SCRS/2001/115 Col.Vol.Sci.Pap. ICCAT, 54(2): 517-526. (2002)

RETROSPECTIVE ANALYSIS OF THE BLUEFIN TUNA NORDIC FISHERIES DATA

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SUMMARY

A retrospective analysis (1951-1979) was carried out on the bluefin tuna Nordic fisheries (Norway and Germany) length and weight data distributions and compared to those of Barbate trap (Gibraltar strait, Spain) to test further Tiews' hypothesis about the disappearance of bluefin tuna in northern seas. The cohorts were identified from weight/length distributions and compared using multivariate analyses. The results showed: (i) a synchronous ageing in the 4 fisheries, (ii) similar dominant cohorts between South Norway and Barbate in the one hand (cohorts born from 1948 to 1952) and North Norway and Germany on the other hand (cohort born in 1945), (iii) a synchronous drop (or collapse) in the catches that occurred in 1963and (iv) significant correlation between yearly catches. These similarities tend to confirm that the Nordic and Gibraltar tuna are likely to belong to the same population. Moreover, the synchronous ageing in the bluefin tuna catches from the end of the 1950's to the 1980's supported Tiews' s hypothesis (1978), according to which the Nordic fisheries collapsed because of a lack of migrating mature tunas in the northern area.

RÉSUMÉ

Cet article présente une analyse rétrospective (1951-1979) des captures des thon rouge des pêcheries nordiques, comparées à celles de la madrague de Barbate, dans le but de tester et d'approfondir les hypothèses de Tiews concernant l'effondrement des pêcheries nordiques. Les cohortes capturées en Norvège, en Allemagne, et par la madrague de Barbate, ont été identifiées puis comparées par des analyses multivariées. Les résultats ont montré : (i) un vieillissement synchrone des pêcheries, (ii) la présence cohortes dominantes identiques, d'une part au sud de la Norvège et à Barbate (cohortes nées de 1948 à 1952), et d'autre part au Nord de la Norvège et en Allemagne (cohorte née en 1945), (iii) un déclin, ou un effondrement, synchrone des pêcheries en 1963, et enfin (iv) des corrélations significatives entre les séries de captures annuelles. Ces similitudes entre les pêcheries supportent l'hypothèse selon laquelle la même population de thon rouge a été exploitée à Gibraltar et au Nord de l'Europe dans les années 1950 à 1980. De plus, le vieillissement synchrone des pêcheries tend à montrer, comme le supposait Tiews (1978), que l'effondrement des pêcheries nordiques a été causé par une diminution du nombre d'individus matures migrant en Mer du Nord et en Mer de Norvège.

RESUMEN

Se ha llevado a cabo un análisis retrospectivo (1951-1979) sobre las distribuciones de los datos de talla y peso de las pesquerías de atún rojo nórdico (Noruega y Alemania) y se han comparado con las de la almadraba de Barbate (Estrecho de Gibraltar, España) para probar y profundizar en la hipótesis de Tiews sobre la desaparición de atún rojo en los mares del norte. Las cohortes se identificaron a partir de distribuciones peso/talla y se compararon utilizando análisis multivariados. Los resultados han mostrado: (i) un envejecimiento sincrónico en las 4 pesquerías, (ii) la presencia de cohortes dominantes similares entre el sur de Noruega y Barbate por una parte (cohortes nacidas entre 1948-1952) y el norte de Noruega y Alemania (cohorte nacida en 1945) por otra parte, (iii) un descenso o hundimiento sincrónico en las capturas que se produjeron en 1963 y (iv) una correlación significativa entre las capturas anuales. Estas similitudes tienden a confirmar que es probable que los atunes nórdicos y los de Gibraltar pertenezcan a la misma población. Además, el envejecimiento sincrónico en las capturas de atún rojo desde finales de los 50 hasta los 80, respalda la hipótesis de Tiews (1978), según la cual las pesquerías nórdicas se han hundido debido a la falta de atunes maduros que migren a la zona del norte.

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INTRODUCTION

Though bluefin tuna has been occasionally caught since the end of the 19th century around the banks of northern Europe, Nordic fisheries only appeared in the 1920's and really became important after World War II, with the development of purse seining (Binet and Leroy, 1987; Mather, 1995). The landings reached a peak in the middle of the 50's and then decreased sharply to a quasi-disappearance after 1962 (figure 1). The German and Norwegian fisheries were the most productive ones. The former was mainly fishing in the central North Sea with hand lines (Hamre and Tiews, 1964, figure 2). Norwegian purse seiners targeted BFT in the northeastern North Sea and the Norwegian Sea (South of 62°N), as well as North of 63°N along the Norwegian coast.

Tiews (1957a; 1957b; and 1978) and Hamre (1958; 1960) studied the composition of German's catches from 1954 to 1958 and Norwegian's catches from 1951 to 1962, respectively. These investigations provided information on the age distribution of the catches and possible migration patterns to northern Europe through the 50's to the early 60's. In summer, a part of the post-spawning bluefin tuna appeared to migrate from the strait of Gibraltar to northern Europe (figure 2). It seemed that the oldest tunas (age 7 and older) came off southern Norway in early July, then migrated northward to the Lofoten area (Norway) and finally, came back in the North Sea from August through October. It was supposed that younger bluefin (age 5 to 7) reached and stayed in the North Sea, South of Norway, from mid-July to September. Since the late 50's, these authors already mentioned a decline in the catches together with an increase in the mean age. Finally, since 1963, only a few old bluefin were observed in the northern Europe area during the summer.

Tiews and Hamre's works were confined to qualitative descriptions of the catches. We aimed here to study the Norwegian, German and Gibraltar data conjointly, using numerical analyses, in order to test further and quantify the assumptions hypothesised by Tiews and Hamre. We first identified the different cohorts from length/weight distributions data in the 50's, 60's and 70's of the major northern fisheries (i.e., Germany and Norway) and compared them to those of Barbate trap (Spain). Then, we carried out multivariate analyses to rise up the main features of each fishery and to compare them in space and time.

MATERIALS

The following data sets were obtained from the literature:

- Barbate trap (Spain): size distribution (fork length) of the annual catches from 1956 to 1979 (Rodriguez-Roda, 1964a; 1964b; 1977; Hamre *et al.*, 1966; 1968; 1971; Aloncle *et al.*, 1974; 1981; Bakken *et al.*, 1980). Catches were not detailed in 1960 and 1962 and the fishery did not operate in 1974.
- German fishery: size distribution (fork length) of the annual catches from 1951 to 1962 (Hamre *et al.*, 1966). The fishery collapsed in 1963 (Figure 1).
- Norwegian fisheries South of 62°N: weight distribution (gilled and gutted) of the annual catches from 1956 to 1979 (Hamre and Tiews, 1964; Hamre *et al.*, 1966; 1968; 1971; Aloncle *et al.*, 1974; 1981; Bakken *et al.*, 1980).
- Norwegian fisheries North of 63°N: weight distribution (gilled and gutted) of the annual catches from 1956 to 1969 (Hamre and Tiews, 1964; Hamre *et al.*, 1971). The fishery collapsed in 1963 but, a few fish were taken in 1966, 1967 and 1968 (Figure 1).

The gilled and gutted weights were transformed into total weight following Hamre *et al.* (1966) relationship: $W_{total} = W_{g\&g} x1.285$

METHODS

First, length or weight distributions were split up into cohorts using the Battacharya's method (1967). The mean length/weight, as well as variances and frequencies were estimated for each cohort. The ages were estimated from BFT growth curves (Farrugio, 1977; Hamre, 1958; 1960; Rodriguez-Roda, 1964), so that a catch matrix by ages and by years could be built for each fishery.

Multivariate Principal Component Analyses (PCA) and Correspondence analyses (CA) were performed to identify and compare the main cohorts and the age distributions of the fisheries. PCA and CA summarise in a few dimensions (i.e. the principal axes) most of the variability of a large number of descriptors and provide the variance explained by each axis (e.g. Hotelling, 1933; Legendre and Legendre, 1998). PCAs were performed on the covariance matrices to identify the dominant cohorts of each fishery, then the results of the 4 PCAs were compared. CAs were carried out on a matrix gathering data of the different fisheries to compare the temporal patterns in their age distribution.

Spearman tests of correlation were further carried out between time-series of annual yields of the 4 fisheries (both on original and detrended data).

RESULTS

Descriptions of weight, length, and age distributions

In 1956, 90% of the catches ranged from 137 to 212 cm at Barbate (figure 3a), 61 to 266 kg in southern Norway (figure 3b), 176 to 279 kg in northern Norway (figure 3c), and 212 to 267 cm in Germany (figure 3d). Then, in 1961, the distribution spread over 157 to 222 cm at Barbate, 138 to 266 kg in southern Norway, 176 to 298 kg in northern Norway, and 232 to 262 in Germany. At last, in 1979, BFT size ranged from 157 to 252 cm at Barbate, 292 to 453 in southern Norway. These results showed that individuals caught at Barbate were younger than individuals taken in southern Norway, then northern Norway, and finally Germany.

The linear regressions revealed an increasing trend in the age distribution of the catches at Barbate ($N=21$, $p<0.0001$; figure 3a) and southern Norway ($N=21$, $p<0.0001$, figure 3b) from 1956 to 1979. For northern Norway, the trend was not significant for the short period 1956-1962 ($N=7$, $p>0.10$; figure 3c), but the time-series was too short and it is worth noting that the linear regression became significant when adding the 1967, 1968 and 1969 years ($N=10$, $p>0.0001$). No significant slope was shown for the German data ($N=7$, $p>0.10$; figure 3d), but here also the number of data is insufficient to obtain reliable results**.**

Comparison of age distributions

We first computed a Correspondence Analysis on age-classes 4 to 14+ (14 and older) and years 1956-1962 of all the fisheries to compare the temporal patterns of the age distributions (figure 4a). The two first factorial axes encompassed 62% of the total variance. These axes displayed a clear ageing in all the fisheries. At Barbate, catches were mainly dominated by ages 5 to 7 in 1956, then ages 8 to 10 in 1961. Catch ages were about ages 10 to 12 in 1956 in southern and northern Norway and Germany, but around ages 11, 14+ and 13 in 1961 for the same fisheries. Another interesting result was the proximity of German and northern Norwegian catch distributions; these two fisheries catching similar age-classes.
To compare the temporal pattern in the age distributions over an extended period, we computed a second CA on Barbate and South Norwegian data, which spread over 1956 to 1979 (figure 4b). The two first factorial axes explained 60% of the total variance and further underlined the ageing in both fisheries. At Barbate, mean age was around 4-5 years at the beginning of the series against 13 years in 1976, which means that the ageing continued after 1961. The CA displayed the same pattern for South Norway, ageing spreading over age 14+ in the last years of the series. Note, however, the occurrence of a reverse trend at Barbate, which displayed a sudden rejuvenation in its catches in 1979.

Determination of the dominant cohorts

We computed PCA for each fishery on covariance matrix to determine the most abundant cohorts. The two first factorial axes of the PCA on Spanish trap data explained 70% of the total variance (figure 5a). The cohorts born from 1947 to 1954 largely dominated the catches. The year-classes 1950 and 1951 were especially abundant during fishing seasons 1957 and 1958. The two first factorial axes of the PCA on South Norwegian data (figure 5b) encompassed 87% of the total variance. The year-classes 1946 to 1952 also dominated the fishery, especially the 1950 cohort during fishing seasons 1961 and 1962. The two first axes of the PCA on North Norwegian data explained 92% of the total variance (figure 5c). The cohorts 1944 and 1945 dominated this fishery, especially during fishing season 1956. The two first axes of the PCA on German data encompassed 91% of the total variance (figure 5d). It appeared that 1945 year-class dominated the German fishery, in particular in 1957.

Correlation analyses between catch time-series

Catches at Barbate (number of individuals) were positively correlated with the Norwegian's annual catches over the 1956-1979 period ($n=30$, $p<0.01$; table 1). Similarly, a significant positive correlation was observed between North and South Norwegian ($N=13$, $p<0.01$; table 1) annual catches for 1956 to 1962. Others tests of correlation on original time-series (i.e. Barbate and North Norway, Barbate and Germany, South Norway and Germany) were not significant (table 1). Detrended time-series were positively correlated between South Norway and Barbate ($n=30$, $p<0.01$, table 1) and between northern and southern Norway ($n=13$, $p<0.05$; table 1), indicating that both trend and year-to-year fluctuations were synchronous. A decreasing trend was shown in both Barbate and southern Norway time series (figure 1), while monotone trend was observed for German and northern Norway, possibly because time-series are shorter and stopped at the beginning of the general decline.

DISCUSSION

Fisheries dissimilarities

First, the fisheries differed by the age composition of their catches. The analyses on size distributions showed that Barbate was dominated by the youngest age-classes, followed by South Norway, North Norway, and finally Germany. Secondly, the fisheries differed in the number of individuals caught: from 1956 to 1962, the highest number of tuna was taken in South Norway, then at Barbate, North Norway, and Germany.

Fisheries similarities

First, the tests of correlation showed that both short- and long-term fluctuations in Barbate and South Norwegian catches were synchronous between 1956 to 1979. Correlation computed on North Norwegian and German data were tested on small data sets (13 years), which might explain why they were not significant. Barbate and South Norwegian catches displayed a linear decreasing trend from 1956 to 1979, whereas North Norwegian and German catches remained relatively stable over 13 years. However, these two fisheries collapsed suddenly the same year, in 1963.

Another major similarity was the general significant ageing in the catches from 1956 to 1962. The North Norwegian and German fisheries collapsed after 1962, but the ageing continued in both South Norway and Barbate. In the former area, the ageing was observed until the last season studied (1979); at that date, the tunas might weighted as much as 453 kg. Barbate, however, displayed a sudden rejuvenation in its catches in 1979.

The PCA outlined other similarities: cohorts born from 1948 to 1952 dominated both North Norway and Barbate fisheries from1956 to 1979. It seems that the cohort of 1950, particularly abundant, accounted for the peak of productivity that occurred in 1957-1958 in Spain and in 1961-1962 in Norway. Similarly, the year-class 1945, particularly abundant both in northern Norway and Germany from 1956 to 1962, could account for the German peak of productivity in 1957. As these two fisheries collapsed in 1963 and were dominated by fish of about 12 to 14 years, the cohorts of 1948 to 1952, dominant at Barbate and South Norway, could not be detected in these fisheries.

CONCLUSION

Our study underlined: (1) a synchronous ageing in the 4 fisheries, (2) similar dominant cohorts, at least between South Norway and Barbate in the one hand and North Norway and Germany on the other, (3) a synchronous drop (or collapse) in the catches in 1963 as well as (4) significant correlation among the longest time-series in annual catches. Therefore, it is likely that tunas caught at Gibraltar and in the Nordic fisheries belong to the same population. Our results support Tiews's hypothesis (1978), according to which the Nordic fisheries collapsed because of a lack of migrating mature tunas in the northern area. The cohorts 1944 and 1945 were probably the last to migrate in number off northern Norway and into the North sea, and year classes 1950 and 1951 appeared to be the last to migrate in number off northern Europe.

It is worth noting that the ageing was also noticeable in the Barbate trap, so that the East BFT population could have suffered bad recruitment years or more important changes in the migration patterns of the spawners. Therefore, it would be interesting to investigate the task II data of all the Atlantic fisheries operating from the 50's to the 70's. However, the recent Icelandic fishery could indicate that the occurrence of BFT in the Nordic seas could be more or less cyclic and dependent on environmental variations (Olafsdottir and Ingimundardottir 2000). Marsac (1999) put forward that the water-cooling in the northeastern Atlantic Ocean since the mid-60's and a concomitant change in the zooplanktonic production could explain the disappearance of bluefin tuna in the northern areas. Therefore, the development of new Nordic fisheries during a warming period tends to support such an environmental hypothesis.

ACKNOWLEDGEMENTS

We wish to thank P. Cornus, A. Fonteneau, J. Hamre, P. Kébé and S. Myklevoll for providing data and giving helpful information.

REFERENCES

ALONCLE H., BAKKEN E., RODRIGUEZ-RODA J., TIEWS K, 1981. – *Seventh Report of the Bluefin Tuna Working Group.* ICES, Copenhagen, N°100, 71p.

ALONCLE H., HAMRE J., RODRIGUEZ-RODA J., TIEWS K, 1974. – *Fifth Report of the Bluefin Tuna Working Group.* ICES, Copenhagen, N°40, 52p.

BAKKEN.E, RODRIGUEZ-RODA J., TIEWS K., 1980. – *Report from the Bluefin Tuna Working Group.* ICES, Copenhagen, 22p.

BHATTACHARYA C.G., 1967. – A simple method of resolution of a distribution into Gaussian components. *Biometrics*, Vol. 23: 115-135.

BINET D., LEROY C., 1987. - La pêcherie du thon rouge (*Thunnus thynnus*) dans l'Atlantique Nord est-elle liée au réchauffement séculaire? *Collective volume of scientific papers.* ICCAT, Madrid, Vol. 26: 314-322.

FARRUGIO.H., 1977. – Estimation de la composition démographique de la pêcherie de surface au thon rouge en Méditerranée française de 1969 à 1976. *Collective volume of scientific papers.* ICCAT, Madrid, Vol. 7(2) : 352-354.

HAMRE. J., 1958. – About the age composition of Norwegian tuna catches in the years 1954-1958. *1958 Scrombiform fish committee.* ICES, Copenhagen , Vol.91: 1-4.

HAMRE. J., 1960. – Tuna investigation in Norwegian waters, 1954-1968*. Biological analyses.* ICES, Copenhagen, Vol.15: 197-211.

HAMRE J., LOZANO F., RODRIGUEZ-RODA J., TIEWS K., 1966. – *Report from the Bluefin Tuna Working Group.* ICES, Copenhagen, N°26, 34p.

HAMRE J., LOZANO F., RODRIGUEZ-RODA J., TIEWS K., 1968. – *Report from the Bluefin Tuna Working Group.* ICES, Copenhagen, N°38, 27p.

HAMRE J., MAURIN C., RODRIGUEZ-RODA J., TIEWS K., 1971. – *Report from the Bluefin Tuna Working Group.* ICES, Copenhagen, N°23, 49p.

HAMRE J., TIEWS K., 1964. – *Report from the Bluefin Tuna Working Group.* ICES, Copenhagen, N°20, 42p.

HOTELLING H., 1933. – analysis of a complex of statistical variables into principal components*. Journal Education and Psychology.* Vol.24: 417-441,489-520.

LEGENDRE P., LEGENDRE L., 1998. – *Numerical ecology (Developments in Environmental Modelling, 20).* Elsevier Sccience, Amsterdam, 853p.

MARSAC F., 1999. - Changements hydroclimatiques observés dans l'Atlantique depuis les années 50 et impacts possibles sur quelques stocks de thons et leur exploitation. *Collective volume of scientific papers ICCAT,* Madrid, Vol. 49(4): 346-370.

MATHER F.J., JONES A.C., 1995. - Historical document: life history and fisheries of Atlantic bluefine tuna. NOAA ed, *Technical memorandum NMFS-SEFSC*, Miami, 165p.

OLAFSDOTTIR D., INGIMUNDARDOTTIR T., 2000. – Preliminary report on experimental fisheries and biological research on bluefin tuna (*Thunnus thynnus*) within the Iceland EEZ, 1996-1998. *Collective volume of scientific papers ICCAT*, Madrid, Vol. 91: 827-838.

RODRIGUEZ RODA J., 1964a. - Biologìa del atún, *Thunnus thynnus,* de la costa sudatlàntica de Espana. *Investigación pesquera,* Vol. 25: 33-146.

RODRIGUEZ RODA J., 1964b. – Talla peso y edad de los atunes, *Thunnus thynnus*(L), capturados por la almadraba de Barbate (costa sudatlántica de España) en 1963 y comparación con e período 1956 a 1962. *Investigación pesquera,* Vol. 25: 3-47.

RODRIGUEZ RODA J., 1977. – Análisis de la poblacion de atunes, *Thunnus thynnus* (L), capturados por la almadraba de barbate (Golfo de Cádiz) durante los años 1963 a 1975. *Investigación pesquera,* Vol. 41(2): 263-273.

TIEWS K., 1957a. - Biologische untersuchungen am roten thun (Thunnus thynnus L.) in der Nordsee. *Berichte der Deutschen Wissenschaftlichen Komission Fur Meeresfsorschung, Stuggart, n.f.*, Vol. 14(3): 192-220.

TIEWS K., 1957b. - Wirtschaftliche Bedeutung der deutschen Thunfischerei. *Berichte der Deutschen Wissenschaftlichen Komission Fur Meeresfsorschung, Stuggart, n.f.*, Vol. 14(3): 221-232.

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

Table 1: Correlation analyses between original and detrended time series. Correlations were tested with Student tests at a 5% threshold value.

Countries	N	Series	Correlation coefficient R	p value (Student t test)
Spain-southern Norway	30	original	0.848	**0**
	30	detrended	0.476	**0.008**
Spain-northern Norway	13	original	0.090	0.770
Spain-Germany	13	original	0.504	0.079
southern Norway-northern Norway	13	original	0.899	**0**
	13	detrended	0.5689	**0.042**
southern Norway-Germany	13	original	0.266	0.381
northern Norway-Germany	13	original	0.026	0.932

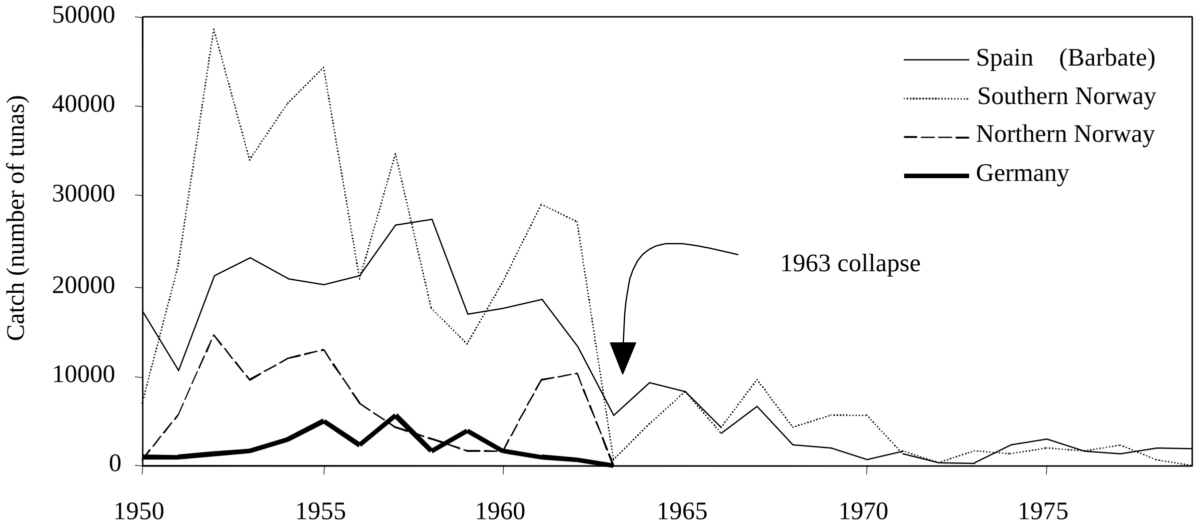

Figure 1: Evolution of Atlantic bluefin tuna fisheries

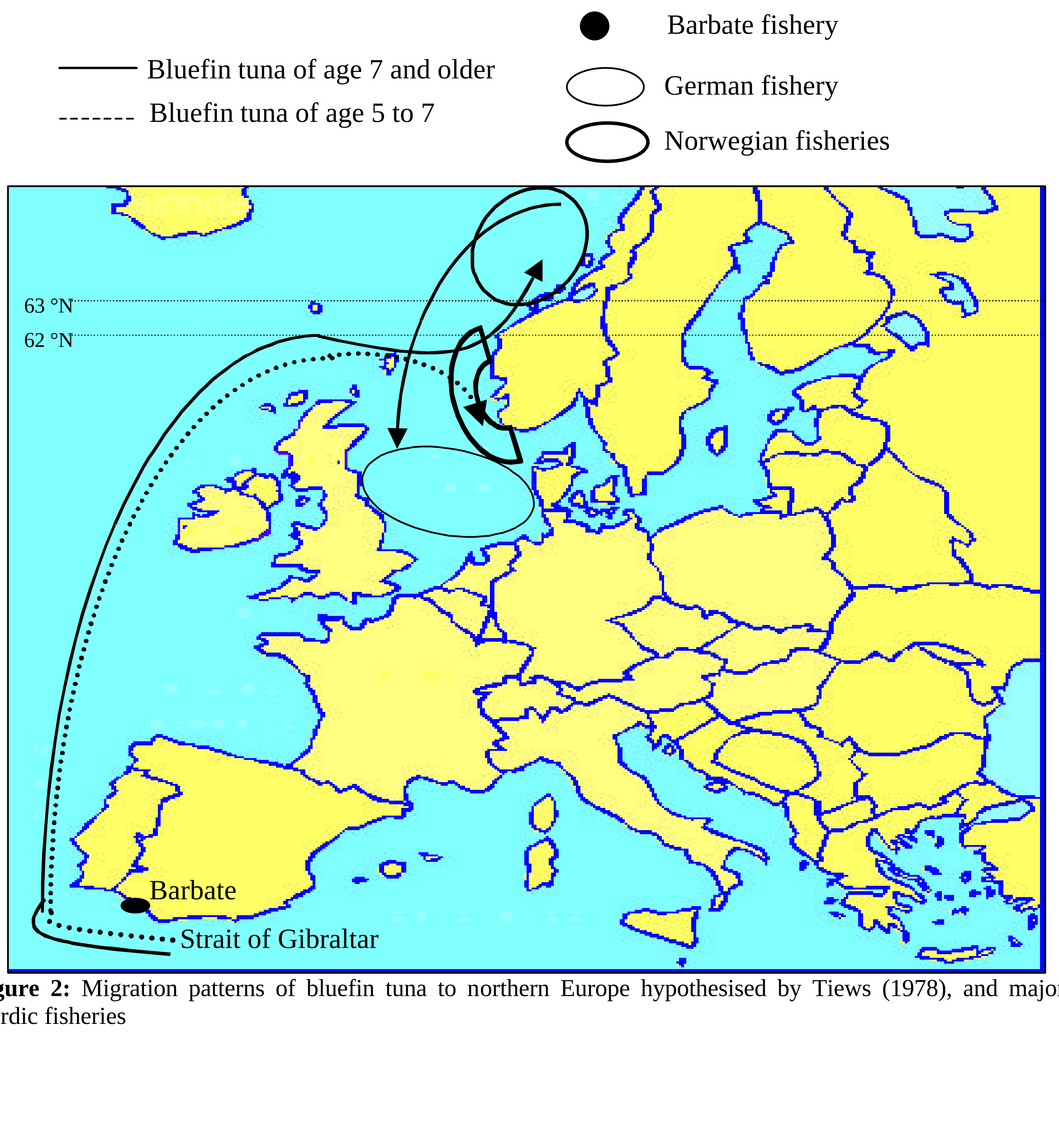

Figure 2: Migration patterns of bluefin tuna to northern Europe hypothesised by Tiews (1978), and major Nordic fisheries

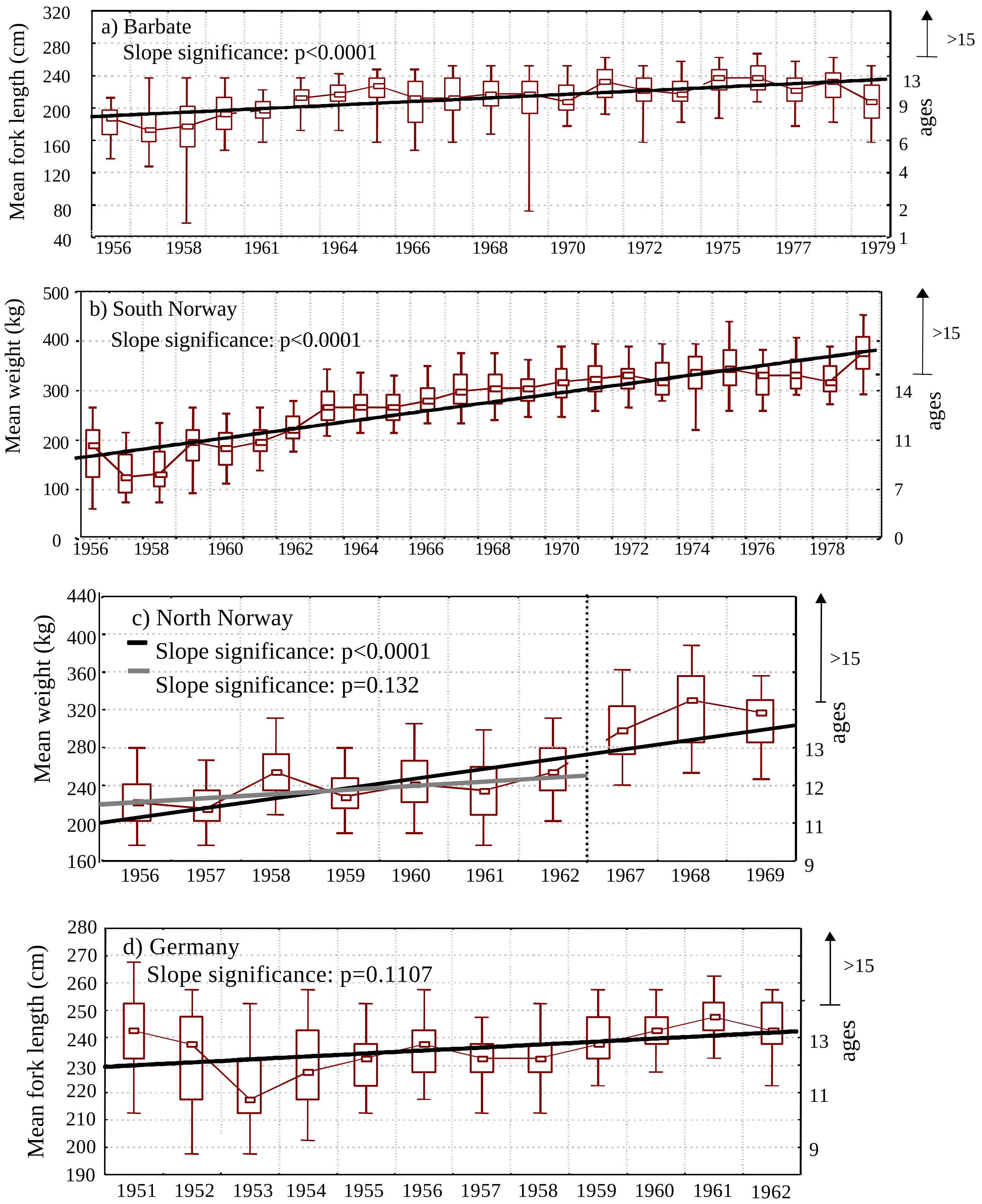

Figure 3: Boxplots of the length, weight, and age distributions of: a) Barbate fishery, b) South Norwegian fishery, c) North Norwegian fishery, d) German fishery. The Boxplots represent median catches, as well as 50% and 90% intervals. Slopes of linear regression were tested with Student test at a 5% threshold value.

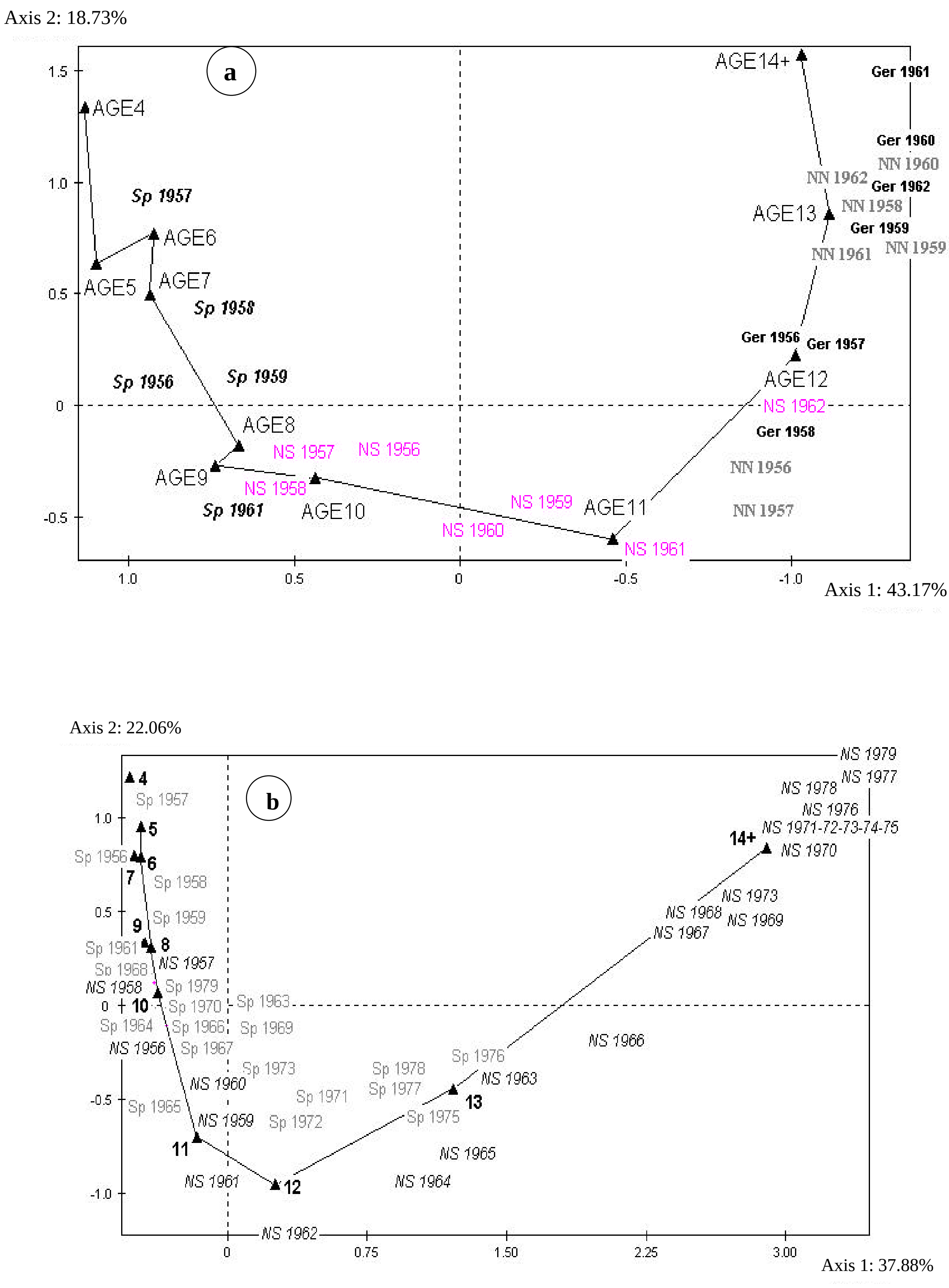

Figure 4: Correspondence analyses of age distributions of a) Barbate, South Norway, North Norway, Germany, from 1956 to 1962; and b) Barbate and South Norway, from 1956 to 1979.
Sp (Spain=Barbate); NS (South Norway); NN (North Norway); Ger (Germany).

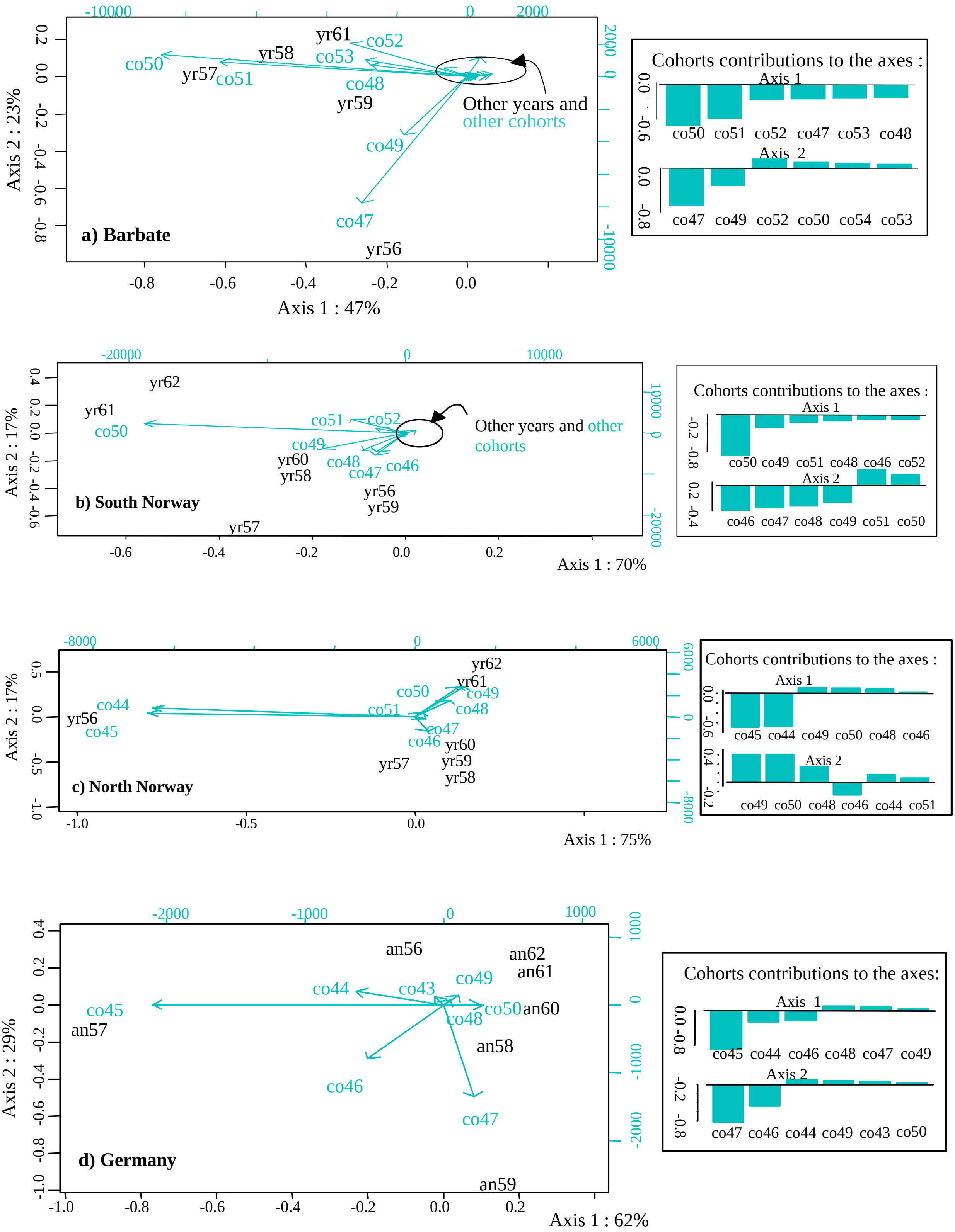

Figure 5: Principal component analyses of dominant cohorts of a) Barbate fishery from 1956 to 1979; b) South Norwegian fishery, from 1956 to 1979; c) North Norwegian fishery, from 1956 to 1962; d) German fishery, from 1956 to 1962