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SEASONALITY AND INTERANNUAL VARIABILITY IN CATCHES OF SKIPJACK TUNA (*Katsuwonus pelamis*) AND BIGEYE TUNA (*Thunnus obesus*) IN THE AREA AROUND THE ARCHIPELAGO OF MADEIRA.

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ABSTRACT

This paper describes the seasonality and interannual variability observed in the catches of bigeye and skipjack tuna carried out by the bait boat fleet in the areas surrounding the archipelago of Madeira during the 1979-2000 period, confirming the seasonal patterns reported previously. There is a description of the fluctuations of some of the local environmental indicators (SST) and global indices (GSNW index) which may be able to explain, in part, the seasonal occurrence of these species or ages, and consequently, the interannual fluctuations in the local abundance and availability in the fishing zones targeted by this fleet. The question is also raised as to relevance of focusing on global atmospheric indicators in the future, in addition to the local indicators, with a view to gain insight into the interannual variability found in the catches. Also discussed are the possible causes for the diminishing captures observed in this fleet in recent years.

RÉSUMÉ

Le présent document décrit le caractère saisonnier et la variabilité inter-annuelle observée dans les captures de thon obèse et de listao réalisées par les flottilles de canneurs dans les zones autour de l'archipel de Madère entre 1979 et 2000, en confirmant les schémas saisonniers signalés auparavant. Y sont décrites les fluctuations de certains indicateurs environnementaux locaux (SST) et globaux (indice GSNW), lesquels pourraient expliquer en partie l'apparition saisonnière de ces espèces ou âges et, par conséquent, les fluctuations inter-annuelles de l'abondance locale et de la disponibilité de ces espèces dans les zones de pêche ciblées par cette flottille. Le document indique en outre qu'il convient de considérer à l'avenir des indicateurs atmosphériques globaux, en sus des indicateurs locaux, afin d'expliquer la variabilité inter-annuelle rencontrée dans les captures. Il examine aussi certaines des causes éventuelles de la diminution des captures observées dans cette flottille ces dernières années.

RESUMEN

En este documento se describe la estacionalidad y la variabilidad interanual observada en las capturas de los atunes patudo y listado capturados por la flota de cebo vivo de las áreas de pesca en torno al archipiélago de Madeira, durante el periodo 1979-2000, confirmando los comportamientos estacionales previamente descritos. Se presenta una descripción de las fluctuaciones de ciertos indicadores medioambientales locales (SST) y globales (GSNW index) los cuales podrían explicar parcialmente la aparición de estas especies o edades y, por consiguiente, las fluctuaciones interanuales de la abundancia local y de la disponibilidad de estas especies en las zonas de pesca de esta flota. El documento indica además la relevancia de considerar en el futuro indicadores globales además de los locales, de cara a explicar la variabilidad interanual encontrada en las capturas. También discute algunas de las posibles causas de la disminución de las capturas observadas en esta flota en los años recientes.

KEYWORDS

Environment, Seasonality, Tunas, Skipjack, Bigeye, Madeira

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1 INTRODUCTION.

The tunas (tribe *Thunnini*) and the so-called tuna-like species (suborder *Xiphioidei*) have relatively widespread distributions, depending on the species. Temperature is one of the abiotic factors that has been recognised as a basic conditioning element in the geographic distribution of these species, as it limits their tolerance to the environment and affects their physiological processes. Moreover a greater or lesser tolerance to temperature usually depends on the body biomass of the specimen, so that younger individuals tend to have stricter thermal requirements than adults and large adults. These species are endowed with specific physiological traits which cause them to be distributed in space (latitude-longitude-depth) and in time, according to these oceanographic conditioning factors. The physiological traits of these species are the fruits of their respective evolutionary processes developed over the course of millions of years in the balance of the oceanic pelagic system.

Although these species tend to be preferentially distributed within their 'ideal oceanographic habitat', their boundaries, however, are not strict and may vary depending on their age or body biomass. Therefore, the distribution areas of these stocks show some variations within certain limits conditioned by environmental temperature and their seasonal, interannual and interdecadal variation in the surface layers (Collete and Nauen, 1983). The geographic distributions of these species of large pelagic fishes may be relatively widespread or cosmopolitan. Some are distributed in tropical and subtropical waters, although they have a preference for warm waters (*Katsuwonus pelamis*). The distribution of other species is less restricted, with a preference for tropical and subtropical areas, often having a seasonal occurrence in the temperate zones (*Thunnus obesus*). Still other species favour more cosmopolitan distributions, preferring warm-temperate waters (*Thunnus alalunga, Xiphias gladius, Thunnus thynnus*) frequently using the temperate zones as predominantly feeding areas, while the warm waters are reserved for reproductive processes. In some of these species geographic segregation by size and sex has even been observed.

Some archipelagos such as the Canary Islands, Madeira and the Azores exhibit special characteristics, given that they are oceanic islands that were formed by volcanic processes. These aspects make it possible for schools of tunas and associated species (and other oceanic large pelagic fish species) to approach these islands during migration. The local seasonal occurrence of these species relatively close to their coasts has long been known to fishermen who have taken advantage of their appearance. Thus, these islands may be considered as very useful 'oceanic observatories' in the study of these species, which are particularly sensitive to the seasonal, interannual and interdecadal variations of the oceanographic variables that condition their behaviour.

Oceanographic factors of a local or global nature play a critical role in the distribution of these species and in their spatial-temporal variability. The archipelago of Madeira is located in a temperate zone (around 33º N- 17º W) and is affected by the wide seasonal variations in the sea surface temperature, which fluctuate between 16º and 26º C between winter and summer. For this reason, the local availability and abundance of some of these species, such as skipjack and bigeye tuna is known to be markedly seasonal, contingent upon the evolution of the isotherms in the surface layers (Gouveia et al., 1990, 2001).

The Gulf Stream current plays a major role in the distribution of heat in the northern hemisphere and it is an essential part of the climate system of the North Atlantic. Therefore its interannual variability could have a huge impact on the variability of the climate in the northern hemisphere. The structure of this current, the amount of water mass transported and the properties of these water masses exhibit geographic and temporal variations and fluctuations of a seasonal, interannual or interdecadal nature.

The latitudinal position of the path of the Gulf Stream over the last three decades has been correlated with the winter North Atlantic Oscillation index (winter NAO) (Hurrel, 1995), so that the NAO would explain roughly 60% of the variance observed in the position of this current during said period. If the winter NAO index presents high values, this would lead to the location of the current farther north approximately two years later (Taylor and Stephen, 1998). Other authors suggest that the same type of relationship exists between the NAO and the Gulf Stream, but with different time lags (Joyce at al., 2000). The Gulf Stream path seems to respond passively to the variability of the NAO with a delay of a year or so (Frankignoul et al., 2001).

The index known as the Gulf Stream NW index (GSNW index) represents the North-South shifts in the position of the Gulf Stream current in the NW Atlantic (Taylor and Stephens, 1980; Taylor, 1996). This shift in latitude has been associated with temperature changes and the abundance of zooplankton in several regions, including very distant areas such as the as those located in the NE Atlantic, which are affected by the changes of this important warm-water current (Taylor, 1995; Taylor and Stephen, 1980). Several authors (Willis et al, 1995; Taylor, 1996) have linked these shifts to possible effects on the local climate, harvest production, vegetation dynamics, etc. Moreover, the fluctuations in the GSNW index are correlated to some extent with the values recorded two years earlier of one measure of ENSO variations in the Pacific Ocean (Taylor et al., 1998).

Considerable changes in the Gulf Stream have been observed in recent decades -particularly as of the early 1970s, becoming more pronounced starting in the late 1980s- due to the extremely high -in fact unprecedented- NAO values, as compared to previous periods. In consequence, in some of the recent years, the Gulf Stream has shifted considerably farther North, so much so that this is the first time that shifts of this magnitude have been recorded in the last 45 years (Frankignoul et al., 2001).

Interannual or interdecadal shifts in the GSNW index could have major repercussions on the ocean dynamics of the North Atlantic as a whole (Greene, 2001), and specifically on the near-surface transport and general pattern of temperature anomalies. Therefore, these effects would also be expected to have an impact on the biology dynamics of the stocks of migratory fishes (for example, on recruitment) and on their geographic distribution, as well as on the definition and intensity of their seasonal migration paths which are highly dependent upon the thermal structure of the surface layers.

This document is a continuation of previous studies (Gouveia et al., 1990) and also highlights other possible approaches to be used in the study of the variability observed in the annual catches of these two tropical tuna species around Madeira and adjacent areas. Special attention has been paid to the local oceanographic indicators used in the past (SST) in addition to more global indicators (GSNW index), which might be a representative indicator of the global thermal structure of the surface layers in broad areas of the North Atlantic. This thermal structure would be an important conditioning factor in structuring the seasonal migration paths of these species, affecting the availability and local abundance of these species in this insular region.

2 MATERIAL AND METHODS.

The fisheries data used in this analysis come from the activity of the bait boat fleet of Madeira (Gouveia et al., 2001). Data on the tuna catches by this fleet date back to the year 1965. However, starting in 1974 a more specific classification became available, with the launching of the scientific monitoring program of these fisheries. The catch data of the two most representative species in the fishery -skipjack (SKJ) and bigeye tuna (BET)- were considered in these analyses.

Information on the intensity of the fishing effort carried out by this fleet was based on the annual records of the number of bait boat vessels operating during the 1979-2000 period, whose fisheries target both tuna species (SKJ and BET). For the purpose of obtaining an approximate annual indicator of the fishing intensity or 'fishing effort', three different categories of vessels were established as follows: category 1: GT< 51, category 2: 50 < GT< 151, category 3 GT > 150; with equivalency factors assumed of 1.0, 2.0 and 2.76, respectively. The equivalencies made it possible to use the number of vessels as a simple aproximation or indication of the annual nominal fishing effort and to compile annual catch rates or nominal 'CPUE' values.

The data were analysed in different ways depending on the species and on the basis of the information available on the seasonal patterns in terms of the presence of the two species and the sizes captured, as well as the varying temperature requirements of each species (Gouveia et al., 1990).

Catches in weight and CPUE in weight of the skipjack were considered globally (combined sizes), as no substantial interannual differences were detected in this zone in the size range under observation, with the catch being dominated by fishes between 40 and 60 cm FL. On the other hand, the availability and abundance of the different size-age elements of the bigeye tuna may vary considerably between years, with each element making a very different contribution to the annual catches, and therefore to the success or failure of the fishing season (Gouveia et al., 2001). The annual size frequency distributions of the bigeye tuna (in number of specimens per 5 cm class) were combined into size groups that were considered to be close to age classes (Anonymous, 2000, based on Cayré and Diouf, 1984): Group 1: size < 70 cm ; Group 2: 70-90 cm; Group 3: 95-110 cm; Group 4: 115-130 cm; Group 5-7+: size > 130 cm. Group 1 was omitted from the final analyses as this group is generally scarce in the annual catches (a yearly average of 7.3 % of the annual catch in number).

Data on the environmental factors in the local area were considered initially, as were data on the SSTs of areas adjacent to Madeira for the 1960-1999 period in addition to quarterly and yearly SST anomalies (Gouveia et al., 1990; 2001).

Data on catch by species (or by species and size class) were compared with the updated annual mean of the Gulf Stream NW index (GSNWindex) (Taylor and Stephens, 1980) first, using correlations and finally, by means of simple *Loess* type adjustments for strictly descriptive purposes. Also, in order to better assess the interannual differences between the availability of the different size classes of BET in the fishing zone, the yearly values of the GSNW index were adjusted to the relative annual values (%) of the catch in number by size class in relation to the total catch. This made it possible to assess the relative contribution of each of the size classes to the annual catch of the fleet, regardless of the annual level of captures made, and to evaluate how they may be linked to the annual values of the GSNW index.

3 RESULTS AND DISCUSSION.

The bait boat fishery targeting the bigeye (BET) and skipjack tuna (SKJ) of Madeira reached a maximum harvest of roughly 9000 t in the mid-1990s. However, there have been substantial fluctuations in the catches across the time series (Gouveia et al., 2001). The bigeye tuna was the most important species in the catches up until the beginning of the 1990s as well as in the most recent years of the series. Catches of the skipjack tuna were relatively modest until the late 1980s, presenting unprecedented peaks between 1990 and 1997, which were particularly high between 1992 and 1995. The skipjack was the most important species between 1991 and 1995, exceeding 5000 t in 1991. The decline in the catches of both species in the most recent years of the time series available is a cause for alarm in the local fleet, and the reasons have not been clarified (**Figure 1.a**).

The 'CPUEw' data (annual values of tons per boat) show very different trends for the two species. The CPUE of the bigeye tuna exhibited moderate fluctuations across the time series, generally ranging between 20 and 50 t / boat with the exception of the 1993 and 1994 values and the continuous drop seen as of 1995. The CPUEw of the skipjack tuna, however, presented very moderate values of around 10 t/boat for most of the series, except for the high yields obtained between 1989 and 1996, when the figures reached a maximum of 100 t/boat in 1991 (**Figure 1.b**). It must be taken into account that the measurement of effort available is not the most appropriate for assessing the annual fishing intensity.

The bait boat fishery targeting the bigeye and the skipjack tuna carried out by this fleet is traditionally seasonal and sequential in nature (Gouveia et al., 1990; 2001). The fishing season of the bigeye tuna (BET) runs preferably from March to July, with maximum values occurring around the month of May. It is therefore a predominantly spring fishery. The fishery of the skipjack tuna (SKJ) usually begins after the bigeye fishery, and would appear to have a seasonal pattern which is not as regular as that of the bigeye. The fishing season of the skipjack is highly variable depending on the years. However the period presenting the greatest skipjack catches usually falls between June and October, with maximum values between July-August-September, and even October during some years. It is therefore a predominantly summer-autumn fishery (**Figure 2**). Thus bigeye catches (BET) –a species having a relatively wider range of thermal tolerance than the skipjack- are usually obtained starting in early spring with maximum values in April and May. The skipjack catches (SKJ), on the other hand, are generally had in the warmer months (July-August-September) as this species has warmer and more restrictive thermal requirements.

Although in the seasonal pattern seen in the catches of the fleets, we should not disregard, 'a priori', the possibility of there being a certain amount of influence from factors such as the harvesting schemes of the fleet itself, the markets, meteorological conditions, etc., in the case at hand, it is highly likely that the exploitation of the two species by the bait boat fleet has adapted to the availability and local abundance (**Annex 1**) of both species in the surface layers of the traditional fishing zones over the course of the decades. Thus it should be assumed that the seasonality observed in the catches of both species represents the seasonality in the availability and local abundance of the respective species in these fishing zones.

This seasonality and the temporal sequence between the two species is caused by the seasonal evolution of the isotherms of the near-surface layers, affecting most of the tuna and associated species studied. Their areas of seasonal occurrence vary (expanding or shrinking) seasonally depending on the evolution of the isotherms of the near-surface layers. While the normal sea surface temperature in the months of April-May in the fishing zone is expected to be (on average) around 18º C, in the months of August and September, however, the expected sea surface temperature would be around 22º C (**Figure 3**). These values have been confirmed by quarterly 'in situ' observations of the SST for the combined period of 1960-1999, which presented mean values of 17.9, 18.9, 22.3 and 20.4 ºC, for each quarter respectively (**Figure 4**).

This would confirm the previous observations in the sense that the catch distribution of the bigeye and skipjack tuna are related to the preferential SST values of 19º and 22º C, respectively (Gouveia et al., 1990).

The seasonality and sequencing of the two fisheries have also been reported in the Canary Islands and the Azores (Gouveia et al., 1990). In the Canary Islands bigeye catches were seen mostly from March to May, with a second, less pronounced peak in autumn (Santana et al., 1987). In the Azores the bigeye tuna was caught from April to June, although predominantly between May and June. The skipjack exhibited maximum catch values in the Azores between June-July with the season possibly extending to autumn (Pereira, 1987).

However, this seasonal variation in temperature in the areas off the Canary Islands-Madeira-Azores tends to have a more significant effect only on the near-surface layers (0-100 m), (Anonymous, 1977). Therefore, what happens in these near-surface layers is critical in terms of favouring, to a greater or lesser extent, the seasonal presence of this species in these regions.

A second factor to be considered is the interannual variability reported in the captures and "proxies" of the CPUEs of both species. Similar to what occurs in the seasonality of the catches, it would be expected that the interannual variations in the basic oceanographic parameters –specifically in the thermal structure of the near-surface layers- would be factors accounting for a major part of the interannual variability observed in the availability and local abundance of these species in certain oceanic regions. In this sense, thermal anomalies have been put forth as one of the most useful indicators to be considered when explaining the variations in local abundance, availability and catchability of these species in some areas, especially in the case of certain surface gears that would presumably be more strongly affected.

The region of Madeira has undergone considerable anomalies in SST (SSTA) (Gouveia et al., 1999; 2001) exhibiting very different periods (**Figure 4**). Cycles with negative annual SSTAs were detected between 1968-1980 and 1991-1994. In contrast, cycles with overall positive SSTAs were seen between 1982-1990 and, particularly, in recent years in the 1995-1999 time series, with some unprecedented positive values in the available series. The values from the more recent years coincide with the high values, also without precedent, of the global atmospheric indicators (winter NAO) and oceanic indicators (GSNW index), which present a strong correlation, and are related to the surface heat flux and SST generation anomalies. The geographical distribution of the annual mean SST variance is closely linked to the position of the Gulf Stream and the North Atlantic Current (Wu and Gordon, in press).

A simple comparison of the annual values of the GSNW index and the annual SSTAs in the zone of Madeira would suggest that similar trends occurred during the predominantly negative phase of the GSNW index between 1966 and 1990, although there was a certain amount of expected time lag between the two. This however, did not occur as of 1990, coinciding with a predominantly positive GSNW index and NAO, never before recorded in the North Atlantic (**Figure 5**). These SSTA values from the early 1990s would therefore coincide with unprecedented changes in both the position of the GSNW index as well as in the eastward baroclinic transport of the Gulf Stream/North Atlantic Current and in the anomaly in the temperature of the deeply convected water in the Labrador Sea (Hurrel, 1995).

The formation of the SSTs in the North Atlantic is complex and they may have different, even contrasting effects on a local scale between areas. Although the Gulf Stream is an important factor in the formation of the SSTs, there is also a number of other influential atmospheric and oceanographic factors –some even originating from distant zones, such as the ENSO through atmospheric teleconnection patterns into higher latitudes of the Northern hemisphere (Nobre and Shukla, 1996). Therefore, it is not easy to establish simple cause-effect relationships and it may be difficult for these relationships to continue throughout indefinite periods, especially on a local level. A long list of international researchers is currently working on this subject, attempting to interpret these complex teleconnected systems, including their possible prediction and their relationship to the SSTs. The accurate interpretation of this information will be critical in order to be able to integrate some of the environmental factors that produce interannual variation in these species of tunas on a global and local level.

The definition of the migration paths of these tuna species and the possibility of seasonally redefining their distribution area is generally contingent upon environmental schemes that are far more complex and global than surface factors or anomalies on a local level. The thermal structure of the near-surface layers of broad areas plays a crucial role in the annual definition of the migration paths defining the seasonal occurrences that affect the abundance and local availability. It is possible that the availability and local abundance of the two species in the fishing zones off Madeira may be affected by oceanographic factors that take place in distant oceanic zones, whose oceanic variables are likely teleconnected to complex oceanographic-atmospheric systems.

The oceanographic phenomena and local anomalies often linked to surface thermal structure in the fishing zones might be able, on occasion, to explain the local variations in the availability-catchability of these species. However, it must be taken into account that the fleets usually have a certain operational flexibility, some geographic mobility as well as empirical knowledge, that help them to minimise the local environmental effects that are moderately adverse. On the other hand, more drastic changes in these environmental factors are more difficult to compensate for by means of changes in fishing strategies (selection of areas-fishing seasons), due to the operational limitations of the small-scale fleets which appear to affect the artisanal bait boat fleets to a greater degree.

For this reason, global indicators are sometimes better able to explain the interannual variability in the availability and local abundance of these seasonal species than the local indicators, even though the local factors may correlate to some extent with the global indicators.

A simple comparison of the annual trends between the SKJ CPUE and the GSNW index, depending on the type of adjustment used, would suggest that this index could explain between 40% and 50 % of the variability observed in the CPUEw of this species obtained by the bait boat fleet of Madeira (**Figure 6**).

Comparisons between the CPUEn (in number) by size classes of BET and the GSNW index may also point to some coincidence between this GSNW index and the local abundance-availability of the different BET size classes. The CPUEn values by size class show substantial fluctuations across the years (**Figure 7**), but also striking is the diminishing CPUEs in all the size groups starting in the mid 1990s, which would explain the drop in the catches of this fleet seen in recent years (**Figure 1.a**). The data suggest that there is some agreement between the values of the GSNW index and the CPUE values of some of the size groups. Groups 2 and 3 would appear to have a positive correlation, while group 5-7+ shows an apparently negative correlation (**Figure 8**), which would be expected, to some extent, based on the differential behaviour according to age.

In the relative annual catch data (%) by size group of the BET, the GSNW index value was seen to coincide somewhat with the changes in the availability of some of the size classes (**Figure 9**). A clear positive relationship was observed in the group of small fishes (group 2), while there was an opposite relationship in the larger sized group of fishes (group 5-7+). These variations in the availability of the different groups would have a major impact on the annual returns in weight obtained by the fleet. Although the size clasess 2, 3, 4 and 5-7+ account for roughly 44%, 24%, 14% and 4 % of the annual catch in number, respectively, their relative importance (%) in biomass, however, would represent an average of 22%, 23%, 23% and 30%, respectively for the combined period 1979-2000. Therefore, the greater or lesser annual availability of the respective size groups may have a critical impact on the success or failure of the fishing season as a whole.

The global abundance of the stock-wide (N_t) and the abundance by age of the stock-wide (N_{ta}), of which only a fraction gain access to the fishing grounds of the local fleets located on the margins of their respective potential areas of geographic distribution, play a critical role in the interannual variability of the 'availability' and local 'abundance' of the two species. These stock-wide abundances are not easy to assess due to the many existing limitations, especially for the more recent years, owing to drastic changes in the levels and patterns of harvesting carried out by some fleets actively targeting these species (Anonymous, 1999). Given that the N_t and N_{ta} may have changed considerably over the course of the time series –especially during the more recent years for the BET- it would appear to be difficult to distinguish between the different causes that might lead to interannual variations in the availability and local abundance of these species in this particular region. This is because an important factor might be due to the environmental variability (interannual-interdecadal environmental anomalies) while other considerations might be attributed to natural variations (R, M) or effects triggered by the fishing effort (F) on the stock.

The general diagnosis of the stock-wide BET would suggest that from the early 1990s, there has been a substantial increase in the overall F, an increase in the capture and mortality due to fishing juvenile specimens, a decrease in recruitment and a declining biomass (Anonymous, 2000). Therefore, the general tendency of the BET stock would be expected to have had at least some effect on the dwindling local abundance and the decrease in the availability of this species-ages in some regions-fleets, particularly on those located on the margins of their distribution area. This might explain, at least partially, the dwindling catches of this species (for several age groups) in the zones under study in recent years.

Taking into consideration the diagnosis of the state of the stocks of both tuna species SKJ and BET (Anonymous, 2002), it is likely that the variability observed in the annual catches and CPUE of SKJ may be greatly (although not necessarily exclusively) affected by environmental factors or factors inherent to the natural dynamics of the stock. The diminishing catches and CPUEs of BET by this fleet may be attributed to a combination of environmental factors and to the possible decline in stock-wide abundance (Anonymous, 1999).

Consequently, environmental factors affecting the migratory behaviour and seasonal occurrence of these species (reported in previous documents) together with elements that influence general stock-wide dynamics may account for the interannual variations detected locally in the catches, and specifically in the declining catches of the bait boat fleet of Madeira in recent years. Based on these findings, it would be advisable to conduct studies taking into account the new data sets from different fleets, the combination of local and global environmental factors, as well as the general situation of the respective stocks-wide.

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ANNEX 1

On the basis of the definitions found in the ICCAT glossary of fishery biology terms (Restrepo, pers. comm.), the following concepts were used in this paper:

Availability: The distribution of fish of different ages or sizes in a particular area/region-time relative to the distribution or demographic composition of the stock. Due to environmental aspects and the physiological-age factors of each species, local availability does not necessarily offer a representative picture of the demographic composition of the stock-wide.

Abundance: Quantitative amount of fishes (number or biomass). The abundance currently refers to abundance stock-wide (Nt, Bt), local abundance in areas-times, abundances of a segment-age of the population, etc. The abundance is currently estimated via models and/or from the CPUE indeces in tuna fisheries.

Catchability: The fraction of the stock which is caught by a standardized (effective) unit of effort. The catchability is affected by fish availability. Specific climatic conditions may result in increased or decreased availability of the fish. This would lead to increased (or decreased) catchability and fishing mortality rates for the same fishing effort.

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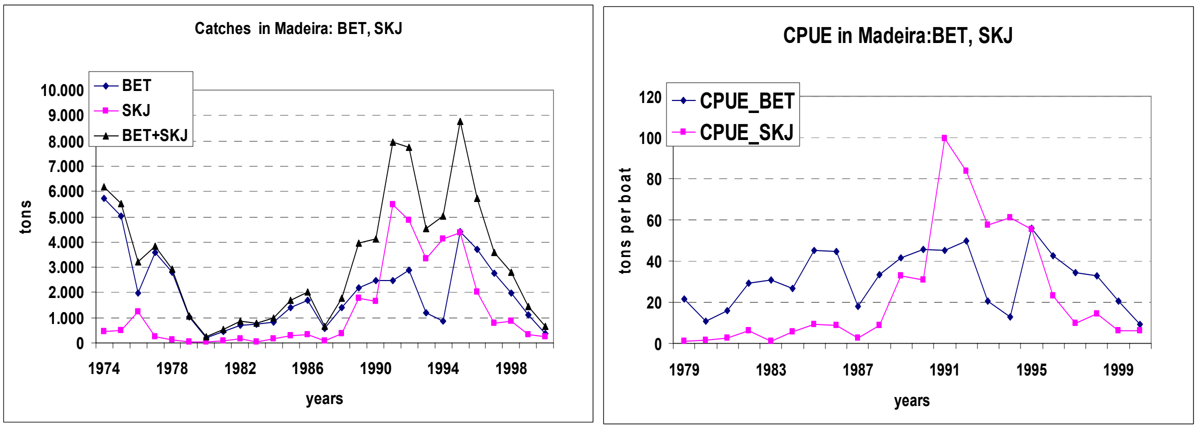


Figure 1. Annual catches of BET and SKJ carried out by the bait boat fleet of Madeira between years 1974 - 2000 and annual catch rates between 1979-2000.

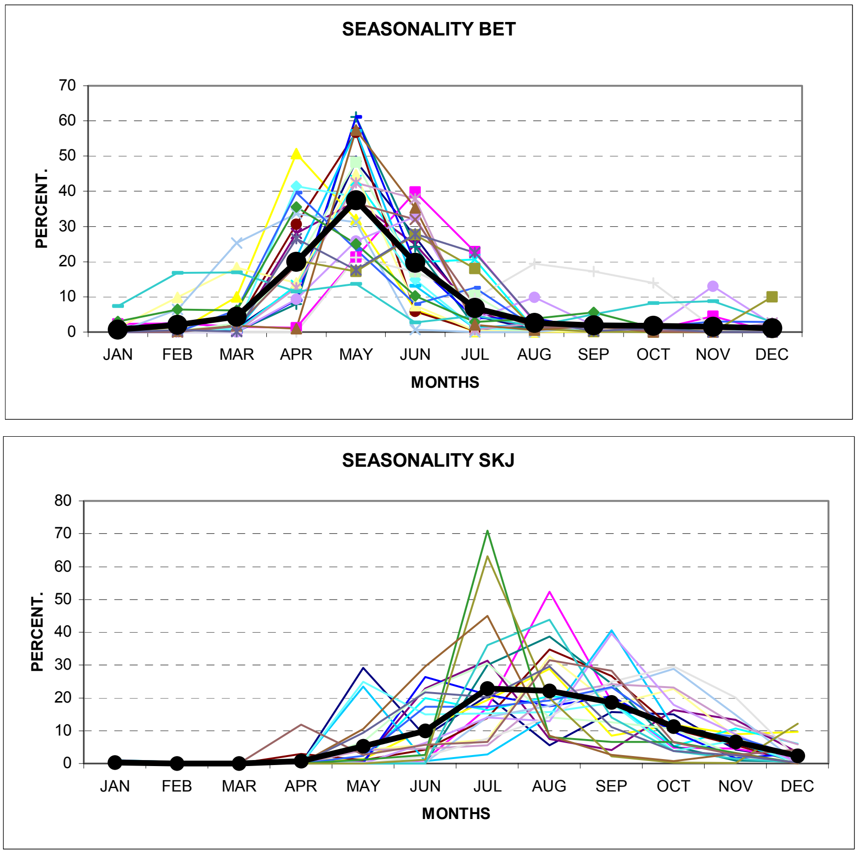


Figure 2. Seasonality (%) of the annual catches of BET and SKJ for the 1979-2001 period (thin lines) and the average for this period (thick line).

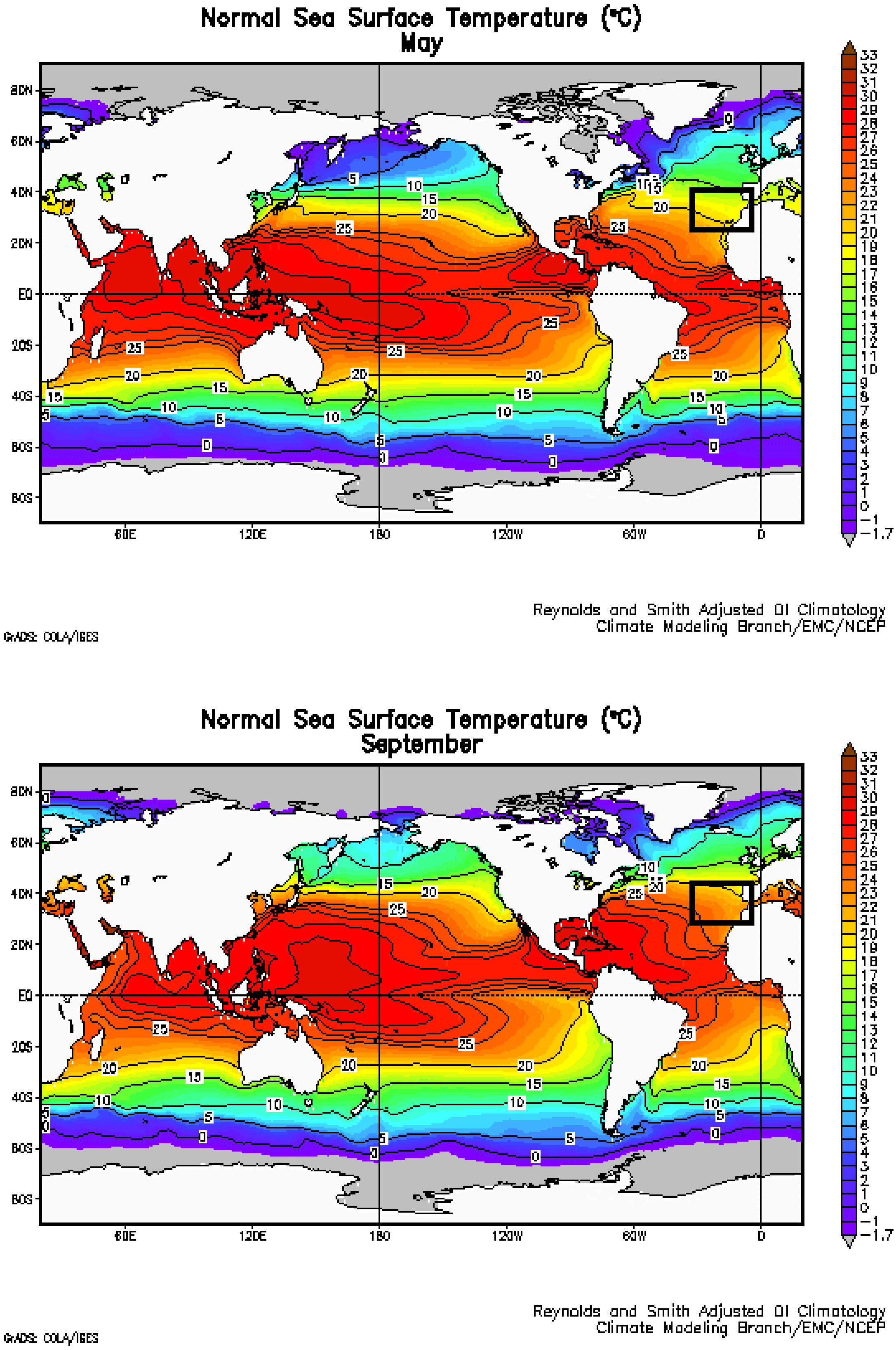


Figure 3. Maps of *normal* sea surface temperature for the months of May and September.

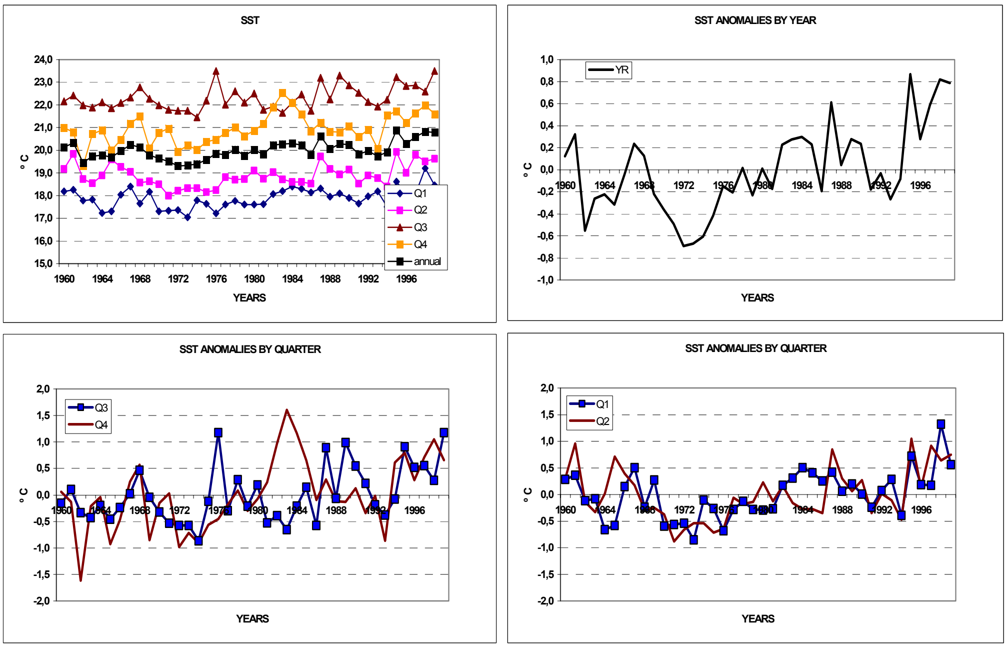


Figure 4. Local values of mean sea surface temperature (SST) and mean temperature anomalies (SSTA), by quarter and year for the 1960-1999 period (data from Gouveia et al., 2001).

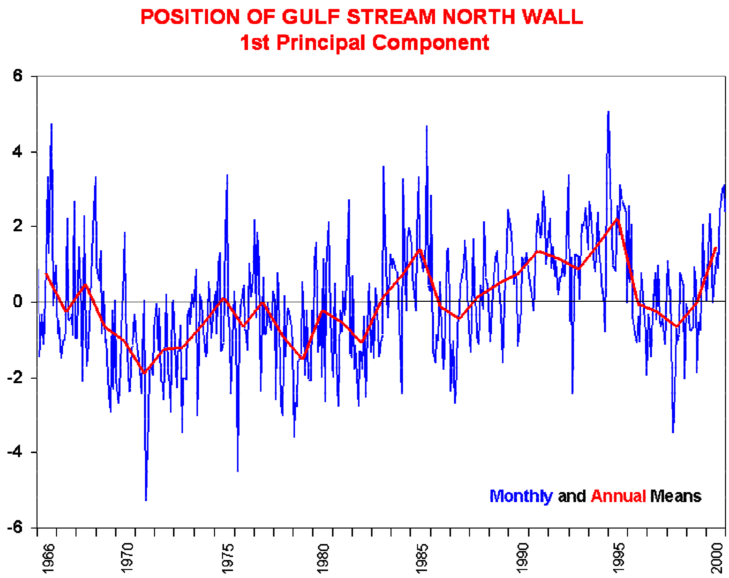
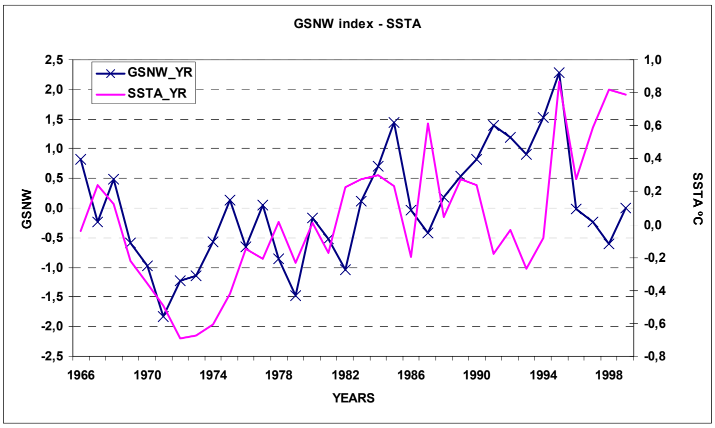


Figure 5. Monthly and annual means of the GSNW index (top) and a comparison between the annual GSNW index and the SST local anomalies around Madeira (bottom).



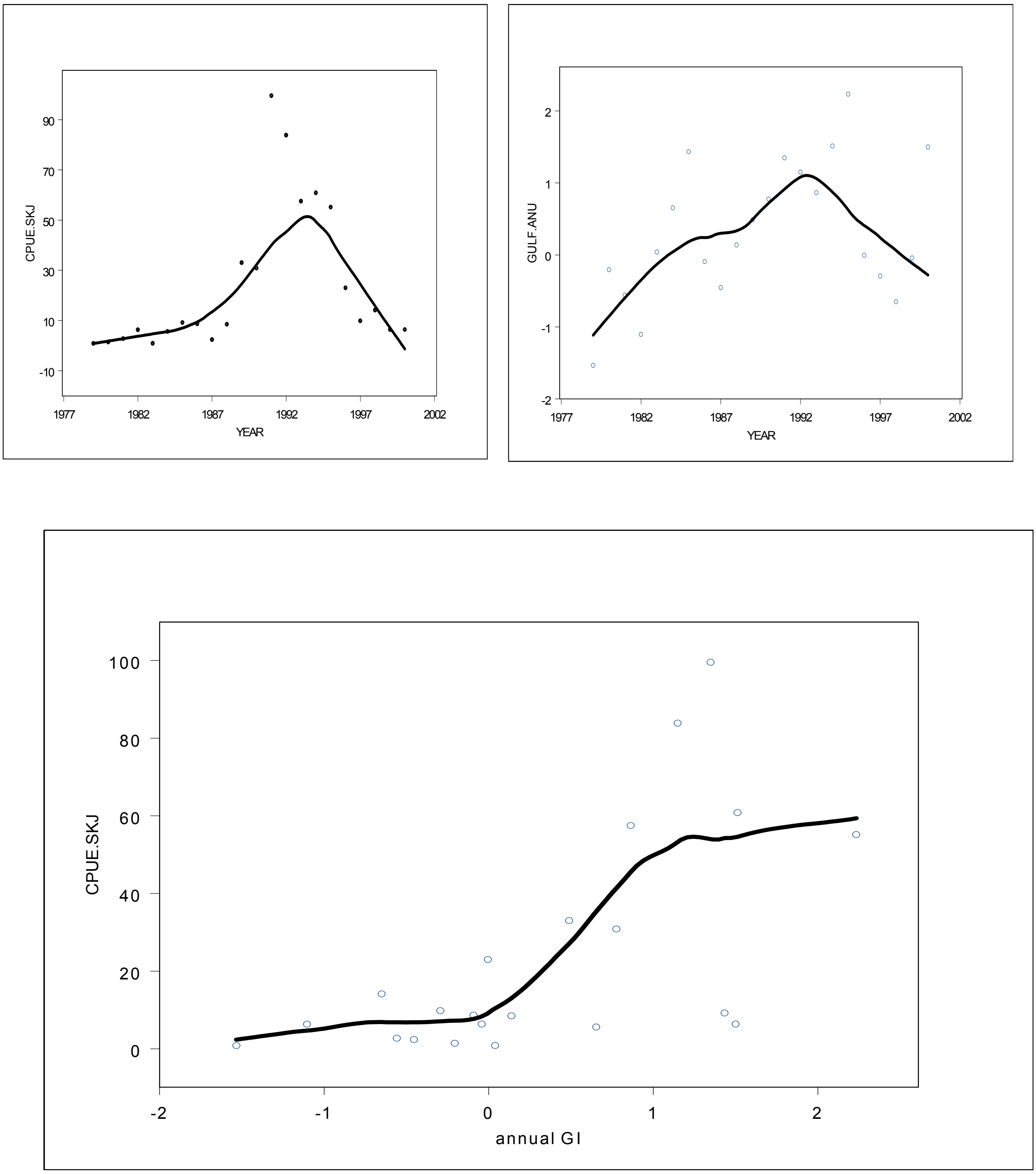


Figure 6 . Annual catch per unit of effort values for SKJ in tons per vessel (top left.), annual GSNW index (top right) and adjustment of the two values (bottom) using a smoothing *Loess* fit.

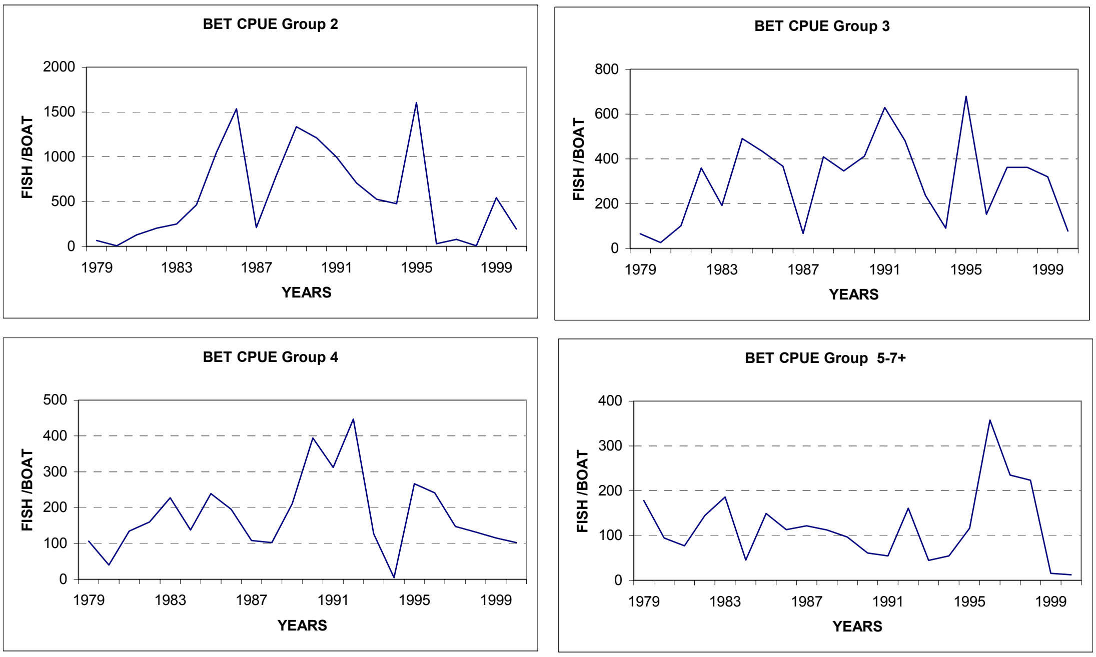


Figure 7. Catch per unit of effort by size class (annual CPUE in number of fishes per vessel) of BET, for the 1979-2000 period.

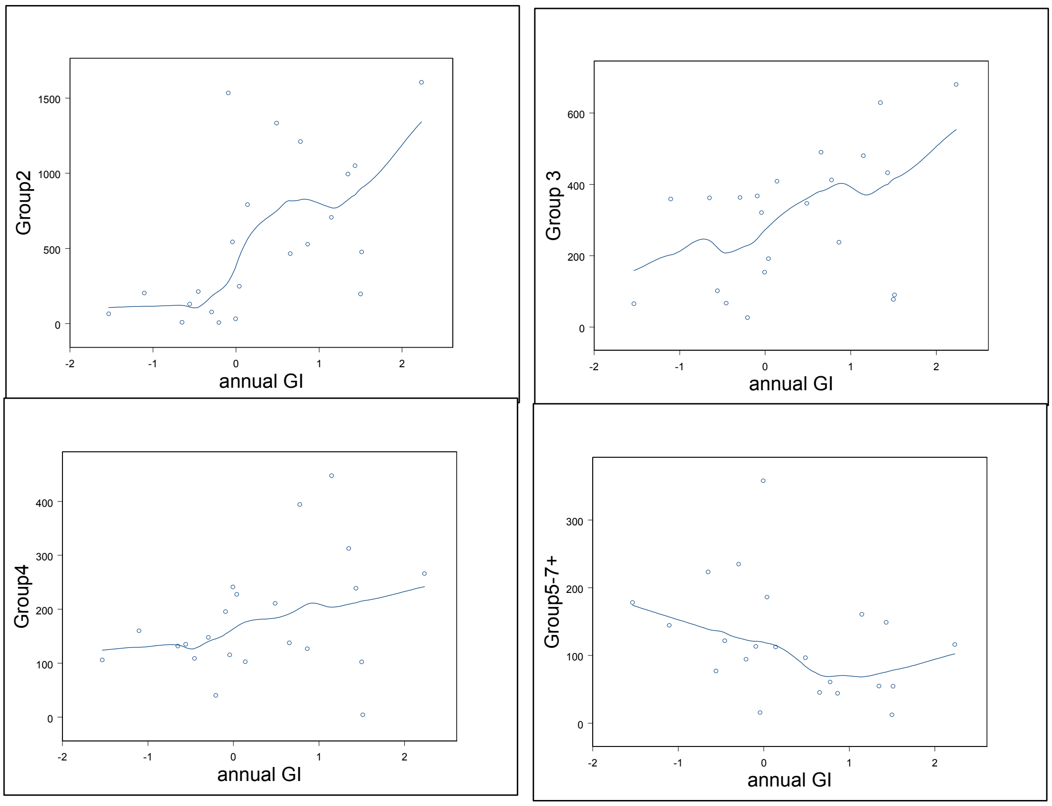


Figure 8. Catch per unit of effort of BET (number of fishes per vessel) for the different size classes defined relative to the annual value of the GSNW index.

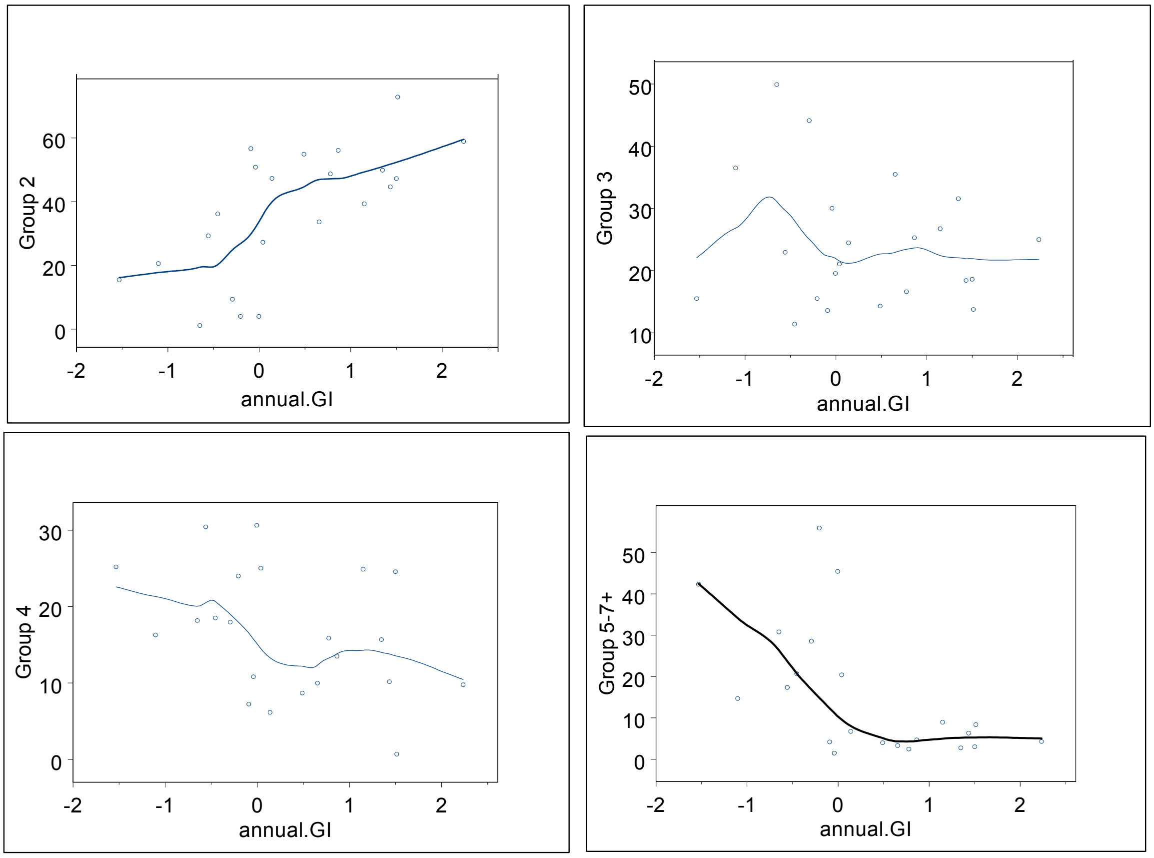


Figure 9. Relative annual composition of the BET catch (annual percentage of number of fishes caught from each size class in relation to the total annual number caught) with regard of the annual value of GSNW index.