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EASTERN ATLANTIC BLUEFIN TUNA: WHAT WE LEARN FROM HISTORICAL TIME-SERIES OF TRAP CATCHES

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SUMMARY

More than one hundred long-term time-series of bluefin tuna catches from the ancestral Mediterranean and Atlantic trap fisheries are used to (1) estimate historical range of BFT yields in the Mediterranean and adjacent Atlantic and (2) investigate spatial and temporal patterns of fluctuations in trap catches. Mean historical catches were around 110 000 tunas/year (± 50 000), i.e. 15 000 tons/year (∈[7 000;25 000]). Fluctuations in trap catches are of large magnitude, periods of high abundance being up to seven times higher than those of low abundance. More interesting was the occurrence of 100-year-long periodic fluctuations as well as 20-year cycles. These medium- to long-term fluctuations, representing more than 50% of the total variability in the time-series, were synchronous all around the western Mediterranean and adjacent North Atlantic. In contrast, short-term variability was only synchronous at a local scale. It is argued that long-term fluctuations in trap catches could be considered as a proxy of those in abundance, and a synthetic time-series has been computed to depict them. Biological and ecological processes that could cause such long-term fluctuations as well as implication of such fluctuations in term of fisheries management are discussed.

RÉSUMÉ

Plus de cent séries long terme de capture de thon rouge par les madragues sont utilisées pour (1) estimer un niveau de prise historique en Méditerranée et sur le proche-Atlantique et (2) étudier les fluctuations spatio-temporelles des captures. Les prises historiques moyennes s'élèvent à 110 000 thons/an (± 50 000), i.e. 15 000 tonnes/an (∈[7 000;25 000]). Les captures des madragues fluctuent de manière importante, avec des périodes de forte abondance pouvant être jusqu'à sept fois plus productives que les périodes de faible abondance. La variabilité temporelle des captures peut être décomposée en trois composantes : des cycles pseudo-séculaires, des variations périodiques d'une vingtaine d'années et des fluctuations inter-annuelles. Les fluctuations moyen et long terme, expliquant plus de la moitié de la variance totale des séries, sont synchrones tout autour du bassin méditerranéen occidental et du proche Atlantique. La variabilité inter-annuelle, en revanche, n'est synchrone qu'à une échelle locale. On montre que les fluctuations long terme des captures des madragues peuvent être considérées comme de bons indices des fluctuations long terme des abondances, et une série synthétique est construite pour les décrire. Les processus biologiques et écologiques susceptibles d'être à l'origine de ces fluctuations, ainsi que leurs implications en terme de gestion des stocks sont finalement discutées.

RESUMEN

Se han utilizado más de cien series temporales a largo plazo de captura de atún rojo procedentes de las almadrabas ancestrales del Mediterráneo y el Atlántico para: 1) estimar el rango histórico del rendimiento del atún rojo en el Mediterráneo y el Atlántico adyacente y 2) investigar los patrones espaciales y temporales de las fluctuaciones en las capturas de las almadrabas. Las capturas históricas medias fueron de alrededor de 110.000 atunes/año (±50.000), es decir, 15.000 toneladas/año (∈ [7.000-25.000]). Las capturas de las almadrabas fluctúan enormemente, los periodos de gran abundancia son hasta siete veces mayores que los de baja abundancia. Más interesante es la existencia de fluctuaciones periódicas de 100 años de duración y de ciclos de 20 años. Estas fluctuaciones de medio a largo plazo, que representan más del 50% de la variabilidad total de las series temporales, eran sincrónicas en todo el

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Mediterráneo occidental y el Atlántico norte adyacente. Como contraste, la variabilidad a corto plazo sólo era sincrónica a escala local. Se demuestra que las fluctuaciones a largo plazo en las capturas de las almadrabas podrían ser consideradas como una aproximación de los índices de las fluctuaciones a largo plazo de la abundancia y se ha calculado una serie temporal sintética para representarlas. Se discuten los procesos biológicos y ecológicos que podrían provocar estas fluctuaciones a largo plazo, así como la implicación de tales fluctuaciones en términos de ordenación.

KEY WORDS

Thunnus thynnus; Time series analyses; Abundance; Population dynamics; Long-term changes; Trapfishing

1.INTRODUCTION

Animal population abundance are known to fluctuate naturally over space and time (Begon *et al*., 1996; Kendall *et al*., 1999; Lundberg *et al*., 2000). In the context of fish population, this paradigm was introduced as early as 1914 by Hjort (1914), but it was often neglected. Fluctuations in fish stock sizes were indeed often ascribed to human exploitation, probably because most studies focus on highly exploited populations (such as the North Atlantic cod stocks) and over relatively short time periods (<50 years, e.g. Garrod and Schumacher, 1994; Hutchings, 1996; Myers *et al.,* 1996; Cook *et al*., 1997). Some studies have, however, linked long-term fluctuations in fish populations to variations in environmental conditions (Cushing and Dickson, 1976; Cushing, 1982; Southward *et al*., 1988; Dickson and Brander, 1993; Fromentin *et al*., 1998) or to changes in biotic processes (May, 1974; Myers and Cadigan, 1993; Fortier and Villeneuve, 1996; Fromentin *et al*., 2001).

In 2000, Fromentin *et al.* described long-term fluctuations in bluefin tuna trap catches, and outlined the hypothesis that such long-term trends in trap catches could represent those in abundance. This study, however, was a restricted data set and it was necessary to look for additional time-series to validate the hypothesis. In this paper, we present several centuries of catches of Atlantic bluefin tuna *Thunnus thynnus* (Linné 1758, BFT) by the ancestral Mediterranean and adjacent Atlantic trap fisheries. We carried out time-series analyses to decompose the temporal signal and tested whether long-term fluctuations in catches could be considered as a proxy of those intrue abundance. Then, we estimated an historical range of catches in the Mediterranean and adjacent Atlantic. We further discuss the implication of such fluctuations in term of fisheries management.

2. HISTORICAL CATCHES FROM TRAP FISHERIES

For ages, fishermen took benefit of the seasonal migrations of bluefin in the Mediterranean by setting traps along its routes (Doumenge, 1998). To catch tuna, fishers traditionally used either traps or beach-seines (Doumenge, 1998), the latter gear sometimes incorrectly referred to also as traps. Unlike traps, beach-seines need many hands to operate, so progressively they have been replaced by fixed gear. The trap system was used throughout the Mediterranean Sea and along the adjacent North Atlantic coasts (Fig. 1), from the 14th century in Sicily, the 16th century in Sardinia and Portugal, and the 19th century in Tunisia, Spain, and Morocco (Berthelot, 1869; Cancila, 1972; Parona, 1919; Pavesi, 1889).

The traps are fixed nets set perpendicular to the coast, that stop the tuna from migrating and guide them through several enclosures to the final "death room". There, tunas are gaffed during the "matanza". Numerous authors have shown that the name and location of the traps has remained the same over time (e.g. Sarmiento, 1757; Parona, 1919; Buen, 1925; Sella, 1929; Anonymous, 1931; Rodriguez-Roda, 1964; Conte, 1985). Moreover, traps were hardly modified until the middle of the

20th century (Thomazi, 1947; Doumenge, 1998), suggesting that fishing effort may have remained roughly unchanged over centuries. However, since the beginning of the 20th century, there have been some modifications. Increasing coastal traffic, noise, and pollution possibly led to a reduction in trap efficiency. Nevertheless, changes remained minor until the 1960s (Doumenge, 1998). Then, technical innovations, such as the replacement of the traditional nets of hemp by nylon nets and, above all, the development of active fishing gears (e.g. purse-seine and longliner) completely changed the context of the bluefin tuna fisheries and rendered the traps progressively less important (Farrugio, 1981; Addis *et al.*, 1996; Doumenge, 1998). For these reasons and to avoid any variations that could result from crucial changes in fishing effort and/or catchability, we restricted the analyses to data prior to 1960.

Traps generally belonged to aristocracy and bankers, who kept detailed accounts of the catches during several centuries. We searched intensively through national and naval archives, scientific libraries and various Mediterranean laboratories for collecting the historical catch data. They were retrieved either from old records published by local authorities or the clergy (e.g. Sarmiento, 1757), in books of historical analyses (e.g. Cancila, 1972), in owners' archives (e.g. Duchy of Medina Sidonia), or in the personal archives of passionate and relentless scientists (e.g. Sella, Scaccini, Rodriguez-Roda).

More than one hundred time series were gathered, but only the 54, that were at least 20 years long, were finally used for the analysis. The oldest time series of trap catches went back to the XVIIth century for Sicily, XVIIIth for Portugal, XIXth for Sardinia and Tunisia, and XXth for Spain and Morocco. About one-third of the time series were more than 50 years long and six ones spread over more than a century. For more details on data collection and/or time-series, see Ravier and Fromentin (in press).

3. HISTORICAL LEVEL OF BLUEFIN CATCHES

Traps were the main gear to catch bluefin tuna in the Mediterranean and near Atlantic for centuries, until the development of modern, active fishing techniques, e.g. purse-seining and longlining, during the second part of the XXth century. Places and periods of activity of most of the traps are known from the literature (Aloncle, 1964; Berthelot, 1869; Cancila, 1972; De Fages and Ponzevera, 1908; Hamre *et al.*, 1966; Pavesi, 1889; Scaccini and Paccagnella, 1965). From the early XVIIth century to the mid-XXth century, the main traps were settled, so our data collection covered most of the fishing activity. However, information on catches are sometimes missing, from place to place or time to time, because of a lack of records (Spain during the XIXth century), or loss or destruction of archives (e.g. the catches of Formica and Favignana traps for the mid-XIXth century in a fire, Guarrasi, pers.com.; the details information on Portuguese traps after 1930, Vasoncelos, pers.com.). Finally, we can consider that the data collection is complete since 1825 for Sardinia, 1863 for Tunisia, 1878 for Sicily, 1896 for Portugal, 1910 for Spain and 1914 for Morocco.

These historical time-series of trap catches allow to estimate a mean level of historical bluefin catches over the Mediterranean and Gibraltar area. The range of historical catches is estimated over the 1910-1930 period, which is well documented (the Spanish traps catches, which represented around 40% of the total catches, are only available after 1910) and corresponds to a period of medium production. Atlantic catches represented 65% of the total trap catches. Average catches could be divided into 42 700 tunas/year for Spain, 22 900 tunas/year for Portugal, 16 000 tunas/year for Sicily, 12 100 tunas/year for Tunisia, 9 300 tunas/year for Sardinia, 8 250 tunas/year for Morocco (Fig. 2). Moreover, minor traps, in Algeria and France, yielded around 1 300 tunas/year. These annual catches were however highly variable and ranged from 50 000 to 160 000 tunas for the western Mediterranean and the adjacent Atlantic. Considering the mean weight of tunas caught by areas (175kg in Portugal, 160kg in Spain and Morocco, 110kg in Sicily, 100kg in Sardinia and 80kg in Tunisia), average annual yield were estimated at around 15 000 tons (from 7 000 to 25 000 tons). However, landings during the period of high abundance (e.g. late XIXth century) were probably clearly above, the available time-series displaying catches from 0.5 to 1.5 times higher the mean, whereas catches during the period of low abundance (e.g. early XIXth century) were 1 to 2 times lower the mean. For comparison, the yields of the East Atlantic BFT declared to ICCAT for the last 10 years, ranged between 30 000 and 53 000 tons/year, i.e., 2 to 3 times higher than average historical yields by traps, but over a larger area.

4. LONG-TERM NATURAL FLUCTUATIONS

Fluctuations in trap catches appear to be of large magnitude, periods of high catches being up to 10 times higher than those of low catches. Spectral analyses show that temporal variability may be decomposed into three main components: pseudo-cyclic fluctuations of about 100-120 years, cycles from 30 to 15 years (with a peak around 20 years), and finally year-to-year fluctuations (Fig. 1). Middle and long-term trend were identified by Eigen Vector Filtering and their quantitative importance were estimated: for all the time-series, trends accounted for a large part, i.e. 45% to 80%, of the total variability.

We aimed then to test whether these long-term trends were synchronous between series from all the Western Mediterranean and the near Atlantic. A simple graphical observation of the time series tends to show a synchronicity between the long-term fluctuations in catches of the different traps: period of decreasing catches (1750-1800, 1870-1960) alternated with period of increasing catches (1800-1870) around Gibraltar as along the Sicilian, Sardinian or Tunisian coasts (Fig. 1). To check this, we computed spatial correlograms to test for significant autocorrelation, i.e. synchrony, between sites located within any given range of distances apart. (Fig. 3). To check whether synchrony was attributable to trends alone or to both trends and year-to-year fluctuations, analyses were performed on both original and detrended time-series. Whatever the distance between the trap, all original time-series appeared to be significantly positively correlated with each other (mean $r \in [0.18-0.51]$). The detrended time-series, on the other hand, appeared to be significantly correlated only up to 200 km apart. Correlograms on long-term time-series thus underline the presence of similar long-term fluctuations in trap catches. We computed others analyses (principal component analyses, test of concordance of Kendall, …), which lead to the same conclusions: long-term trends in trap catches are synchronous over the Western Mediterranean and the near Atlantic coasts, whereas a short-term variability appears at a local scale.

As indicated above, the trap is a passive gear, being submitted to low modification for centuries, which catches bluefin tunas during their yearly spawning migrations. In that way, a trap could be thought as a sampling gear, that would catch each year the same proportion of the migrating bluefin tuna population. These features, together with preliminary analyses (Sella, 1929; Fromentin *et al.*, 2000), lead us to put forward that long-term fluctuations in trap catches could reflect those in true abundance if they vary in the same way all around the Western Mediterranean and the near Atlantic.

The above results would then support the hypothesis according to which long-term fluctuations in trap catches are a good proxy of those in population abundance. Indeed, if the traps did not catch a representative proportion of the bluefin tuna population, there would have been no reason that long-term fluctuations appear synchronous all around the Western Mediterranean basin and along the South coasts of Spain and Portugal.

Finally, a synthetic time-series was calculated to depict the general temporal pattern in Mediterranean bluefin tuna abundance. A filter was applied on this time series to depict the long- and medium-term fluctuations. The trend of this series, which explained 78% of the total variance, can summarise the long-term fluctuations in Mediterranean bluefin tuna abundance from 1634 to 1960, i.e., three 120 years cycles with peaks around 1635, 1760 and 1880 and drops around 1710, 1820, 1930, on which cycles of about 20 years are superimposed (Fig. 4).

5. DISCUSSION

5.1 Hypotheses on the origin of the long-term fluctuations

Several authors have observed and documented periodic fluctuations in bluefin tuna catches (Parona, 1919; Neuparth, 1923; Buen, 1925; Sella, 1929; Lozano Cabo, 1958; Rodriguez-Roda, 1966). Our numerical and statistical analyses specified that the eastern Atlantic bluefin tuna population displayed long-term fluctuations with a period of about 100-120 years, together with cyclic variations of about 20 years. Three main factors have been commonly put forward to explain long-term fluctuations in fish populations:

1) human activity, mainly through overexploitation and pollution of spawning and nursery areas,
2) environmental events,
3) biotic processes, such as predation, cannibalism and competition.

Overexploitation is a well-known feature of many North Atlantic fish populations (Myers *et al.*, 1996; Cook *et al.*, 1997). However, it is unlikely to explain the 100-120 years cycle of variations in bluefin tuna abundance. First, exploitation can hardly lead to cycles of about the same length (more than a century) over different periods and in different locations. Second, trap is a passive gear and the number of traps remained more or less constant over the period analysed, so that the effort is likely to have been constant. In the case of bluefin tuna, factors 2) and/or 3) are more likely.

The environment probably influences migration patterns of fish populations. It could therefore be argued that the 100–120 years cycle in catches of bluefin tuna could result from a switch between Mediterranean and West Atlantic spawning sites attributable to changes in oceanographic conditions and/or food availability. Although the bluefin “homing behaviour” tend to dismiss this hypothesis, new mark-recapture studies do not allow to establish if this natal homing to is strict or not (Cury et al., 1998, Block et al., 2001).

Finally, we put forward that long-term fluctuations in eastern bluefin tuna abundance could be related to two origins. The first one is based on the one hand on the old, but still pertinent, concept of Hjort (1914, 1926), and the works of May (1974) and Cushing (1990), according to which environmental and biotic factors can effect long-term variations in bluefin tuna trap catches, through enhancing or impacting recruitment (see also Fromentin, 2001). The second one is related to biotic processes, such as predation, cannibalism, and competition resulting from food and habitat limitations, which can generate cycles and long-term fluctuations in fish stocks, through density-dependent-mortality/growth and resonant effects (Caley *et al.*, 1996; Knell, 1998; Bjørnstad *et al.*, 1999; Fromentin *et al.*, 2001).

5.2 Fisheries implications

The ICCAT convention states that stocks should be managed of their respective maximum sustainable yield (MSY). The search for a unique and absolute reference point to manage a stock implicitly supposes that the population is at an equilibrium or a steady state. However, our results showed that long-term variations in population abundance are of importance, so that the concept of MSY could be irrelevant for a population with complex dynamics, such as the Northeast Atlantic and Mediterranean bluefin. It appears critical to define a suitable approach that would take into account the natural variability of this stock, by determining, for instance, a level of reference being time dependent instead of a simple reference point.

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7. REFERENCES

ADDIS, P., Cau, A., Davini, M.A., Secci, E., and Scibaldi, G. 1996. Collection of tuna catches by trap-nets in Sardinia : historical (1825-1980) and recent caches (1992-1995). ICCAT Scientific Papers 46(2); pp.132-139.

ALONCLE, H. 1964. Note sur le thon rouge de la baie ibéro-marocaine. Bulletin de l'Institut des pêches du maritimes du Maroc, Casablanca 12; pp.43-59.

ANONYMOUS. 1931. *La pesca nei mari e nelle acque interne d'Italia,*. Ministerio Agric. e Foreste, Instituto Poligrafico dello Stato vol II.

BEGON, M., Harper, J.L., and Townsend, C.R. 1996. Ecology (Third ed.). Blackwell Science, Oxford. 1068.

BERTHELOT, S. 1869. Etudes sur les pêches maritimes dans la Méditerranée et l'océan. Ed. Challamel ainé, Paris. 211.

BJØRNSTAD, O.N., Fromentin, J.M., Stenseth, N.C., Johannessen, T., and Gjosaeter, J. 1999. A new test for density-dependent survival: the case of coastal cod population. Ecology 80; pp.1278-1288.

BLOCK, B.A., Dewar, H., Blackwell, S.B., Williams, T.D., Prince, E.D., Farwell, C.J., Boustany, A., Teo, S.L.H., Seitz, A., Walli, A., and Fudge, D. 2001. Migratory movements, depth preferences, and thermal biology of Atlantic bluefin tuna. Science 293; pp.1310-1314.

BUEN (de), F. 1925. Biologia del atun (*Orcynnus Thynnus* L.) (Resultado Campañas Realizadas por Acuerdos Internacionales 1:). Commission Internationale pour l'Exploration Scientifique de la mer Méditerranée, Madrid. 118.

CALEY, M.J., Carr, M.H., Hixon, M.A., Hughes, T.P., Jones, G.P., and Mennge, B.A. 1996. Recruitment and the local dynmics of open marine populations. An. Rev. Ecol. Syst. 27; pp.477-500.

CANCILA, O. 1972. Aspetti di un mercato Siciliano. Trapani nei secoli XVII - XIX (Storia Economica di Sicilia . Unione delle camere di commercio industria ed agricoltura della regione siciliana, Castanissetta. 262.

CONTE, G. 1985. Addio Amico tonno. Indagine sulle tonnare di Portopaglia, Portoscuso e Isola Piana dal XVI secolo ai giorni nostri. Edizione della torre, Cagliari. 135.

COOK, R.M., Sinclair, A., and Stefansson, G. 1997. Potential collapse of the North Sea cod stocks. Nature 385; pp.521-522.

CURY, P., Anneville, A., Bard, F.X., Fonteneau, A., and Roy, C. 1998. Obstinate North Atlantic bluefin tuna (*Thunnus thynnus thynnus*): an evolutionary perspective to consider spawning migration. ICCAT Scientific Papers 50(1); pp.239-247.

CUSHING, D.H. 1982. Climate and fisheries. Academic Press, London. 373.

CUSHING, D.H. 1990. Plankton production and year class strength in fish populations: an update of the match/mismatch hypothesis. Adv. Mar. Biol. 26; pp.249-293.

CUSHING, D.H., and Dickson, R.R. 1976. The biological response in the sea to climatic changes. Adv. Mar. Biol. 14; pp.1-122.

DE FAGES, E., and Ponzevera, C. 1908. Les pêches maritimes de la Tunisie. Imprimerie J. Picard and Cie, Tunis. 318.

DICKSON, R.R., and Brander, K.M. 1993. Effects of a changing windfield on cod stocks of the North Atlantic. Fish. Oceanogr. 2; pp.124-153.

DOUMENGE, F. 1998. L'histoire des pêches thonières. ICCAT Scientific Papers 50(2); pp.753-802.

FARRUGIO, H. 1981. Exploitation et dynamique des populations de thon rouge, *Thunnus thynnus* (Linné 1758), Atlanto-Méditerranéennes. Doctorat d'Etat: Université des Sciences et Techniques du Languedoc. 266.

FORTIER, L., and Villeneuve, A. 1996. Cannibalism and predation of fish larvae by larvae of Atlantic mackerel, *Scomber scombrus*, trophodynamics and potential impact on recruitment. Fish. Bull. 94; pp.268-281.

FROMENTIN, J.-M. 2001. Can stochastic variations in recruitment induce long-term fluctuations in the carrying capacity? ICCAT Scientific Papers, in press.

FROMENTIN, J.-M., Fonteneau, A., and Farrugio, H. 2000. Biological key reference points and natural long-term fluctuations : the case of the Atlantic bluefin tuna. ICCAT Scientific Papers 51; pp.2072-2084.

FROMENTIN, J.-M., Myers, R.M., Bjørnstad, O., Stenseth, N.C., Gjøsæter, J., and Christie, H. 2001. Effects of density-dependent and stochastic processes on the stabilization of cod populations. Ecology 82(2); pp.567-579.

FROMENTIN, J.-M., and Restrepo, V. 2001. Recruitment variability and environment: Issues related to stock assessments of Atlantic tunas. ICCAT scientif Documents ; pp.1780-1792.

FROMENTIN, J.-M., Stenseth, N.C., Gjøsæter, J., Johannessen, T., and Planque, B. 1998. Long-term fluctuations in cod and pollack along the Norwegian Skagerrak coast. Marine Ecology Progress Series 162; pp.265-278.

HAMRE, J., Lozano, F., Rodriguez-Roda, J., and Tiews, K. 1966. *Report from the Bluefin Working Group*. Cons. Perm. Int. Expl. Mer.

HJORT, J. 1914. Fluctuations in the great fisheries of northern Europe. Viewed in the light of biological research. Rapport et Procès-verbaux des Réunions du Conseil International pour l'Exploration de la Mer 20; pp.1-228.

HJORT, J. 1926. Fluctuations in the year classes of important food fishes. Journal du Conseil International pour l'Exploration de la mer 1; pp.5-38.

KENDALL, B.E., Briggs, C.J., Murdoch, W.W., Turchin, P., Ellner, S.P., McCauley, E., Nisbet, R.M., and Wodd, S.N. 1999. Why do population cycle? A synthesis of statistical and mechanistic modelling approaches. Ecology 80(6); pp.1789-1805.

KNELL, R.J. 1998. Generation cycles. TREE 13(5); pp.186-190.

Lozano Cabo, F. 1958. Applications des échosondeurs à l'étude des migrations de thon. CGPM Tech. Pap. 8.

LUNDBERG, P., Ranta, E., Ripa, J., and Kaitala, V. 2000. Population variability in space and time. Trends in ecology and evolution 15(11); pp.460-464.

MARSAC, F. 1999. Changements hydroclimatiques observés dans l'Atlantique depuis les années 50 et impacts possibles sur quelques stocks de thons et leur exploitation. ICCAT Scientific Papers 49; pp.346-370.

MAY, R.C. 1974. Larval mortality in marine fishes and the critical period concept. *In* the early life history of fish, 3-19. Ed. by J.H.S. Blaxter. Springler-Verlag, New-York.

MYERS, R.A., and Cadigan, N.G. 1993. Density-dependant juvenile mortality in marine demersal fish. Can. J. Fish Aquat. Sci. 50; pp.1576:1590.

MYERS, R.A., Hutchings, J.A., and Barrowman, N.J. 1996. Hypotheses for the decline of the cod in the North Atlantic. Mar. Ecol. Prog. Ser. 138; pp.293-308.

NEUPARTH, A.E. 1923. Les variations de rendement des madragues portugaises. Comm. Int. Explor. Mer, Paris. .

OLAFSDOTTIR, D., and Ingimundardottir, T. 2000. Preliminary report on experimental fisheries and biological research on bluefin tuna (Thunnus thynnus) within the Icendic EEZ in 1996-98. ICCAT Scientific Papers 51; pp.827-838.

PARONA, P. 1919. Il tonno e la sua pesca. Memoria, R. Comitato Talassografico Italiano 68; pp.265.

PAVESI, P. 1889. L'industria del tonno. Relatione alla commissione reale per le tonnare, Ministero di Agricultura, Industria e Commercio, Roma. 354.

RAVIER, C., and Fromentin, J.-M. in press. Long-term fluctuations in the Eastern Atlantic and Mediterranean bluefin tuna population. ICES Journal of Marine Science .

RODRIGUEZ-Roda, J. 1964. Biologia del Atun, *Thunnus thynnus* (L.), de la costa sudatlantica de Espana. Investigacion Pesquera 25; pp.33-146.

RODRIGUEZ-Roda, J. 1966. El atun, Thunnus thynnus (L.), de la costa sudatlantica de España en la campaña almadrabera del año 1964 y consideraciones sobre las fluctuaciones periodicas. Investigacion pesquera 30; pp.9-35.

SARMIENTO, F.M. 1757. De los Atunes y sus Transmigraciones y Conjesturas sobre la decadencia de las Almadrabas y sobre los medios para Restituirlas. Caixa de Pontevedra, Madrid. 105.

SCACCINI, A., and Paccagnella, V. 1965. Considérations sur les tendances de la pêche au thon par les madragues italiennes. Proc.gen.Fish.Coun.Medit. 8; pp.391-394.

SELLA, M. 1929. Migrazioni e habitat del tonno (*Thunnus thynnus*, L.) studiati col metodo degli ami, con osservazioni su l'accrescimento, sul regime delle tonnare ecc. Memoria, R. Comitato Talassografico Italiano 156; pp.511-542.

SOUTHWARD, A.J., Boalch, G.T., and Maddock, L. 1988. Fluctuations in the herring and pilchard fisheries of Devon and Cornwall linked to change in climate since the 16th century. J. mar. Biol. Ass. U.K. 68; pp.423-445.

THOMAZI, A. 1947. Histoire de la pêche des âges de la pierre à nos jours. Ed. Payot, Paris. 645.

TIEWS, K. 1978. On the disappearance of bluefin tuna in the North Sea and its ecological implications for herring and mackerel. Rapport et Procès-verbaux des Réunions du Conseil International pour l'Exploration de la Mer 172; pp.301-309.

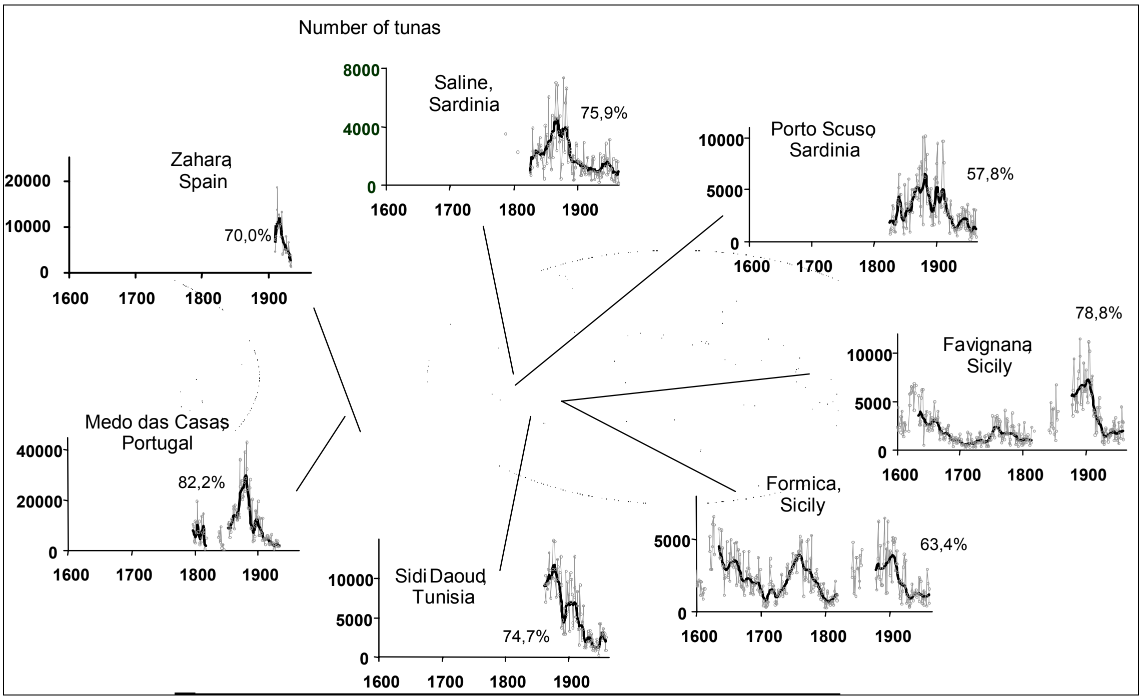

Fig. 1. Some series of trap catches from the Western Mediterranean and the near Atlantic (grey), smoothed by an eigen vector filter (black). The percentage of variance explained by the trend is given.

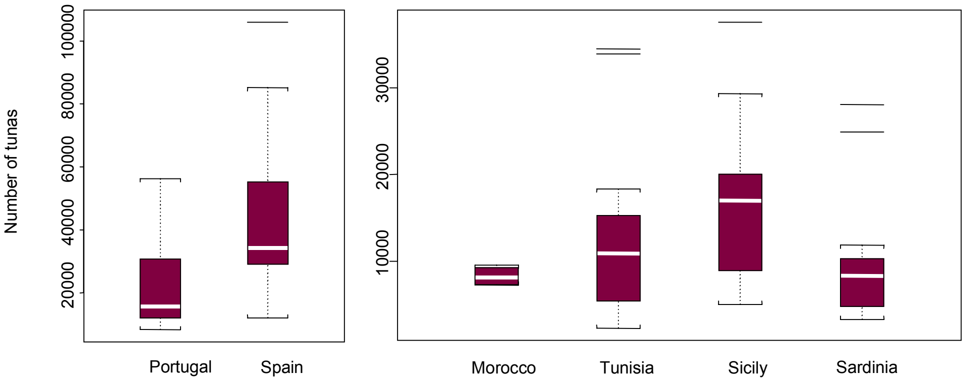

Fig. 2. Regional catches (number of tunas), estimated for the period 1910-1930. The boxplots represent median catches, inferior and superior quarters.

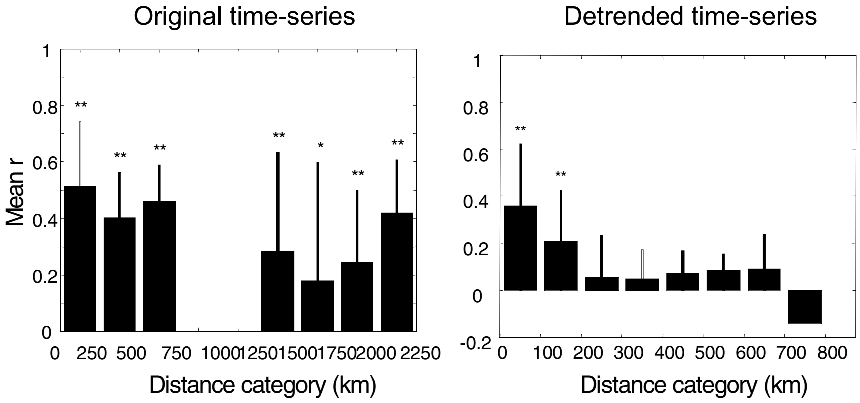

Fig. 3. Correlogram computed on original (left) and detrended time-series (left). Pairwise correlations were divided into distance categories. Mean (+standard deviation) are plotted. Significance is indicated by asterisks, *=p<0.05, **=p<0.01.

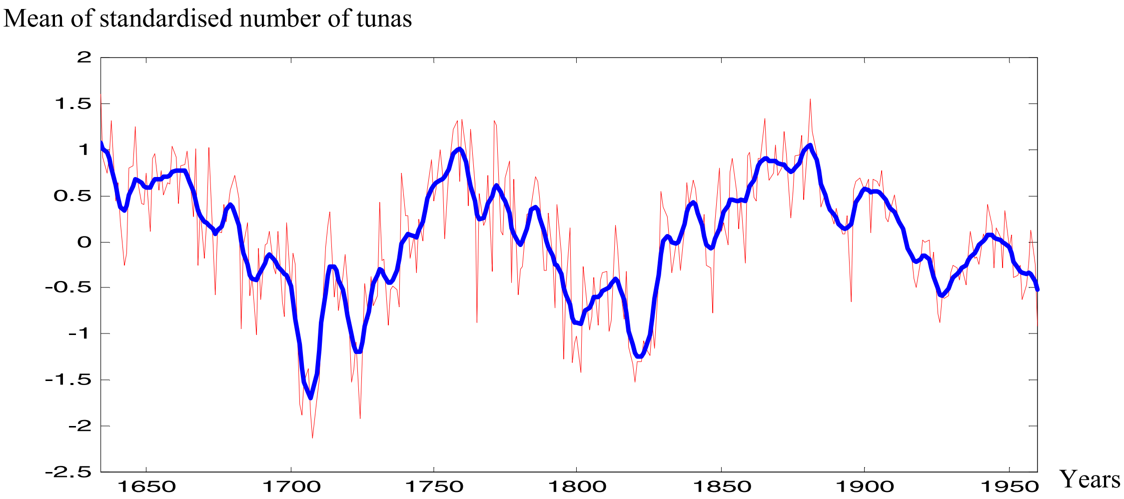

Fig. 4: Synthetic series computed from the data set of trap catches time series (thin line). The trend (bold line) constitutes an index for long-term fluctuations in abundance.