well.-described event in 1831, it emerged again for a few days in 1846 and 1863.

following variables are more relevant or more frequent than others, but they were all able to affect (usually in a negative manner) the yield of the single fishing operations or the yearly activity of the traps.

- *Mistakes in setting and positioning the trap* were more common than it usually thought; they may happen when a new Rais had to take over the management of a given trap or whenever a Rais decided to change the previous position of the trap for any reason. When a trap was set in a wrong position, then it was impossible to change the setting in time during the same fishing season and the whole season might be fully or partly compromised in terms of yield. These events have also occurred in very recent times, in some traps (Favignana, in Sicily, in 2006).

- *Late or anticipated deployment of the trap,* which might be caused by many factors, including wrong choices or wrong interpretation of environmental or oceanographic conditions. In case of a late deployment, this fact might cause a negative variation in CPUE or CPU (yield), while an anticipated deployment does not necessarelly affect the yields in a negative way (might also positively influence the yearly catch), but more often it has negative economic effects on the activity, because of the higher labour costs.

- *Pollution:* There is considerable documented evidence on the effects of industrial pollution on tuna traps (e.g,: Portoscuso and Isola Piana in Sardinia, Santa Panagia and Magnisi in Sicilia are the most known), particularly when big industrial plants were settled near already existing traps. In the case of the tuna trap of Magnisi, active since 1336, and Santa Panagia, active since the XI century, located in the area immediately north of Syracuse (E. Sicily), both traps ended their fishering activity one after the other after WW II, when a huge chemichal plant was built in the area of Augusta and Priolo Gargallo, just a few miles north of the traps, along the "return" course of the bluefin tunas (Lippi Guidi, 1993; Russo, 1983; Siragusa, 1980). The tuna traps of Portoscuso (Sardinia) and Isola Piana – Carloforte (Isle of S. Pietro, Sardinia), active respectively since 1497 and 1698, were seriosly affected by the big industrial plant for aluminium located in Portovesme, just attached to Portoscuso. In these cases, the long and complex disputes are well documented by the mass of reports and expertise presented to various Courts. Old disputes in the same area concerned the water waste of several mines located inland close to the coast. In the case of the traps in Sardinia, pollution affected the course of "incoming" bluefin tunas (Anonimous, 1905; Caruso, 1974; Conte, 1985; Di Gregorio & Massoni-Novelli, 1992; Grassi, 1913; Greco, 1999, Levi Morenos, 1899, Mazzarelli, 1917; Parona, 1915; Roule, 1913; Roule & Thulet, 1912). Thanks to the more advanced waste treatment and depuration, the impact was smoothed in recent years and the traps are still active. The decreasing transparency (or the increasing turbidity) of many coastal waters along the Mediterranean coats or the eastern Atlantic coasts where traps were or are still active, caused by the increasing number of human settlements in coastal areas, is only suspected as one of the causes for inducing bluefin tunas swimming more offshore.

- *Anthropogenic noise:* Coastal and pelagic environments had a dramatic change from a physical point of view after the introduction of marine engines on ships and vessels since the second part of the XIX century, which are suspected for having caused behavioural changes in several pelagic species. In the case of tuna traps, there is the evidence about the impact of the underwater noise caused by the high number of hydrofoils and ferries crossing the shallow area between the city of Trapani and the Isle of Favignana (Western Sicily) on the yields obtained by the ancient tuna trap in Favignana (Sarà 1983, 1998; Sarà *et Al*., 2007), active since 1341, which ceased its activity in 2008 because of the too low yields. Well before the introduction of engines on ships, the increasing maritime activity in the port of Cadiz which was close to some tuna traps (due to the maritime activities to and from the American continent, shifted from Sevilla to Cadiz), caused a serious negative impact on tuna trap yields (Sarmiento Martin, 1757a). High-speed ferries and pile-hammers used for building docks are also suspected to have impacts on bluefin tuna migration couses. The extraction of marine sands, mainly in coastal areas, for the supply purpose of the increasing demand of this material for building needs, as has been the case in the last decades, using very noisy marine equipment, may contribute to both noisy atmosphere and highly turbid waters where traps are set.

- *Underwater explosions.* This problem was mostly mentioned after the 2nd World War, when important quantities of explosives were available for several people. Some fishermen used explosives in several coastal areas for illegally catching fish and this activity was carried out, with decreasing intensity, for at least more than two decades. When these explosions were made close to traps or along the incoming courses of tunas to traps, these are known to negatively affect the yield (Gangemi, 2011; Sarà, 1983). In more recent times, the development of oil exploration with underwater explosions made by air-guns should be also considered, but in this case no scientific information is available concerning the effects on bluefin tuna behaviour.

- *Alterations of the natural light conditions*: This is a particular type of anthropogenic alteration of a natural condition, caused by the presence of lights along coastal roads or harbours. The effect of coastal lights on nesting or newborn marine turtles is well known. The effects on bluefin tuna are only suspected by several fishermen, but have never been scientifically proved. Anecdotical stories report either a negative impact when coastal diffused lights are too close to a tuna trap or, or the opposite, i.e., higher yields when high-power lights are able to attract small pelagics and subsequently tunas, in areas along the course to the trap (Russo, 1913; Sanzo, 1927). This type of impact should have reasonably increased after 1960.

- *Impact caused by the fishery of juvenile tunas in the same area:* This is a recurrent topic in several papers, particularly concerning Italian traps, since the XVIII century to the first part of the XX century (Avolio Di Paola, 1805; Parona, 1919; Pavesi, 1889). In several cases, trap owners and some scientists claimed that the intense fishery of juvenile tunas in the areas near to the traps was causing a general decrease in yields in following years. In this case, the direct correlation is not easy to be found, either because it is very difficut to assess the quantities of juvenile tunas taken by the coastal artisanal fisheries (the data are usually missing from the reports), or because the population structure of bluefin tuna is still not fully identified and, as a consequence, it is difficult to assess the impact over a fraction of a population. At any rate, it is clear that the fishery of juvenile bluefin tuna is a very old problem.

- *Conflicts among traps:* This specific type of conflict was the origin of many papers and documents over the last five centuries, and possibly before. When the trap fishery was more practiced and the tuna traps were set along most of the Mediterranean coasts (but also in the Atlantic areas close to the Strait of Gibraltar and in the Black Sea) (**Figures 1** and **2**), the activity was conditioned by the tuna movements (possibly not only the migratory courses) along the coasts, with traps catching bluefin tunas which were thought "entering" into the Mediterranean Sea[3] and other traps catching those possibly "returning" to the Atlantic Ocean[4]. Those two main movements were made complicated by the "resident" tunas, those staying in the Mediterranean for more than one year, but traps were taking advantage of the main massive movements of pre-spawners, spawners and post-spawners, consequently were set one after the other in some areas (Parona, 1919; Pavesi, 1889). Setting a new trap before an already existing one along the course of the tunas was always considered to create a strong negative impact on the yield of the latter (Farrugio, 2012; Fernández-Duro, 1866; García García, 2012; González & Maroto, 1906; Gourret, 1894, Lippi Guidi, 2004; Molinari, 1912, Perrin, 1925; Siragusa, 1989; Tomaseti, 1837), inducing many disputes before the local Courts. Maybe the most famous is a dispute that occurred in Sicily just at the beginning of the XIX century, because the lawyers of the two parties (Avolio di Paola, 1805; D'Amico, 1816; Dorotea, 1863) wrote two books on this issue, providing one of the most complete descriptions of the trap fishery at that time. In most of the cases, the disputes were about the non-compliance with the minimum distance between traps established by the laws, usually not less than three nautical miles (Romeo, 1920), and several traps had serious economic problems (due to decreasing yields) for this reason. In some other cases, more common in Spain (Ortuño, 1842), the traditional set traps (the "almadraba de buche"[5] or the "almadraba de monteleva"[6]) had conflicts with traps operated by long beach seines (called "almadraba de vista" or "almadraba de tiro"[7]), which were not respecting the distances. More recently, the same conflicts took place within the Moroccan Atlantic coast where the Fisheries Authorities succeeded to manage the concerned coastal line (from Rabat to Tangiers) to fit almost 20 traps, through an appropriate allocation of positions, respecting agreed distances between each trap and their contiguous ones.

- *Conflicts with other fishing gears:* These problems are quite often generally referred to (i.e., with artisanal or trawl fisheries), but in some cases they are specifically identified (Avolio di Paola, 1805; D'Amico, 1816; Garcia Garcia, 2012; Turrel, 1872, 1875). Usually, there are references to the purse seine fisheries for small pelagics, which are considered capable of disturbing the tunas while feeding close to a trap. In some cases, driftnets used close to the traps are reported to interfere, causing a yield decrease, since the

[3] These traps were called "di corsa" in Italian and "derecho" or "de paso" in Spanish.
[4] These traps were called "di ritorno" in Italian and "retorno" or "revés"
[5] This type of tuna trap was a mixset system, with a part of set nets and one or more mobile nets, manouvered by small vessels close to the entrance, having the role of pushing the tuna school into the inner part of the trap. These nets are not used nowadays.
[6] This type of tuna trap is made only by nets fixed to the seafloor, forming a complex of chambers; the tuna traps used in the last decades are all of this type.
[7] These traps should be very common in the XVI century, because the first available image for the trap fishery (Braun and Hogenberg, 1572-1598; Di Natale, in press) shows this method. These traps are not used anymore.

XVIII century, particularly in Italy (Anon., 1850; Avolio di Paola, 1805; D'Amico, 1816; Russo, 1913; Sarà, 1998).

- *Staff and crew management conflicts*: These are variables able to seriously affect a fishing season. In the few cases whenever the history of a trap is fully available, these conflicts were not so rare, particularly when the salaries for the fishermen were extremely low and sometimes the crew reacted with local strikes, preventing the normal activity of the trap. More often, there were conflicts between the trap owner and the Rais, or between the old Rais and the new coming one, with direct effects on the fishing activities and their yields. In some case, the tuna trap workers prevented relevant technological changes of the gear type; two cases are known, thanks to the description provided by Sarmiento Martin (1757a): in Conil (1727) and in Zahara (1746) the substitution of the tuna beach seine ("almadraba de tiro") with a set tuna trap ("almadraba de buche") was prevented by serious riots, because these changes would be able to reduce the number of workers necessary for operating the traps, then consequently inducing social and economic problems in the village.

- *Lack of experienced staff*: this problem happened several times in various traps, as a consequence of attacks by pirates or economic problems, when the trap owner was forced to use workers coming from the agriculture sector (Gangemi, 2011), who were not traines sufficiently for any type of fishery. This problem caused less efficient activities during the fishing season and, as a consequence, lower yields.

- *Pirates, corsairs and war events*. The tuna trap fishery crosses a large range of centuries and pirates and corsairs have a long history as well. The coastal areas were obviously the most affected by the incursions of pirates, and the old towers close to the traps had very often a double role: observing the tuna movements nearby and observing vessels approaching the coast with hostile intentions. There are many documents about the effects of pirates and corsaires on the trap fishery (Altara, 2007, Bonaffini, 1983; Boscarino, 1963-64; Doneddu & Gangemi, 2000, Mazzarella & Zanca, 1979; Russo Petronilla, 1988), including the archives of the Duque of Medina Sidona (García García, 2012), and in some cases fishermen were taken as hostages by pirates or even killed, and in these and other cases it was sometimes impossible to carry out the fishery in some years. War events also affected the tuna trap fishing activities, both directly when war events occurred in the same area of a tuna trap, preventing or affecting the fishing activity, or indirectly when tuna trap workers were kept or forced to enroll in the army, then substituted by inexperienced workers.

- *Economic and financial problems*: As usually happens in all economic activities, economic issues also have a direct impact on the tuna trap industry (Farina, 1931; Fortini, 1923; Leach, 1928; Gangemi, 2011; Lentini, 1986; Lippi Guidi, 2004; Navarro Sainz, 1988; Russo, 1947; Savarino, 1960; Siragusa, 1980; Sorbello, 2010 ; Vial & Revelli, 1767). Going through the long history of this fishery, it is possible to identify many economic factors which had serious effects on the fishing activity, sometimes imposing period of closures or very marginal activity in some years:

  a) Shortage of funds after paying high taxex or tributes after one year of high yields followed by one year of low yields;
  b) Economic problems of the owner, caused by various activities other than the fishery (bankruptcy, family economic problems, gambling, etc.);
  c) Inheritance disputes within the owner's family;
  d) Lack of an economic agreement with the crew (see also the previous point on "Staff and crew management problems");
  e) Economic problems induced by the market; these were particularly visible at the end of the XIX century and at the beginning of the XX century, when the concurrence of cheaper bluefin tuna coming from the Spanish traps caused serious problems to some Italian traps.

- *Unreliable or manipulated catch statistics*: Even tuna trap catch statistics show problems whenever it is possible to access all the full documents of a given trap, including the personal notes of the main managers of the activity, the notes taken by the "Rais" are usually the most complete, including even the by-catch, the home-register carefully written by the tuna trap administrator ("razionale" in Italian[8]), including all costs and revenues, but not the small fish distributed to the crew and the workers, and the official catch statistics prepared for tax purposes, which were usually lower than all the others. From a bluefin tuna fishery point of view, the home register is usually the best document to consider, when

[8] It was not possible to find any other definition for this role in any language other than Italian.

available. If all documents are available (and this fact happens very rarely), even if for a limited number of years, it is possible to develop correction factors or get a better overview of the trap fishery.

2.3 Technological variables

In the case of tuna traps, there is no technological creeping in recent decades, contrary to what is occurring in most of the fishing activities and fisheries.

However, tuna traps were always considered as a unique typology of fishing gear, and it is not the case. As a matter of fact, as is known since at least five centuries (Abad Cerdán, 2003; Di Natale, 2012b; García Vargas & Florido del Corral, 2010; Rodiguez Santamaria, 1929, 1923; Sañez Reguart, 1791; Vargas *et Al*., 2010), there were at least five main types of tuna traps, while at the moment only the two last types reported on the list are used, as mentioned before:

- *Tuna beach seine,* with several variables, which was the first represented on an etching (XVI century), and that was possibly one of the most widely used for many years. In some cases, the trap was used as a traditional beach seine; in others, only one of the ropes was on the beach, while the other was kept on board a small vessel; in some other cases, two nets were used, one behind the other (**Figure 3**);

- *Tuna boat seine,* with several variables. There is evidence of this fishery at least up to the end of the XVIII century, sometimes with several boats engaged for the same fishing operation (**Figure 4**);

- *Mix type tuna trap*, formed by a set net, with a mobile part manoeuvred by one or more vessels. In this case, in some traps it was also possible to change the position of the entrance of the trap according to the period/season of the year. Several variables are known (**Figure 5**);

- *Small set-type tuna trap used in the northeastern Adriatic Sea,* which had one single chamber, a mobile closure and where tunas were spotted by an observer on the top of a long pole. These traps were used to catch small-medium size tunas along the coasts, between the second part of the XIX century and the first part of the XX century (**Figure 6)**;

- *Traditional set-type tuna trap,* anchored to the bottom, with several chambers of various size, which is used close to the shore for medium and large tunas. It is in use since at least five centuries ago and there are infinite variables. Usually, many scientists refer only to this type of trap (**Figure 7**).

- *Traditional small set-type of tuna trap*[9], always anchored to the bottom, with a smaller number of chambers and set close to the coast, which target a variety of species and not only bluefin tuna; in some places, both type of set traps, one in marginal seasons and the other during the main passage (**Figure 8**).

Defining, when possible, the type of tuna trap which produced the yields in each series will help in better understanding the CPUEs.

2.4 Position variables

When tuna traps were numerous and distributed all along the coast, the position was also very important. There are three main variables to be taken into account:

- Position in relation to the tuna movements, with two sub-variables:
  - tuna traps targeting fish entering into the Mediterranean or going to the spawning grounds
  - tuna traps targeting fish after spawning or leaving the Mediterranean Sea.

- Position in relation with the target, with two sub-variables:
  - tuna traps targeting adults (see the previous point)
  - tuna traps targeting small-medium tunas

- Position of the tuna trap with reference to other tuna traps. If a tuna trap was set after or before another trap along the same course of the bluefin tuna, this possibly had an impact on the yield. In some areas the

[9] This type of trap is called "tonnarella" in Italian.

density of traps was high. In some areas the traps belonged to the same owner and so, from a commercial point of view, their yields only created additional income, independently from the single yield.

2.5 Impact of regulatory measures

Whenever regulations or specific rules for tuna traps have been enforced, some of them may have impacts on the yields. This happened at times in the past when some traps were stopped by courts for various reasons or, more recently, after the adoption of the ICCAT Multi-annual Recovery Plan for Bluefin Tuna, which set a quota for each ICCAT Contracting Party, Cooperating non-Contracting Party, Entity or Fishing Entity (CPC) concerned. To enforce ICCAT Recommendation 98-05 and subsequent Recommendations (Rec.00-09, Rec.02-08; Rec.06-05, Rec.08-05, Rec.09-06 and Rec.10-04), some ICCAT CPCs established specific catch limits for tuna traps and these, of course, limited their annual yield. This is a very important factor to be taken into account when analysing the annual CPUEs for the tuna trap.

Another factor to be considered in terms of yields is the minimum size limit adopted by ICCAT, which partly limited the yields in those traps that usually have some small adults in their catch. In these cases, the impact might be relevant, when the presence of small adults (usually between 24 to 30 kg) prevents the full harvesting of the bluefin tunas in the death chamber if the trap crew is not able to separate these undersize tunas from the larger tuna. This is due to the lack of reference to tuna traps when the tolerace of undersize catch was established by Rec.08-05 and Rec.10-04. At the same time, the minimum catch limit affects the small tuna traps still active, because these were mostly targeting undersize tunas.

3. Conclusion

This review of the most relevant factors which may be able to impact the yields of the tuna traps shows very clearly the very high complexity of this ancient fishery and the strict limits we all have to precisely assess the CPUE data from tuna traps.

Not all the factors listed above can be easily detected or identified, since some of the data are extremely difficult to find, while for others very complex research is needed.

Reducing uncertainties and biases for a better understanding of this ancient fishery is a long and complex task. Data should be possibly analysed trap by trap and then for each trap it should be necessary to track its history for better detecting the most relevant factors to be considered for a refined standardisation.

This will require a very long time and considerable effort, but the tuna trap fishery may possibly deserve this, because it may be the only opportunity we have to understand the fluctuations of bluefin tuna throughout the last five centuries at least.

In the meantime, more simple analyses are always possible, but taking into account that they can describe only the yield over the years, while fluctuations can be detected only by a very serious analytical and historical work, able to exclude or include the various factors.

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5. Bibliography

Abad Cerdán R., 2003, Las almadrabas de Almería. http://marenostrum.org/pesca/almadrabas/index.htm

Adams W.M., 1883, A popular history of fisheries and fishermen in all countries, from the earliest times. Intern. Fish. Exib. Lit., Handbook 1, part 1: 18-19.

Altara E., 2007, Guida alle torri costiere della Sardegna. 1000 anni d'incursioni barbaresche. Graf. Calosci, Cortona: 1-279

Anon., 1850?, Sul divieto degli ordegni da pesca denominati alalungare. Memoria dei proprietari delle tonnare di Sicilia. Palermo: 1-13.

Anon. 1905, Raccolta di documenti e sentenze di Tribunali comprovanti il danno che arrecano le acque torbide e i gettiti di detriti e le variazioni del lido alla pesca del tonno nelle Tonnare di Porto Paglia e Porto Scuso. Tipografia Coop. Leonina, Roma: 1-72.

Anon., 2009a. Report of the World Symposium for the Study into the Stock Fluctuation of Northern Bluefin Tunas (*Thunnus thynnus* and *Thunnus orientalis*), Including the Historical Periods (Santander, Spain, April 22 to 24, 2008). Collect. Vol. Sci. Pap. ICCAT, 63: 1-49.

Aubet M.E., 1987, Tiro y las colonias fenicias de Occidente, Edicions Bellaterra, Barcelona: 1-323.

Avolio Di Paola F., 1805, Delle Leggi Siciliane intorno alla Pesca. Reale Stamperia, Palermo: 1-239.

Azcoytia C., 2007b, Historia de las almadrabas y salazones en el sur de España.
http://www.historiacocina.com/historia/garum/almadrabas.html

Azcoytia C., 2007b, Historia del atún en el Mediterráneo.
http://www.historiacocina.com/historia/garum/atun.html

Azcoytia C., 2007c, Historia y elaboración del Garum.
http://www.historiacocina.com/historia/articulos/garum.htm

Azcoytia C., 2008, Baelo Claudia (Cadiz), la mayor factoría de salazones y manifactura de garum de la Hispania Romana. http://www.historiacocina.com/paises/articulos/baelo/index.htm

Azcoytia C., 2009, Lixus (Larache, Marruecos), la mas alejada factoría de garum y salazones de Roma. http://www.historiacocina.com/historia/garum/lixus.htm

Azcoytia C., 2011, Historia de las almadrabas y los salazones en el sur y levante de España entre los siglos XIII y XX. http://www.historiacocina.com/historia/garum/salazonescervantes.htm

Bacci G.M., 1982, Antico insediamento per la pesca e la lavorazione del tonno presso Portopalo. Kokalos, F. Serra Ed., Roma, 28-29: 345-347.

Baskett J.N., 1899, The story of the fishes. New York: 1-268.

Bekker-Nielsen T. (ed.), 2005, Ancient fishing and fish processing in the Black Sea Region. Aarus University Press, Aarus.

Bekker-Nielsen T., Bernal Casasola D. (ed.), 2010, Ancient Nets and Fishing Gear. Proceedings of the International Workshop on "Nets and Fishing Gear in Classic Antiquity: a first approach". Univer. Cadiz, Serv. Publicaciones and Aarhus University Press, Cadiz, Nov. 15-17, 2007.

Ben Lazreg N., Bonifay M., Drine A., Trousset P., 1995, Production ed commercialisation des salsamenta de l'Afrique ancienne. Actes VI colloque Hist. Et Archéol., de l'Afrique (Pau, 25-29 Octobre 1993), CTHS, Paris: 103-142.

Bernard Casasola D., 2009, Arqueología de la pesca en el Estrecho de Gibraltar : de la prehistoria al fin del mundo antiguo. Universidad de cadiz, Serv. Publ., Cadiz.

Bonaffini G., 1983, La Sicilia ed i barbareschi. Incursioni corsare e riscatto degli schiavi (1570-1606). IIa Palma, Palermo.

Boscarino S., 1963-64, La Torre di Vendicari, Quaderni di Disegno, Università di Catania.

Braun G., Hogenberg F., 1572-1617, Civitates Orbis Terrarum. Colonia: 340 tabl.

Caballero Alfonso Á.M., 2011, Recent and historical variability effects on the population dynamics of several marine species. Thesis Doctoral. Departamento de Biologia, Universidad de Las Palmas de Gran Canaria: 1-271

Caballero-Alfonso A.M., Ganzedo U., Zorita E., Ibarra-Berastegi G., Sáenz J., Ezcurra A., Trujillo-Santana A., Santana del Pino A., Castro-Hernández J.J., 2012, Climate and historic fluctuations in the Gibraltar Strait and western Mediterranean. Presented at the ICCAT-GBYP Symposium on Trap Fishery for Bluefin Tuna, Tangier (23-25 May 2011). Collect. Vol. Sci. Pap. ICCAT, 67(1) (in this volume) (PowerPoint presentation only available on DVD with Vol. 67).

Campos J.M., Péres J.A., Vidal N., 1999, Las cetariae del litoral onubense en época romana. Publ. Diput. Prov. Cadiz., Huelva.

Caruso I., 1974, Relazione dei periti giudiziari sulla causa tra Portopaglia e Portoscuso contro la Societá Malfidano.

Consolo V., 1987, La pesca del tonno in Sicilia. Sellerio Ed., Palermo: 1-203.

Conte G., 1985 – Addio amico tonno. Indagine sulle tonnare di Portopaglia, Portoscuso e Isola Piana dal XIV secolo ai giorni nostri. Edizioni della Torre, Cagliari: 1-135.

Corwin G., 1929, A bibliography of the Tunas. Div. Fish and Game California, Fishery Bullettin n. 22: 1-103.

Cristo B., Storai T., Zuffa M., Zinzula L., Floris A., 2006, Presenza di *Carcharodon carcharias* (Chondrichthyes, Lamnidae) nelle acque sarde (Mediterraneo centrale). Biol. Mar. Medit., 13: 266–267.

Curtis R., 1988, Spanish trade in salted fish products in the 1st and 2nd centuries AD. Intern. Journ. Naut. Arch. Underw. Explor., 17(3): 205-210.

Curtis R.I., 2005, Sources for production and trade of Greek and Roman processed fish. In: Ancient fishing and fish processing in the Black Sea Region. Aarus University Press, Aarus: 31-46.

D'Amico F.C., 1816, Osservazioni pratiche intorno alla pesca, corso e cammino de' tonni. Società Tipografica, Messina: 1-164.1925,

D'Ancona U., 1925, La pesca del tonno nel Quarnero. Rivista Marittima, nov.: 493.

D'Ancona U., 1927, Biologie générale. Distribution géographique et migrations des organismes animaux et végétaux de la Méditerranée. Proc.-Verb. Comm. Expl. Médit. 2: 108-109.

D'Angelo M., 1985, Vincenzo Florio, mercante-imprenditore (1799-1868). Atti Conv. studi: Il Mezzoggiorno d'Italia, Bari.

D'Anzuso G.L., Zinna E., 1987, La Mattanza: il ritorno di Ulisse. Giuseppe Maimone Ed., Catania: 1:105.

Dean J.M., Addis P., Cau A., 2003, Sustainable fishing in the Mediterranean for Bluefin tuna: a case study of ancestral fishing technologies and contemporary practices. Workshop on farming, Management and conservation of bluefin Tuna, 2003, Istanbul: 102-117.

Dean J.M., Addis P., Cau A., 2005, Mediterranean bluefin tuna: an ancient fishery copes with modern demands. http://mareblucamogli.com/mediterranean_bluefin_tuna.htm

Dean J.M., Andrushchenko I. and Neilson J.D., 2012, The western Atlantic bluefin tuna trap fishery. ICCAT-GBYP Symposium on Trap Fishery for Bluefin Tuna, Tangier, 23-25 May 2011. Collect. Vol. Sci. Pap. ICCAT, 67(1) (in this volume).

De Arriaga R., 1934, La industria pesquera marítima. s.i., Madrid: 1-64.

De Bragança C. (Dom), 1899, A pesca do atun no Algarve en 1898. Resultados Investigações scientificas feitas a bordo do yacht « Amelia ». Pescas maritima. I. A pesca do atum en Algarve em 1898. Lisboa: 1-104.

Delefosse S., 1999, Analyse numérique des séries historiques de thon rouge provenant des madragues méditerranéennes. Rapport de DEA. Université Paris VI, Paris.

Deveriyan K., 1915, Balih ve Bahhçilik. Kafih Hakuk Muhlfin Hadur, Dumhadis, Istanbul (in Ottoman) : 1-440 + 60.

Deveryian K., 1926 – Pêche et Pêcheries en Turquie. Imprimerie de l'Administration de la Dette Publique Ottomane, Istanbul : 1-480.

Di Gregorio, F., Massoli-Novelli, R. 1992. Geological impact of some tailings dams in Sardinia, Italy. Environ. Geol. 19: 147-153.

Di Natale A, 2007, I cambi climatici nel Mediterraneo: modificazioni della struttura della pesca e possibili adattamenti. Cambiamenti Climatici: Conferenza Nazionale, MATTM, 20/07/2007, Brindisi: 22 p.

Di Natale A, 2012a, Literature on the Eastern Atlantic and Mediterranean Tuna Trap Fishery. ICCAT-GBYP Symposium on Trap Fishery for Bluefin Tuna, Tangier (23-25 May 2011). Collect. Vol. Sci. Pap. ICCAT, 67(1) (in this volume).

Di Natale A., 2012b, The iconography of tuna traps: Essential information for the understanding of the technological evolution of this ancient fishery. ICCAT-GBYP Symposium on Trap Fishery for Bluefin Tuna, Tangier (23-25 May 2011). Collect. Vol. Sci. Pap. ICCAT, 67(1) (in this volume).

Di Natale A., Mangano A., 1983, Killer whale, *Orcinus orca* (Linnaeus) and false-killer whale, *Pseudorca crassidens* Owen, in the Italian seas. CIESM, Rapp.Comm. Int.Mer Médit., 28(5): 181-182.

Di Natale A, Notarbartolo di Sciara G., 1994, A review of the passive fishing nets and traps used in the Mediterranean Sea and of their Cetacean by-catch. In: Gillnets and Cetaceans. IUCN-IWC Workshop on Cetacean Mortality, La Jolla (USA), Oct. 1990. Rep. Int. Whal. Commn. (Special Issue), 15: 189-202.

Doneddu G.,Gangemi M. (ed.), 2000, La pesca nel Mediterraneo occidentale, secoli XVI – XVIII. Atti Convegno di Studi, 23-24 September 1994, Bosa. Ist. Storia Economica, Università di Bari, Puglia Grafica Sud, Bari, X : 1-255.

Dorotea L., 1863, Sommario storico dell'alieutica che si esercita nelle aree meridionali e della legislazione correlativa alla stessa. Tip. F. Vitale, Napoli: 1-48.

Doumenge F. 1998 - L'histoire des pêches thonières. Collect. Vol. Sci. Pap. ICCAT, 50: 753-802.

Doumenge F. 1999, La storia delle pesche tonniere. Biol. Mar. Medit., 6(2): 107-148.

Dumont J., 1976-77, La pêche du thon à Byzance à l'epoque hellénistique. REA 78-79 : 96-119.

Dumont J., 1981 - Halieutika. Recherches sur la pêche dans l'antiquité greque. Doct. Let., Paris VI, Histoire, 4 vol.: 1-1298.

Edmondson J.C., 1987, Two industries in Roman Lusitania: mining and garum production. BAR Int. Ser., 362, Oxford.

Eschilo, 472 b.C., Persiani. Athens: 422-428

Esopo F., 1592, Piscatorius. In : Aesopi Phrygis et Aliorum Fabulae. Elegantissimis Iconibus in gratiam studiose iuventutis illustrate, pluribusq. aucte, & diligentius quam ante hac emendata. Com Indice locupletissimo. Ioannen Fiorinam, Firenze: 282.

Fage L., 1924, Les fluctuations de la pêche du thon rouge sur les côtes du Portugal. Bul. Soc. Oceanogr., 4 (15): 366-367.

Farina L., 1931, L'attuale crisi dell'industria delle tonnare. Boll. Pesca Piscic. Idrobiol., VII: 652-659.

Farrugio H., 2012, Données historiques sur les anciennes madragues françaises de Méditerranée. ICCAT-GBYP Symposium on Trap Fishery for Bluefin Tuna, Tangier (23-25 May 2011). Collect. Vol. Sci. Pap. ICCAT, 67 (in this volume).

Fergusson I.K., Compagno L.J.V., 2000. Distributional note on the dusky shark *Carcharhinus obscurus* from the Mediterranean Sea, with first record from the Maltese Islands. In: Séret, B., Sire, J.Y. (Eds.), Proceedings of the 3rd European Elasmobranch Association Meeting, Boulogne-sur-Mer, France: 57-65.

Fernández-Duro C., 1866, Almadrabas. Reseña histórica de su empleo en las costas de España y reglamento para su régimen. Tip. Estrada, Díaz y López, Madrid: 1+108+3 tab.

Fernandez Gómez F., Yaňez Polo M.A., Hurtado Rodriguez L., 2007, Las Almadrabas del Atún Rojo en Conil de la Frontera y Aguas Atlanticas del Estrecho desde la antigűedad hasta nuestros dias. UNESCO Proyecto Oceanus, Fundacion Toro Albalá, Còrdoba: 1-174.

Fonteneau A., 2009, Atlantic bluefin tuna: 100 centuries of fluctuating fisheries. Collect. Vol. Sci. Pap. ICCAT, 63: 51-68.

Fortini P., 1923, Sulla diminuzione del prodotto della pesca nel compartimento marittimo di Palermo. Problemi Italiani, IV.

Fromentin J.M., 2002a, Can stochastic variation in recruitment induce long-term fluctuation in the carrying capacity? Collect. Vol. Sci. Pap. ICCAT, 54: 985-981.

Fromentin J.M., 2002b, Is the recruitment a key biological process in the hypothetical NAO-Atlantic tunas relationships? Collect. Vol. Sci. Pap. ICCAT, 54(4): 1008-1016.

Fromentin J.M., 2002c, STROMBOLI. Spatial and temporal trends in the catch of Mediterranean bluefin tuna. Historical observations and latest inquires. EU-DG XIV contract 99/022.

Fromentin J.M., 2003, The East Atlantic and Mediterranean bluefin tuna management: uncertainties and alternatives. Sc. Mar., 67: 51-62.

Fromentin J.M., 2009, Lessons from the past: investigating historical data from bluefin tuna fisheries. Fish and Fisheries, 10 (2):197-216.

Fromentin J.M., Fonteneau A., Farrugio H., 2000, Biological key reference points and natural long-term fluctuations: the case of the Atlantic bluefin tuna. Collect. Vol. Sci. Pap. ICCAT, 51(6): 2072-2084.

Fromentin J.M., Kell L., 2008, Evaluation of the performance and robustness of VPA-based stock assessment and MSY-based management strategy to process error: the Atlantic bluefin tuna case study. Collect. Vol. Sci. Pap. ICCAT, 44(2): 491-506.

Fromentin J.M., Farrugio H., 2011, The Gold Mine from the Atlantic Bluefin Tuna Trap Fisheries. Presented at the ICCAT-GBYP Symposium on Trap Fishery for Bluefin Tuna, Tangier (23-25 May 2011). Collect. Vol. Sci. Pap. ICCAT, 67(1) (in this volume) (PowerPoint presentation only available on DVD with Vol. 67).

Gangemi M., 2011, La pesca nel Mezzogiorno tra otto e novecento: tonnare, pesci, spugne e coralli. Cacucci Ed., Bari, 1-214.

García del Hojo J.J., 2002, Liberalizacíon y sobreexplotacíon pesquera en la Andalucía Atlantíca de la primera mitad del siglo XIX. Pub. Diput. Huelva.

García García P., 2012, Las almadrabas de la costa andaluza bajo el dominio de la casa ducal de Medina Sidonia. Su tipología, sus producciones et sus problemáticas. ICCAT-GBYP Symposium on Trap Fishery for Bluefin Tuna, Tangier (23-25 May 2011). Collect. Vol. Sci. Pap. ICCAT, 67(1) (in this volume).

García Vargas E., 2001, Pesca, sal y salazones en las ciudades fenicio-púnicas del sur de Iberia. J. Fenandez & B. Costa Eds., in: De la mar y de la tierra. Producciones y productos fenicio-púnicos. XV Jornadas de Arquelogía Fenicio-púnica, Ibiza, 2000. Trabajos del Museo arquelógico de Ibiza y Formentera, 47: 9-66.

García Vargas E., Florido del Corral D., 2010, The origin and development of tuna fishing nets (Almadrabas). In: Ancient Nets and Fishing Gear. Proceedings of the International Workshop on "Nets and Fishing Gear in Classic Antiquity: a first approach". Univer. Cadiz, Serv. Publicaciones and Aarhus University Press, Cadiz, Nov. 15-17, 2007: 205-228.

González F., Maroto C., 1906, Manual de legislación sobre la pesca marítima. Imp. del Asilo de Huérfanos del S.C. de Jesús, Madrid: VIII-1-686+1tab.

Gourret P., 1894, Les madragues de Marseille. I. Ann. Mus. Hist. Nat. Marseille (Zool.), 4: 59-75.

Grassi, B. 1913, Conflitto tra le tonnare Porto Paglia e Portoscuso contro la Società Anonima Malfidano. Ed. Corsi e Ciarlo, Genova.

Greco S., 1999, Situazione e prospettive delle tonnare di Carloforte e Portoscuso. Civiltà del Mare, ICIMAR, Sassari, X (2).

Herodotus, V b.C., Histroriae, lib.1 Ch. 62.

Ingrassia G.F., 1576, Informazioni del pestifero e contagioso morbo. Palermo: 1-656.

Karakulak F.S., Oray I.K., 2009, Remarks on the fluctuation of bluefin tuna catches in Turkish waters. Collect. Vol. Sci. Pap., ICCAT, 63: 153-160.

Kideys A., 2004, History of marine populations in the Black Sea. Mediterranean History of Marine Animals Populations, HMAT-MED Meeting, Barcelona, 20-22 September: 1-48.

Lagona S., 1990, Pesca ed attività connesse sulle coste dell'antica Turchia. Atti V Rassegna Archeol. Subac., Giardini-Naxos: 147-156.

Leach L.H., 1928, Report on economic conditions in Portugal with notes on the financial tituation in Angola and Mozambique. Dept. Overseas Trade, London: 33.

Lemos R.T., Gomes J.F., 2004, Do local environmental factors induce daily and yearly variability in bluefin tuna (*Thunnus thynnus*) trap catches? Ecol. Model. 177: 143-156.

Lentini R., 1986, Economia e storia delle tonnare in Sicilia. In: La pesca del tonno in Sicilia. Sellerio Edit. Palermo: 32-53.

Levi-Morenos D., 1899, Il conflitto tra l'industria peschereccia e mineraria in Sardegna. Neptunia, 14 (19-20): 239-252.

Levine D., 2006, Tuna in ancient Greece. University of Arkansas, American Institute of Wine and Food, New York: 9 p.

Li Greci F., 1981, Nota sui microgradienti termici osservati in acque coinvolte dal movimento del tonno, *Thunnus thynnus* (L.). Atti Conv. UU.OO. Risorse Biologiche ed Inquinamento Marino, CNR, Roma.

Li Greci F., Berdar A., Riccobono F., 1991, Mattanza. Le tonnare messinesi scomparse. Edizioni G.M.B., Messina.

Lippi Guidi A., 1993, Tonnare. Tonnaroti e malfaraggi della Sicilia sud-orientale. Ed. Zangarastampa, Siracusa.

López Capont F., Armesto C., 1991, Seminario sobre Estadistica Ordenada. Las Estadisticas de Pesca de Túnidos del Padre Sarmiento. II Jornada del Banco de Datos. Universidade de Santiago de Compostela.

Lopez Linage J., Arbex J.C., 1991, Pesquerias tradiciobales y conflictos ecológicos (1681-1794). Una selección de textos pioneros. Ministerio de Agricultura, Pesca y Alimentación, Madrid: 1-315.

Marion A.F., 1894, Observations climatériques faites à la station zoologique d'Endoume pour servir à l'étude du régime des pêches régionales. Ann. Mus. Hist. Nat. Marseille (Zool.), 4: 20.

Marion A.F., 1897, Notes sur les conditiones climatériques des années 1893, 1894, 1895 pour servire à la statistique des pêches des côtes de Marseille. Ann. Mus. Hist. Nat. Marseille (Zool.), 5: 5-8.

Mastromarco G., 1988, La pesca del Tonno nella Grecia antica: dalla realtà quotidiana alla metafora politica. Rivista di cultura classica e medioevale, 1-2: 229-236.

Mather F. J.III, Mason J. M., Jones A.C., 1995. Historical Document: Life History and Fisheries of Atlantic Bluefin Tuna. NOAA Technical Memorandum, NMFS-SEFSC, 370.

Mazzarella S., 1984, Dell'Isola Ferdinandea e di altre cose. Ed. Sellerio, Palermo: 1-151.

Mazzarella S., Zanca R., 1979, Il libro delle torri. Le torri costiere di Sicilia nei secoli XVI-XX. Biblioteca Siciliana di Storia e Letteratura, n. 20, Sellerio Edit., Palermo: 1-512.

Mazzarelli, G. 1917, Conflitto fra tonnare e miniere in Sardegna. Rivista di Pesca e Idrobiologia, Anno XI (XVIII), 4: 139-163.

Merino J.M., 1991, La pesca desde la preistoria hasta nuestros dias. Departamento de Agricultura y Pesca, Gobierno Vasco, Vitoria-Gasteiz: 1-494.

Mila y Pinell J., 1902, Memoria sobre la antigüedad de la pesca de los atúnes, importancía de esta industria y decadencia en que estuvo. La Coruña.

Mojetta A., Storai T., Zuffa M., 1997, Notes on the presence and distribution of the white shark (*Carcharodon carcharias*) in Italian waters. Quad. Civ. Staz. Idrobiol. Milano. 22: 125–128.

Molinari C., 1912, Indole e natura del diritto d'impianto di tonnara e specialmente in riguardo alle tonnare di Sicilia. Foro Italiano, Città di Castello, XXXVII (IV): 1-7.

Morales-Muñiz A., Roselló-Izquierdo E., 2007, Los atunes de Baelo Claudia y Punta Camarinal (s. II a.C.). Apuntes preliminares. In : Las cetariae de Baelo Claudia. Avance de las investigacíones arqueológicas en el barrio industrial (2000-2004). Arqueología Monografías, Sevilla : 489-498.

Morales-Muñiz A., Roselló-Izquierdo E., 2008, Twenty thousand years of fishing in the Strait : the archeological marine fauna assemblages from southern Iberian. In : Human impacts on marine environments. University of California Press, Berkley : 243-278.

Moreno Páramo A., Abad Casal L., 1972, Aportaciones al estudio de la pesca en la antigüedad. Habis, 2 : 209-221.

Muñoz Vincente A., de Frutos Reyes G., 1999, La industria pesquera y conservera púnico-gaditana : balance de la investigación. Nuevas perspectivas. Actos II Congreso de Arquelogia Peninsular, Zamora, 1966 : 49-57.

Muñoz Vincente A., de Frutos Reyes G., 2004, El comercio de las salazones en época fenicio-púnica en la bahía de Cadiz. Estado actual de las investigaciones : los registros arqueologicos. In : XVI Encuentros de Historia y Arqueología de San fernando. Las industria alfareras fenicio-púnicas de la Bahía de Cadiz. (San Fernando, 13-15 diciembre de 2000), Córdoba: 131-167.

Navarro Sainz J.M., 1988, Aspectos económicos de los señorios de los Duques de Medina Sidonia a princípios del siglo XVI. In : Huelva en su historia, 2 : 319-345.

Neuparth A.E., 1924, Quelles sont les causes du déplacement du thon ? (*Orcynus thynnus*). In : A pesca maritima, Lisboa, 19 : 123-131.

Neuparth A.E., 1925, Note sur les fluctuations de la pêche du Thon (*Thunnus thynnus* L.) sur la côte du Portugal. Rapp. Proc. Verb., Conseil Permanent International pour l'Exploration de la mer. Rapp. Proc.-Verb. Comm. Expl. Médit., Andr. Fred. Host et Fils, Copenhagen, 35: 51-56.

Ninni E., 1923, Primo contributo allo studio dei pesci e della pesca nelle acque dell'Impero Ottomano. Miss. Ital. Esplor. Levante, 5: 1-53+15 tab.

Omerus, VII b.C., Odyssea. Lib. 12.

Oppianus, 177 b.C., Alieuticon. In: Salvini A.M., 1738, Della Caccia e della Pesca. Firenze: 1-510.

Ortuño A., 1842, Reseña analitica dirigida a las Cortes actuales sobre las Almadrabas de buche de Conil y Zahara. Imp. de Vega, Madrid: 1-8.

Parona C., 1915, Per la storia della pesca in Italia. Tonnare e miniere in Sardegna. Atti Soc. Ligustica Sci. Nat. Geogr., 26: 1-38.

Parona C., 1919, Il Tonno e la sua pesca. R. Comit. Talass. Ital., Venezia, Mem. LXVIII: 1-259.

Pavesi P., 1889, L'industria del Tonno. Relazione alla Commissione Reale per le Tonnare. Min. Agric. Indust. Comm., Roma, Tip. Eredi Botta: 1-254.

Pepe C. (Ed.), 2006, Rotte dei tonni e luoghi delle tonnare nel Mediterraneo dalla preistoria ad oggi. Quaderni della Ricerca Scientifica, Serie Beni Culturali, Università degli Studi Suor Orsola Benincasa, Napoli, 5: 1-199.

Pérez Gomez F., Yañez Polo M., Hurtado Rodiguez L., 2007, Las Almadrabas de Atún rojo en Conil de la Frontera y aguas Atlántica del Estrecho, desde la antigüedad hasta nuestros días. UNESCO, Prgetto Oceanus, Cordoba: 1-174.

Perrin S., 1925, Etude judirique sur les anciennes pêcheries provençales appelées bourdigues et madragues. Thèse, Univ. Aix Marseille : 1-73 et suiv.

Powell, J. 1996, Fishing in the Prehistoric Aegean. Studies in Mediterranean Archaelogy and Literature, pocket book n. 136, Paul Åströms Förlag, Jonsered, Sweden: 1-266.

Radclife W., 1921, Fishing from the earliest times. New York,: 1-250.

Ravier-Mailly C., 2003, Fluctuation à long terms du thon rouge. Validité, origines et conséquences. These, Ecole Nationale Superieure Agronomique de Rennes, 2003-16, H50 : 1-177.

Ravier C., Fromentin J.M., 2001a, Dynamique long terme de la population de thon rouge de Méditerranée et d'Atlantique Est. Description et implication en terme de gestion. In: Halieutique: complexité et décision, 5ème Forum halieumétrique, session 1: "incertitudes et décisions". Lorient, France. IFREMER, Actes de colloque, 33: 28-29.

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

Ravier C., Fromentin J.M., 2001c, Trends in NE Atlantic and Mediterranean Bluefin Abundance. PFRP Newsletter, 6(4): 1-7.

Ravier C., Fromentin J.M., 2002, Eastern Atlantic bluefin tuna: What we learnt from historical time-series of trap catches. Col. Vol. Sci. Pap. ICCAT, 54(2): 507-516.

Ravier C., Fromentin J.M., 2003, Long-term fluctuations in Atlantic bluefin tuna (*Thunnus thynnus*): are they environmentally driven? Col. Vol. Sci. Pap. ICCAT, 55(3): 1208-1216.

Ravier C., Fromentin J.M., 2004, Are the long-term fluctuations in Atlantic bluefin tuna population related to environmental changes? Fish. Oceanogr., 13: 146-160.

Reina P., 1658, Introduzione delle notizie di Messina. Folio 35.

Rey J.C., 1982, Considerations on the migrations of tunas in relation to the hydrology of the Strait of Gibraltar. Collect. Vol. Sci. Pap. ICCAT, 18(3): 758-764.

Rey J.C., 1983, El paso del atún rojo, *Thunnus thynnus* (L., 1758) a través del Destrecho de Gibraltar y su relación con la hidrología. Bol. Inst. Esp. Oceanogr., n.s. 1(1): 85-94.

Rey J.C., 1999, Migraciones entre el Atlántico y el Mediterráneo a traves del Estrecho de Gibraltar y consideraciones hidrológicas. Biol. Mar. Medit., 6(2): 220-222.

Rodriguez-Roda J., 1965, Sobre las fluctuaciones en la produccion de atunes de las almadrabas sudatlanticas, Publicaciones Tecnicas de la Junta de Estudios de Pesca, Madrid. 4: 205-209.

Rodriguez-Roda J., 1966, El atún, *Thunnus thynnus* (L.), de la costa sud-atlántica de España en la campaña almadrabera del año 1964 y consideraciones sobre las fluctuaciones periódicas. Investigación Pesqueras, Barcelona, 30: 9-35.

Rodriguez-Roda J., 1970a, El atún, *Thunnus thynnus* (L.), del sur de España en la campaña almadrabera del año 1968 y su relacíon con la temperatura del agua del mar. Investigación Pesqueras, Barcelona, 34(2): 157-170.

Rodriguez-Roda J., 1970b, El atún, *Thunnus thynnus* (L.), del sur de España en la campaña almadrabera del año 1969 y su relación con la temperatura y transparencia del agua del mar. Investigación Pesqueras, Barcelona, 34(2): 503-514.

Rodriguez Santamaria B., 1920, Esplicación de las láminas que contienen los principales artes, aparejos e instrumentos que se emplean para la pesca marítima en las costs de España. Mateu, Madrid: 1-149+1-35 plt.

Rodriguez Santamaria B., 1923, Diccionario de Artes de Pesca de España y sus posesiones. Sucesores de Rivadeneyra, Madrid: 1-332.

Romeo G., 1920, Il diritto antico di calar tonnara e i nuovi ordinamenti nella pesca. Tip. La Rinascente, Catania.

Rondelet G., 1554, Libri de piscibus marinis in quibus verae piscium effiges expressae sunt. Mattiam Bonhomme, Lugduni: 1-490.

Roule L., 1913, Etude complémentaire sur la migration et le détournement des thons (*Orcynus thynnus* L.) dans la region des thonnares de Porto Paglia et Porto Scuso (Sardaigne)., Paris.

Roule L., 1921, Sur les changements périodiques du thon commun (*Orcynus thynnus*) et sur leur liason avec les conditions du mileu. Com. Rend. Acad. Des Scien., Paris, 173.

Roule L., Thulet J., 1912, Rapport sur le litige pendant entre les propriétaires des thonnaires de Porto Paglia et Porto Scuso et la Soccieté Anonyme des Mines de Malfidano. Paris : 1-45.

Ruiz-Acevedo J., Lópéz-González J.A., 2005, Series históricas de captura de atún rojo. In: Acuicultura, pesca y marisqueo en el Golfo de Cádiz. Consejería Agric. & Pesca, Junta Andaluc., libro electrónico.

Russo A., 1913, Effetti della pesca con le sorgenti luminose sul prodotto delle reti da posta a Catania e sul prodotto delle tonnare della Sicilia orientale. Atti Accad. Gioenia Sci. Nat., 5 (6): 1-19.

Russo A., 1947, Problemi connessi alla chiusura ed alla riattivazione delle tonnare del Mediterraneo. Atti Acc. Naz. Lincei, Roma, serie 8 (3): 28-34.

Russo Petronilla M.A., 1988, Le incursioni corsare dal XV al XVI secolo. Editekna, Trapani: 1-193.

Russo S., 1983, Siracusa e la prima inchiesta industriale. Riv. Provincia di Siracusa, II (6).

Sañez Reguart A., 1791, Diccionario Histórico de los Artes de la Pesca Nacional. Imp. Joaquim Ibarra, Madrid, t.1: 1-406.

Sanzo L., 1927, Reazione negativa del Tonno alla luce e suo sfruttamento benefico delle nostre tonnare (1). R. Com. Talass. Ital., Ist. Centr. Biol. Mar., Messina (134) : 1-9.

Sarà R., 1983, Tonni e Tonnare. Libera Università di Trapani Ed., Trapani: 1-128.

Sarà R., 1998, Dal mito all'aliscafo. Storie di Tonni e Tonnare. Banca Aegusea Ed., Favignana-Palermo.

Sarà R., Dean J.M., D'Amato D., Buscaino G., Oliveri A., Genovese S., Ferro S., Buffa G., Lo Martire M., Mazzola S., 2007, Effect of boat noise on the behaviour of bluefin tuna *Thunnus thynnus* in the Mediterranean Sea. Marine Ecology Progress Series, 331: 243-253.

Sarmiento Martin G., 1757a, De los atunes y sus transmigraciones y conjeturas sobre la decadencia de las almadrabas y sobre los medios para restituirlas. Reprint: Caixa de Pontevedra, Madrid.

Sarmiento Martin G., 1757b, Almadrabas y Atúnes. Tomo XII, folio 44.

Savarino R., 1960, La famiglia Nicolaci: strategie economiche ed ascesa sociale (1693-1774). Atti e Memorie ISVNA, Noto.

Scordia C., 1925, Le condizioni fisico-biologiche delle acque della tonnara del Tono (Milazzo) durante la campagna di pesca del 1929. Boll. Ist. Zool. Univ. Messina, 4.

Scordia C., 1929, Osservazioni sulle condizioni fisico-chimiche delle acque della tonnara di S. Lucia

Siragusa G., 1980, Una ricerca sulla decadenza delle tonnare in Sicilia. Boll. Soc. Geogr. Italiana, XI (1-6): 1-212.

Sorbello S., 2010, La pesca del tonno nel capolinea del Sud: Vendicari/Marzamemi/Portopalo di Capo Passero. Emanuele Romeo editore, Siracusa: 1-119.

Storai T., Cristo B., Zuffa M., Zinzula L., Floris A., Campanile T.A., 2006, The Sardinian large elasmobranch database. Cybium 30: 141–144.

Storai T., Zinzula L., Cristo B., Human B., 2007, First record of *Carcharhinus brachyurus* (Gunther 1870) (Chondrichthyes; Carcharhinidae) from Sardinian waters (central Mediterranean). Annales Series Historia Naturalis, 17: 177–182.

Storai T., Zinzula L., Repetto S., Zuffa M., Morgan A., Mandelman J., 2011, Bycatch of large elasmobranchs in the traditional tuna traps (tonnare) of Sardinia from 1990 to 2009. Fish. res., 109: 74-79.

Strabonis, I a.C., Geografia, lib. V. De Situs Orbis, Lib. XVII. Reprint (1564), Erincum Petri, Basilae: 1-500.

Tomaseti R., 1837, Expediente de los empresarios de buche de Punta La Isla (San Fernando). Archivo Histórico Provincial de Cádiz: Gobierno Civil, Caja 213.

Turrel L., 1872, La question des Madragues. Bull. Soc. Acclim. France, 2, sér., 9: 564-577.

Turrel L., 1875, La trêve des filets trainants. Bull. Soc. Acclim. France, 3, sér. 2: 453-457.

Vacchi M., Biagi V., Pajetta R., Fiordiponti R., Serena F., Notarbartolo di Sciara G., 2002, Elasmobranch catches by tuna trap of Baratti (northern Tyrrhenian Sea) from 1898 to 1922. In: Vacchi, M., Lamesa, G., Serena, F., Séret, B. (Eds.), Proceedings of the 4th European Elasmobranch Association Meeting. ICRAM/ARPAT/SFI, Livorno: 177–183.

Vargas G., Alberto E., Florido del Corral D., 2010, The origin and development of tuna fishing nets (almadrabas). In: Proceedings of the International Workshop on "Ancient Nets and Fishing Gear in Classical Antiquity. A First Approach". Monographs of the Sagena Project 2. Aarhus University Press, Aarhus: 205-227.

Vial G., Revelli G.M.P:, 1767, Disputa per l'illustre Marchese di Villamarina D. Fernandino Pes convenuto contro l'Illustre Duca di San Pietro e Carlo Forte D. Alberto Antonio Genovese, e de Roma Cervellon Marchese della Guardia attore nella causa tra essi vertente avanti questo S.R.C. in virtù di lettere causa vivendi 10 Febbraio 1758 per la Tonnara volgarmente detta della Isola Piana. Gaspare Bajno Stampatore, Torino: 1-31 and attachments.

Zaitsev Y., Mamaiev V., 1997, Biological diversity in the Black Sea. A study of change and decline. United Nations Publications, Black Sea Environment Series, 3: 1-204.

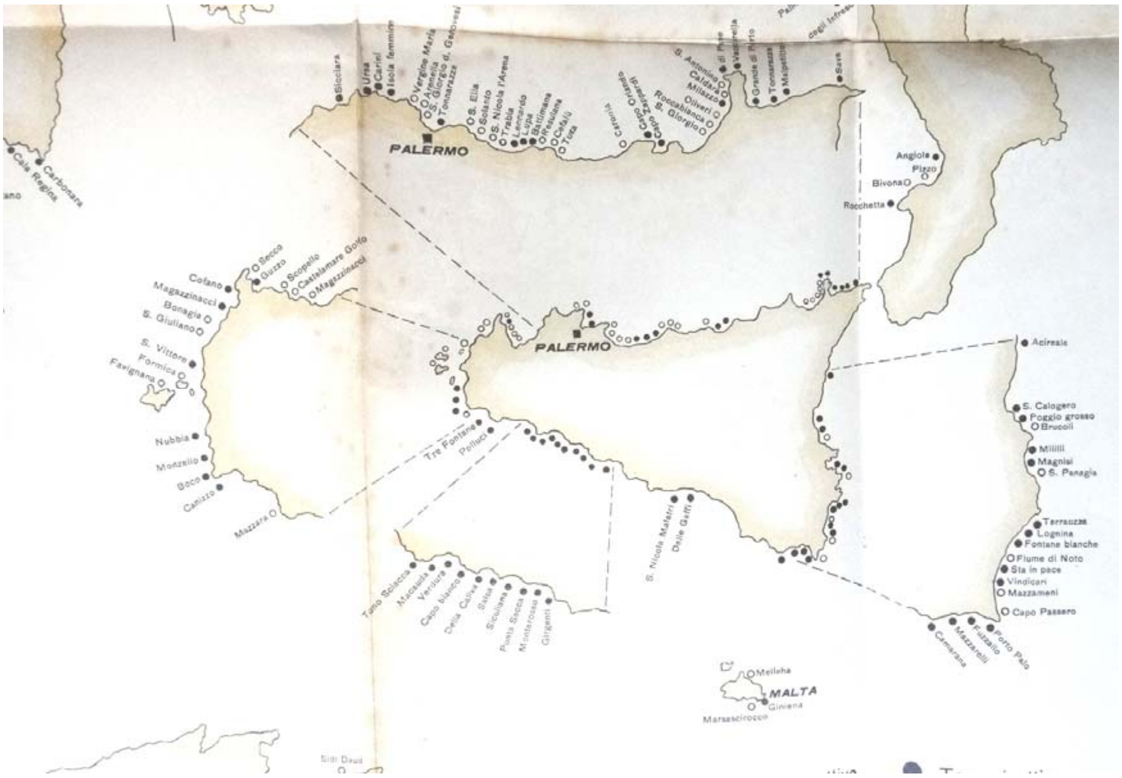

Figure 1. Map showing the distribution of tuna traps in Sicily in the first part of the XX century, the area with the highest concentration of tuna traps in the Mediterranean (from Parona, 1919). (white dots indicate active traps).

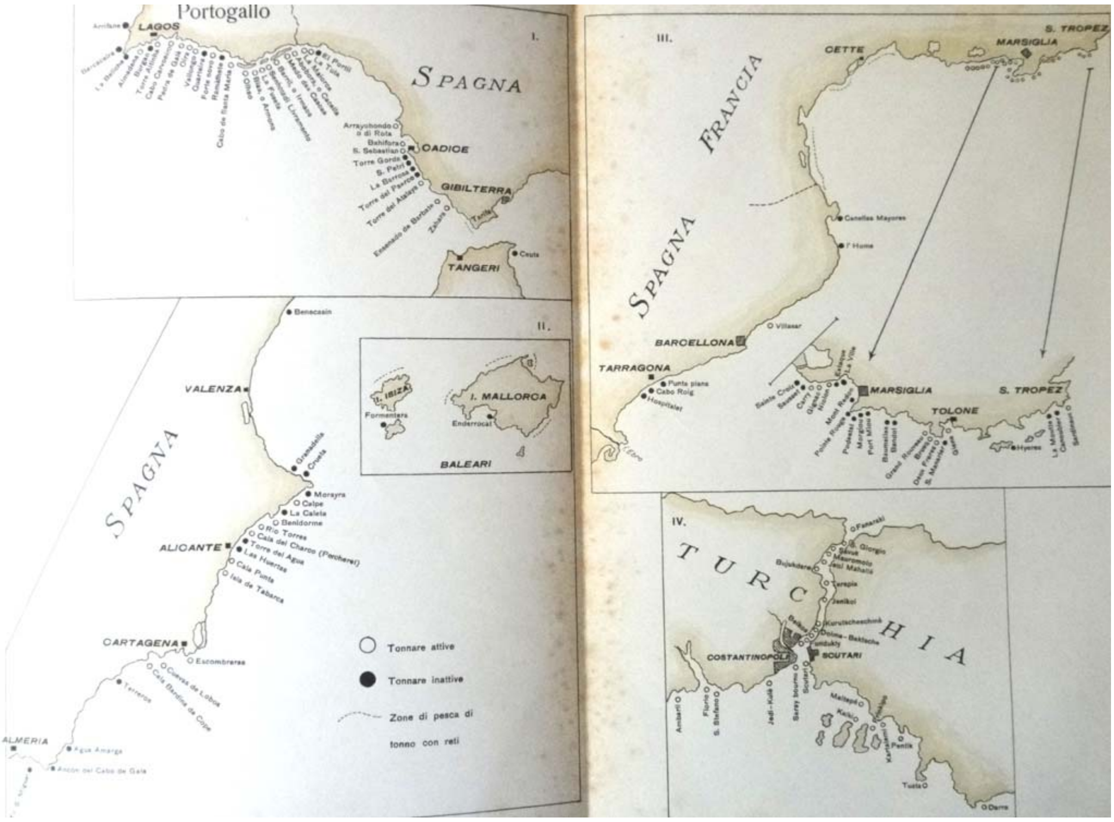

Figure 2. Map showing the distribution of tuna traps in Portugal, Spain, France and Turkey in the first part of the XX century (from Parona, 1919) (white dots indicate active traps).

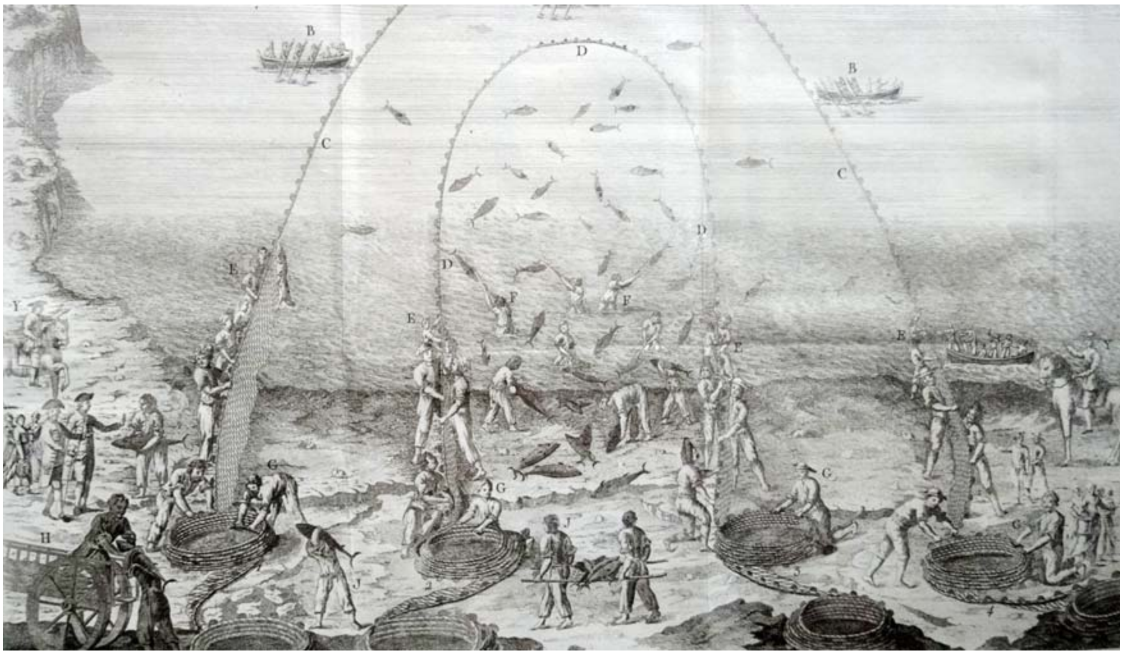

Figure 3. Beach seine “tuna trap” (almadraba de tiro) (from Sañez Reguart, 1791).

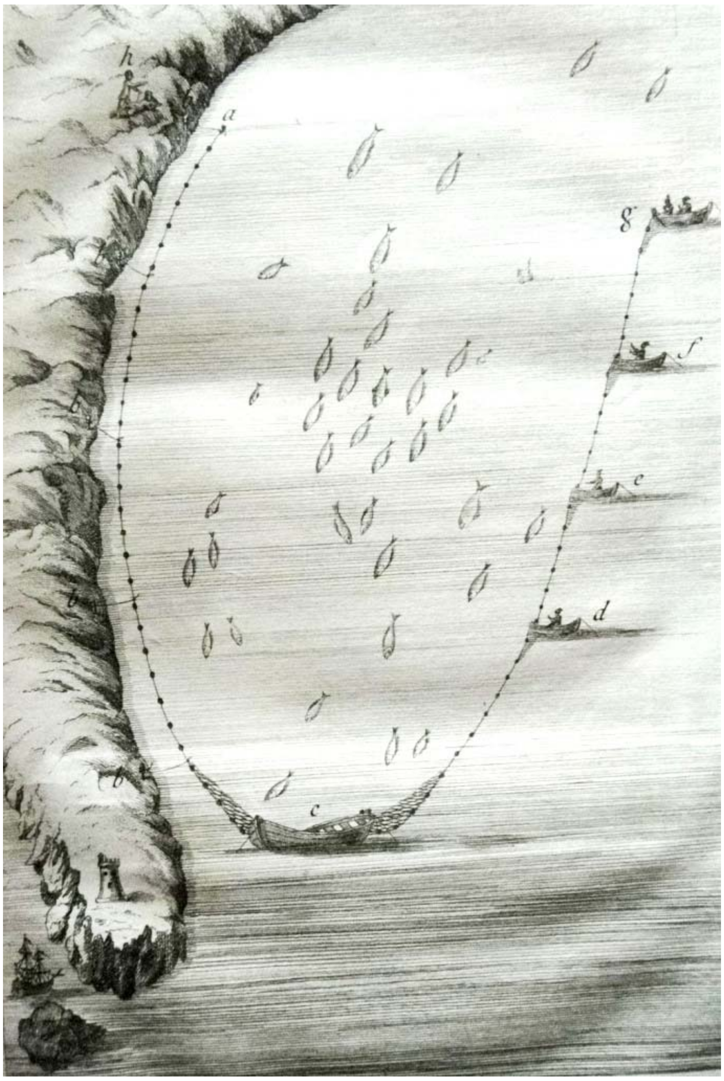

Figure 4. Boat seine “tuna trap” (almadraba de tiro) (from Sañez Reguart, 1791).

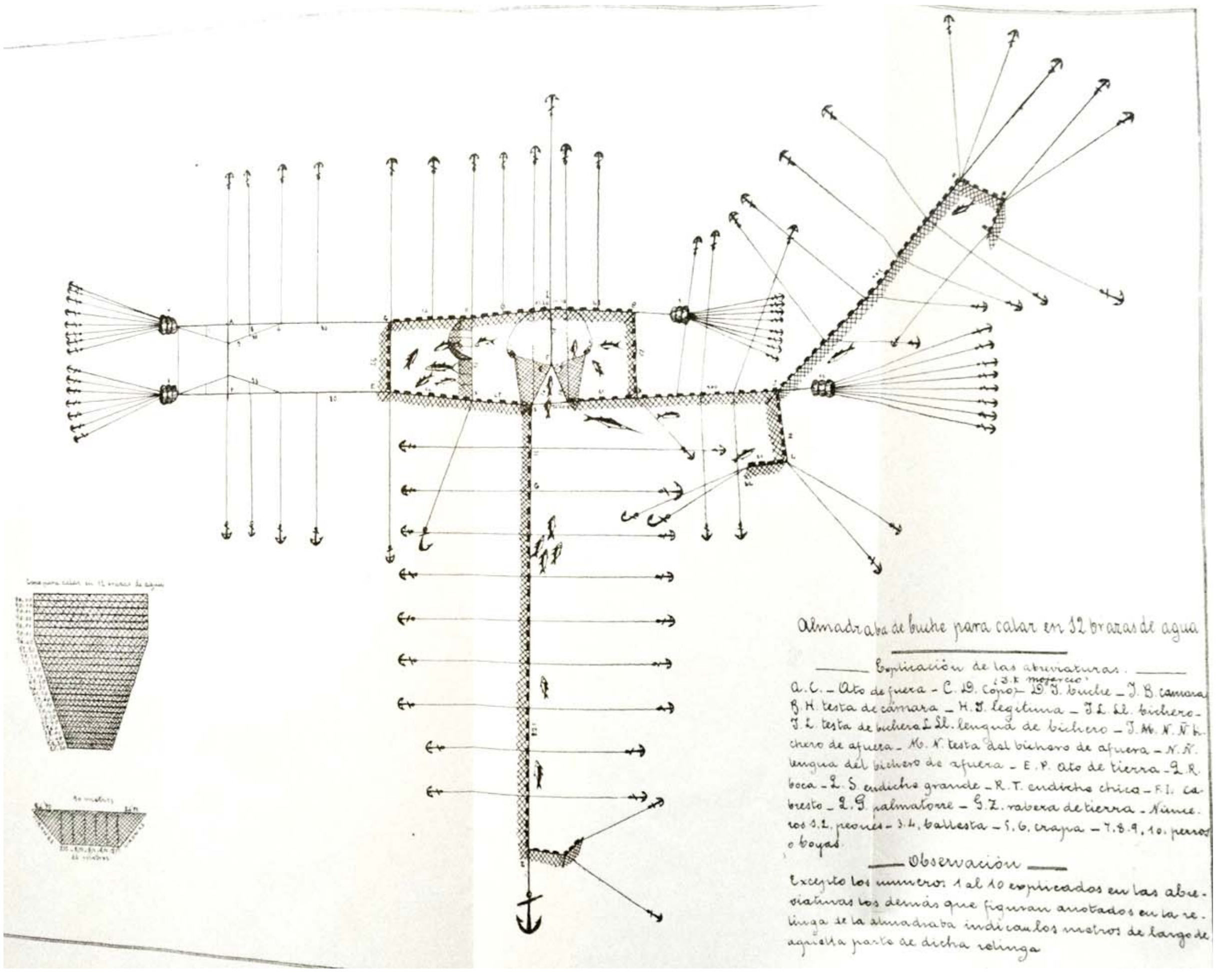

Figure 5. Mix type tuna trap (almadraba de buche, in a particular configuration) (from Rodriguez Santamaria, 1920).

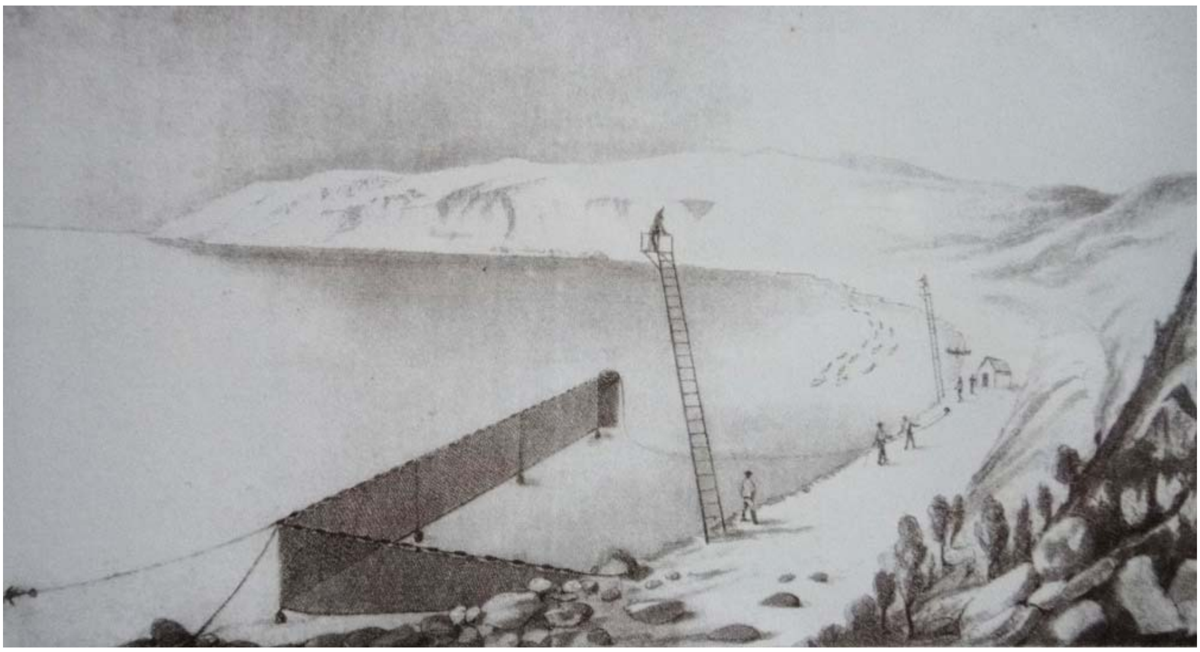

Figure 6. Mix type tuna trap (almadraba de buche, in a particular configuration) (from Rodriguez Santamaria, 1920).

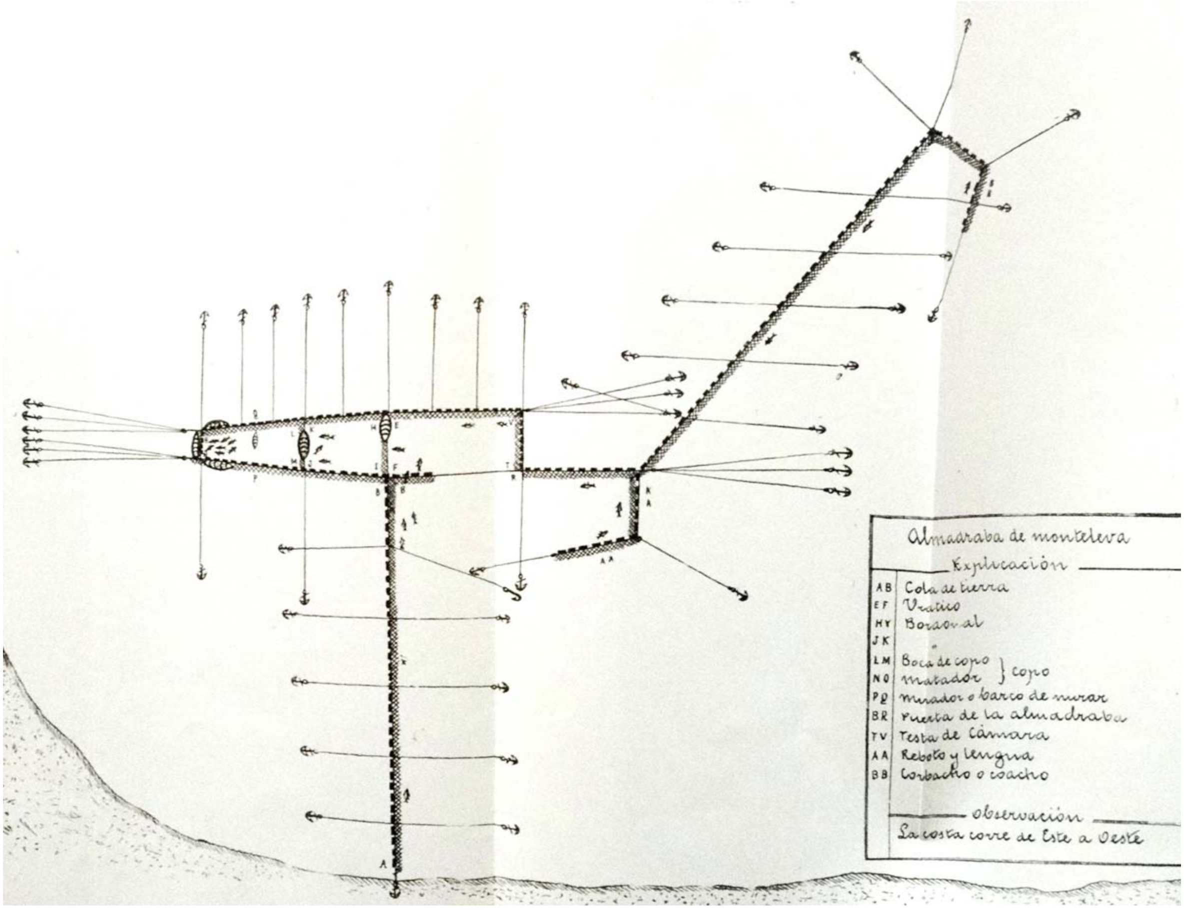

Figure 7. Traditional set-type tuna trap (almadraba de monteleva, in a particular configuration) (from Rodriguez Santamaria, 1920).

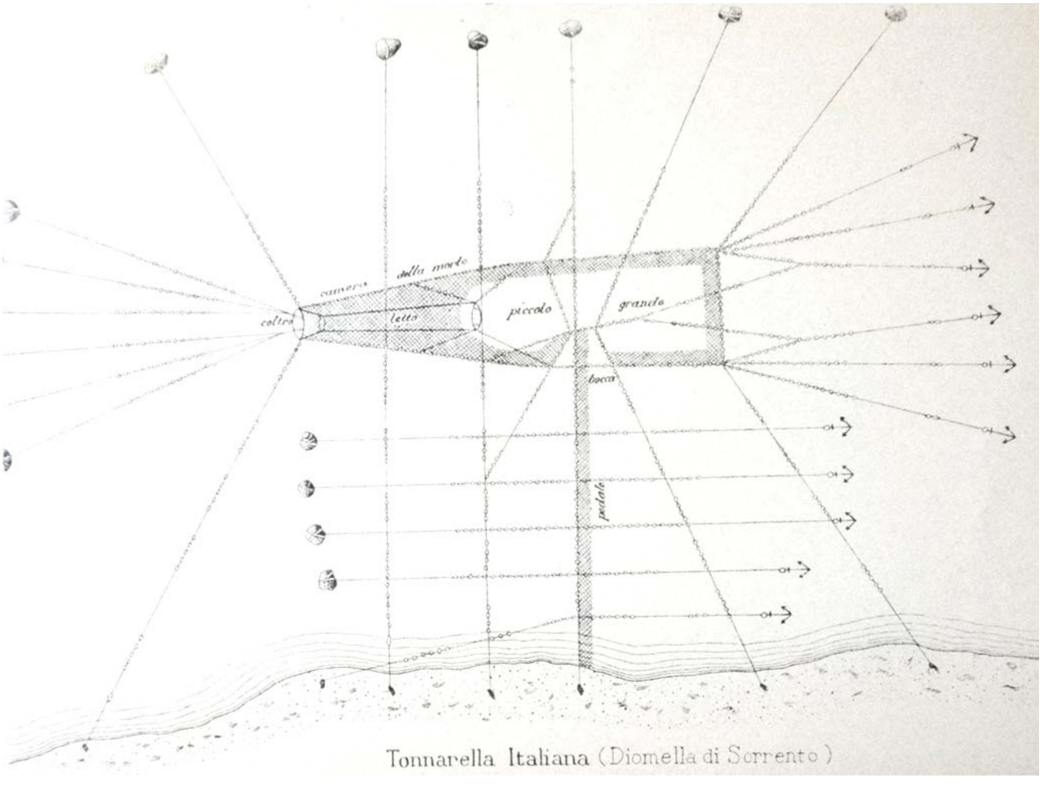

Figure 8. Traditional small set-type tuna trap ("tonnarella" or "petit madrague") (from Parona, 1919).