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Stock Annex: Blue Whiting in Subareas I-IX, XII and XIV

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Blue Whiting in Subareas I-IX, XII and XIV
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A. General

A.1. Stock definition

Blue whiting (*Micromesistius poutassou*) is a pelagic gadoid that is widely distributed in the eastern part of the North Atlantic. The highest concentrations are found during spawning along the edge of the continental shelf in areas west of the British Isles and on the Rockall Bank plateau where it occurs in large schools at depths ranging between 300 and 600 meters but is also present in almost all other management areas between the Barents Sea and the Strait of Gibraltar and west to the Irminger Sea. Adults reach maturation at 2-7 years old and undertake long annual migrations from the feeding grounds to the spawning grounds (Bailey, 1982). Most of the spawning takes place between March and April, along the shelf edge and the banks west of the British Isles. Juveniles are abundant in many areas, with an important nursery area believed to be the Norwegian Sea, at least in times of high abundance. Morphological, physiological, and genetic research has suggested that there may be several components of the stock which mix in the spawning area west of the British Isles. Due to the large population size, its considerable migratory capabilities and wide spatial distribution, the stock composition and dynamics require continued monitoring. The migration routes of blue whiting in the north Atlantic are shown in Figure D1.

Blue Whiting Stock Identity

Prior to 1993, for the purposes of assessment, it was assumed that blue whiting had two components, a northern and a southern component. The Northern stock was known to feed in the Norwegian Sea and spawn to the west of the British Isles. The Southern stock was found along the continental shelf off the coast of Spain and Portugal with the main spawning areas towards the Porcupine Bank. The Porcupine Bank was considered a transitional area between the two main stocks (ICES, 1990). In 1993 it was argued that there was no strong evidence to maintain this division between the two stocks. Results from an otolith age reading workshop at that time showed no significant difference in mean annual ring diameter between northern and southern stocks. It was agreed by ACFM in 1993 that the two stocks should be combined for assessment purposes (ICES, 1995). Since then this stock has been assessed as one unit.

Several approaches have been employed to investigate the stock structure of blue whiting. The details of studies relating to genetics, larval otolith growth patterns and the movements of eggs and larvae have been published in recent years.

Blue Whiting have a wide geographic distribution and large population size, which is generally advantageous for the accumulation and preservation of genetic variability (Mork and Giaever, 1995). The first genetic work was carried out in the early 1990s. A study was carried out by Mork and Giaever, 1995 included samples from most of the eastern Atlantic but the amount of samples from the southern part of this area was generally low. Further work revealed significant geographic heterogeneity with reproductive units found at the fringes of the distribution range. A genetically distinct population was found in the Barents Sea and potential populations identified in the Mediterranean and Romsdalsfjord area of Norway. Samples taken from the area west of the British Isles and from the Norwegian Sea were genetically similar, which suggests a single blue whiting stock throughout the area (Giaever and Stein, 1998). Genetically distinct populations were also found in the Barents Sea and Mediterranean by Ryan *et al* 2005 by using one minisatellite and five microsatellite loci. Temporal variation was also seen between samples collected on the main spawning area. In this case there was insufficient data to identify explicitly the geographic range of these possible stocks. The most recent study conducted by Was *et al*, 2008 used a landscape genetics approach which combines spatial and genetic information to detect barriers to gene flow. This microsatellite analysis found that samples collected and analysed from along the south flowing current from the Porcupine Bank i.e. the Celtic Sea and Bay of Biscay were genetically different from those in the northward flowing current. Temporal variation was seen in samples collected in the Rockall Bank area and the reasons for this are inconclusive.

Oceanographic modelling has been used to examine movements of blue whiting eggs and larvae. Larval drift is an important factor in recruitment. A hypothesis put forward by Skogen *et al*, 1999, was that the southern stock will spawn in an area where the eggs and larvae are likely to drift southwards and the northern stock where the eggs and larvae will drift northwards. Based on modelled drift patterns they found that a possible separation line was located at 54.5ºN but this was subject to significant interannual variability over the twenty years studied. Work conducted by Bartsch and Coombs (1997) used a three dimensional baroclinic model suggests that particles released on the Porcupine Bank drifted southwards with a separation at about 53-54ºN. This work gave some additional information about stock separation but suggested that the division might be more southerly. Additional testing of the use of this type of model was recommended.

An investigation of larval growth histories was carried out in 2007 (Brophy and King, 2007). Groups that are spatially or temporally distinct after hatching show measurable differences in the larval portion of the otolith. This study has shown that larvae from the Bay of Biscay grow faster than those from more northerly spawning areas. It also confirmed that fish spawning to the west of Ireland and Scotland, do not form a randomly mixing unit and that subunits within this aggregation have experienced differences during the larval phase. It was hypothesised that the dispersal of larvae could influence the subsequent dispersal of spawning adults. The fish that are found in the feeding assemblages throughout the distribution may not contribute equally to the spawning assemblages in the north and south of the spawning grounds.

In 2009 the stock identification methods working group (SIMWG) stated that the perception of blue whiting in the NE Atlantic as a single unit stock is not consistent with recently observed differences in genetics and growth and should be revised; based on current available data. They recommended that a precautionary approach should initially treat blue whiting populations in areas VIIk and VIIj and further south as a separate unit from all other NE populations. SIMWG is in support of an initial, precautionary delineation of "two main stocks" but also vigorously suggests that a large, interdisciplinary project on this species is needed in order to comprehensively understand blue whiting stock structure in the NE Atlantic so that SIMWG may provide more robust advice (ICES, 2009a).

Recent results from length-at-age and otholith shape analysis presented in at WKPELA in 2012 (ICES, 2012?) did not provide evidence two separate stocks but rather substantial mixing of individuals on the common spawning grounds. At this meeting following a full review of available studies on blue whiting stock structure in the northeast Atlantic. The working group came to the conclusion that there is no scientific evidence in support of multiple stocks with distinct spawning locations or timings. The emerging picture is one of a single stock whose large scale spatial distriution varies as a function of hydrographic conditions and total abundance; this is commonly described as an abundance-occupancy relationship. Further, there seem to be a number of core nursery and feeding areas with marginal areas being occupied at times of high stock abundance. As a result, the working group decided to recommend treating blue whiting in ICES subareas I–IX, XII and XIV as a single stock for assessment purposes.

A.2. Fishery

Since 1988, 18 national fleets have been involved in the blue whiting fisheries. The highest landings have been reported by Norway, followed by the USSR/Russia, Iceland and the Faroes. Over the last decade, 13 or 14 national fleets land parts of the blue whiting quota each year. The highest concentrations of catches are generally found along the edge of the continental shelf in the area west of the British Isles, on the Rockall and Hatton Banks and around the Faroe Islands in quarter 1. In the following quarters catches are generally taken further north in the Norwegian Sea and also in the North Sea with lesser quantities of blue whiting caught in the southern area off Spain and Portugal.

Most of the catches are taken in the directed pelagic trawl fishery in the spawning and post spawning areas (Divisions Vb, VIa, b, and VIIb, c). Catches are also taken in the directed and mixed fishery in Subarea IV and Division IIIa, and in the pelagic trawl fishery in the Subareas I and II and in Divisions Va and XIVb. These fisheries in the northern areas have taken between 360,000–2,300,000 t per year in the last decade, while catches in the southern areas (Subarea VIII, IX, Divisions VIId, e and g–k) have been in the range of 20,000–85,000 t. The proportion of landings originating from the Norwegian Sea fluctuates greatly, having increased from 5% of the total in the mid-1990s to around 30% in 2003–2004, after which the proportion decreased again to below 10%. These fluctuations are thought to be linked to fluctuations in recruitment. In Division IXa blue whiting is mainly taken as bycatch in mixed trawl fisheries (ICES, 2008a). The proportions of landings originating in each area are mapped and presented in the annual working group reports.

The procedure of the working group is to split length frequency data into three areas, although it is recognised that the northern area comprises both spawning size fish and juveniles. The three areas are as follows:

1. The southern area around Spain and Portugal
2. The northern area which includes the spawning grounds and the Norwegian Sea
3. The North Sea and the Skagerrak.

A.3. Ecosystem aspects

The blue whiting stock has seen an almost threefold increase in spawning stock biomass since the mid 1990's. In recent years the stocks has declined in terms of spawning stock biomass and the year classes from 2005 and onwards are all poor. However, some signs of improved recruitment were observed from the two surveys in 2011 where young blue whiting were caught in the northern areas of the spawning stock survey in April (IBWSS) as well as in the May Ecosystem survey in the Nordic Seas (IESNS). Throughout this low period, recruitment strength in the Bay of Biscay and Celtic Sea seemed to have been high for the regions, indicating a anti-cyclic pattern. The early life stages have a significant influence on the reproductive success of this stock. The main blue whiting spawning areas are located along the shelf edge and banks west of the British Isles and Ireland. The eggs and larvae spawned on the Porcupine Bank area (west of Ireland) can drift both towards the south and towards the north, depending on the spawning location, oceanographic conditions and the effects from wind force, while the spawning products from the northern spawning area west of the Hebrides always drift northwards. The northward drift spreads the major part of the juvenile blue whiting to the Norwegian Sea and adjacent areas from Iceland, Faroes and North Sea to the Barents Sea. The larvae usually settle on the deeper areas of the various shelf-edges in the autumn and stay more or less associated with bottom the first winter or more, gradually becoming part of the mature stock after 2 or 3 years. Adult blue whiting carry out active feeding and spawning migrations in the same area as herring. Blue whiting has consequently an important role in the pelagic ecosystems of the area, both by consuming zooplankton and small fish, and by providing a food resource for larger fish and marine mammals (ICES, 2009b). However, a study by Utne *et al*. (in press 2012) suggest that the vertical overlap between blue whiting and herring/mackerel in the Norwegian Sea during the summer feeding period is limited as blue whiting prefer to stay in deeper waters than the other two species. These indicate that the food competition might be limited between blue whiting and mackerel/herring during the summer months in certain areas.

During the spawning stock survey on blue whiting in 2009, large amounts of mackerel were observed throughout the spawning grounds. The mackerel was distributed from 60-300 meters and fed heavily on pearlsides (*Maurolicus mülleri*) (PGNAPES, ICES RMC/06, 2009). The overlapping distribution of feeding mackerel within the blue whiting spawning grounds suggests a possible ecologic interaction between the two stocks, and predation from mackerel on blue whiting egg and larvae could be a contributing factor to the collapse in blue whiting recruitment observed. This interaction may have increased significantly both with the growth in the mackerel stock and with the changes observed in mackerel distribution in recent years. It is strongly suggested that investigations are carried out on this relationship in order to evaluate possible effects of mackerel on blue whiting recruitment.

Environmental conditions in the main spawning areas have undergone significant changes during this time. Changes in temperature, salinity and circulation have been recorded in long term trend data. Blue whiting are sensitive to temperature and salinity and will only spawn in waters with suitable ranges. Hatun *et al.* (2009a) suggests a temperature range of 9°-10°C and salinity ranges of between 35.35 and 35.45 psu.

The ICES report on ocean climate (ICES, 2008b) provides a summary of long term trends in environmental conditions until the end of 2007. Increases in temperature and salinity have been recorded over the blue whiting distribution area. An increase in sea surface temperature (SST) was shown at several of the monitoring stations in the NE Atlantic with temperatures up 3°C since the early 1980s (ICES, 2008c). Salinity has shown some fluctuations throughout the time series. In the Rockall trough salinity reached a peak in 2003 and has declined slightly since then. The same trend can be seen in the Faroes Shetland Channel. In the Norwegian Sea increases in both temperature and salinity have occurred since the mid 1990s (ICES, 2008b).

The circulation of the North Atlantic is characterized by two large gyres: the subpolar and subtropical gyre. Some of the water in the subtropical gyre is re-circulated to the west of the Mid Atlantic Ridge (MAR) and some water continues east and crosses the MAR in the Azores Current and the remainder forms the North Atlantic Current (NAC) (ICES 2008f). The subpolar gyre controls the flow trajectory of the NAC in the Northeastern Atlantic. When the gyre is strong, it extends eastwards, branches off and carries cold less saline water to the Rockall Trough and over the Rockall plateau (Figure D2a). When the gyre is weak it moves west and allows subtropical water to spread north and west and this results in warmer more saline conditions (Figure D2b) (Hatun, *et al.* 2009a).

Work carried out by Hatun, *et al.* 2007 used a gyre index value which is obtained from the simulated sea surface height over the entire North Atlantic Ocean and it reflects the shape and strength of the subpolar gyre. Since blue whiting are known to spawn in water masses with a relatively narrow temperature and salinity range the variability in the strength of the gyre index influences their spawning distribution. A strong gyre index is associated with cold and fresh conditions in the North East Atlantic and this seems to coincide with spawning to the east, along the continental slope and the Porcupine Bank area. The post spawning migration takes place in the Faroe Shetland channel and is possibly associated with a smaller total fish stock. When the gyre index is weak spawning takes place on the western slope of the Faroe plateau and over the Rockall plateau. The post spawning migration is also on the west through the Faroe Bank channel and is possibly leads to a larger stock size. The estimated threefold increase in blue whiting biomass coincided with major changes in the marine climate and this shift between east and west during the mid 1990s indicates a possible connection.

Hatun, *et al.* 2009a explored the hypothesis that the spawning distribution is predominantly controlled by the marine climate conditions west of Ireland, along the continental slope and west of Rockall when the subpolar gyre is weak and towards the Porcupine bank when the subpolar gyre is strong. This study used hydrographic, acoustic biomass and larval data as well as catch statistics and data from the regional gyre index. This study showed that the spawning distribution of blue whiting is determined by oceanographic conditions to the west of Great Britain and Ireland which in turn are regulated by the North Atlantic subpolar gyre.

Further work was carried out to examine large scale bio-geographical shifts in the northeast Atlantic from the subpolar gyre which used an ocean circulation model and data from four trophic levels including phytoplankton, zooplankton, blue whiting and pilot whales (Hatun, *et al.* 2009b). This study found that changes in the distribution of blue whiting are caused by variable stock size and by shifts in the migration pattern. The subpolar gyre influences this process either by:

1. Directly regulating the currents and or hydrographic conditions that will influence the migration routes

   or

2. Indirectly via trophodynamics.

This work suggests that recent advances in simulating the dynamics of the subpolar gyre may provide a potential for predicting the distribution of the main faunal zones in the north-eastern Atlantic a few years into the future. This in turn would facilitate more rational management of commercially important fish species.

Recruitment

A workshop was held in 2009 that examined blue whiting recruitment. The group reviewed and updated existing work on both the oceanography in the region and the distribution dynamics of blue whiting, particularly focusing on the most recent observations. A broad selection of hypothesizes were examined that may explain the recruitment dynamics of this stock. The group focused on two potential mechanisms that may account for the hypothesized links between the oceanographic climate and the recruitment dynamics.

1. The predation hypothesis

This hypothesis examines the role of mackerel predation and changes in the spawning distribution of blue whiting. Changes in the spawning distribution lead to changes in the mackerel-blue whiting larvae overlap, and therefore the degree of predation.

2. The food hypothesis

This hypothesis is based on the amount and availability of food to the larvae and juveniles. Changes in the oceanographic conditions may change the food availability and ultimately impact larval/juvenile growth, survival and recruitment. More research if required to examine these topics (ICES, 2009c, RMC:09)

Finally, the workshop examined potential schemes that could be used for generating recruitment forecasts. A high-degree of autocorrelation is present in the time-series, and indeed the assumption that recruitment in the following year is the same as the recruitment in the previous year was found to give relatively good predictions ($r2=0.57$). However, in the absence of a detailed process understanding, it was not possible to move beyond such basic schemes towards making genuine, knowledge-based, forecasts though qualitatively forecasts (high or low) might be feasible. Further research is required.

B. Data

B.1. Commercial catch

SALLOCL

Commercial catch data is obtained from national laboratories of nations exploiting blue whiting. Data exchange spreadsheets are submitted to the stock coordinator. Prior to 2009 the data in the exchange spreadsheets were allocated samples to catch using the SALLOCL-application (Patterson, 1998). This programme produced the standard outputs on sampling status and biological parameters. It also clearly documented any decisions made by the stock co-ordinators for filling in missing data and raising the catch information of one nation/quarter/area with information from another data set.

InterCatch

InterCatch which is a web-based system for handling fish stock assessment data was first used in 2009. Blue Whiting data are submitted using the 'Data Submission Workbook' spreadsheet and converted into the InterCatch format by the program "InterCatchFilemaker", developed by Andrew Campbell from Marine Institute, Galway, Ireland. The total International Catch-at-Age was available through the InterCatch web program. The allocations for those countries reporting catches without samples, were generally made using all available data for the same ICES Division and the same quarter. In cases where this was not possible, data from the nearest Divisions and the same quarter were used.

B.2. Biological Data

Sampling Protocol

In recent years all of the main countries participating in this fishery have provided sampling data to the working group. The European Commission Regulation 1639/2001 sets out the minimum and extended programmes for the collection of data in the fisheries sector and includes guidelines for blue whiting. This regulation requires EU Member States to take a minimum of one sample to be taken for every 1000 t landed in their country. Detailed information on the number of samples collected, number of fish aged and measured by year and by country is presented in the working group report (ICES, 2008a). This regulation applies to EU member states and there are currently no guidelines in place for other countries. Current precision levels of the sampling intensity are unknown and the group recommends reviewing the sampling frequency and intensity on a scientific basis and providing guidelines for sampling intensity.

Age Reading

The most recent age reading workshop took place in Hirtshals Denmark in June 2005. Guidelines for ageing blue whiting are outlined in this report and all of the workshop participants agreed to follow these guidelines. The workshop found that overall there was a high level of agreement between age readers. The two main reasons for disagreement between age readers were firstly the position of the first ring when the Bowers ring is clear and secondly true rings not counted by less experienced readers. Younger fish achieved better precision than older fish. This illustrates the problems associated with ageing older fish and is a common problem among many fish species (Worsøe Clausen, *et al* 2005).

An otolith exchange was carried out in 2009/2010 for a workshop in 2011. Age reading problems of 1 and 2 group blue whiting became evident during the 2011 May survey where small blue whiting was aged as 1, 2 or a combination of 1 an 2 years, pending on which country read the otoliths. This clearly demonstrates the need to calibrate the age-readings by each institute participating in the surveys.

Age composition in the catch

The catch numbers at age were mean standardised by year and are presented in Figure D3. Strong year classes can be seen in the past as they moved through the fishery. In recent years the numbers of fish at younger year classes are not as abundant and there are no signs of incoming strong recruitment.

Weight at age in the catch and Weight at age in the stock

Mean weight at age in the catch data are calculated on an annual basis from data supplied by Denmark, the Faroes, Iceland, Ireland, the Netherlands, Norway, Portugal, Russia, Scotland and Spain. Figure D4 shows the mean weight at age for the total catch from 1981–2009 which is used in the stock assessment in 2010.

Maturity

Maturity at age used in the assessment was obtained by combining maturity ogives from the southern and northern areas, weighted by catch in numbers at age (ICES, 1995). These values have been used since 1994. Although the values of maturity at age may be too low, sufficient information for estimating new ogives is not available.

Natural Mortality

It is known that blue whiting is a common prey amongst many different fish, cetacean and mammal predators. Defining how this impact varies over time is not a trivial issue for such a widely distributed stock that also exhibits notable changes in stock productivity over time. The current M of 0.2 was derived from investigations undertaken in the 1980s that examined the age distribution of the stock before the industrial fishery started. The possible need for revising the current estimate of instantaneous natural mortality rate *M* for blue whiting was discussed in detail by the 2002 WG (ICES, 2002). The value of M estimated from different methods was in the range of 0.38 to 0.60. Although it was acknowledged that the current estimate M =0.2 yr might be too low, there is not a strong basis for revision. At the WKPELA pelagic benchmark meeting, in 2012, various methods to attempt to estimate how M may vary over ages were explored. The relationship between natural mortality and body weight was applied to the blue whiting data to determine a variable M by age. The values ranged from around 1.1 at age 0 to 0.7 at age 10, which is considerably higher than the value used so far. Methodological work by WGMG (ICES, 2003a) emphasizes that natural mortality rate cannot be estimated reliably with information normally available for stock assessment models, so it is considered that further examination would be necessary in order to incorporate such values into the assessment. The effect a change in the assumed natural mortality in the assessment would have on assessment results would also need to be explored. At present it is considered that there is no new information to support a revision of the current estimate of M.

F and M before spawning

Both are set at 0, equivalent to spawning on the 1^{st} January.

Discards

Discards of blue whiting are thought to be small. Most of the blue whiting caught in directed fisheries are used for reduction to fish meal and fish oil. However, some discarding occurs in the fisheries for human consumption and as bycatch in fisheries directed towards other species.

Reports on discarding from fisheries which catch blue whiting were available from the Netherlands for the years 2002–2007 and 2012-2014. A study carried out to examine discarding in the Dutch fleet found that blue whiting made a minor contribution to the total pelagic discards when compared with the main species mackerel, horse mackerel and herring (Figure D5). The length frequencies of landed and discarded fish caught were compared and from this data it is clear that herring and blue whiting are not selected and discarded for length reasons (Figure D6). It is more likely that in sorting and processing of mackerel small fish are commonly discarded (Borges, et al 2008).

Information on discards was available for Spanish fleets since 2006. Blue whiting is a bycatch in several bottom trawl mixed fisheries. The estimates of discards in these mixed fisheries in 2006 ranged between 23% and 99% (in weight) as most of the catch is discarded and only last day catch may be retained for marketing fresh. The catch rates of blue whiting in these fisheries are however low. In the directed fishery for blue whiting for human consumption with pair trawls, discards were estimated to be 13% (in weight) in 2006.

Since 2004, was available the blue whiting discards data produced by Portuguese vessels operating with bottom otter trawl within the Portuguese reaches of ICES Division IXa. The discards data are from two fisheries: the crustacean fishery and the demersal fish fishery. The blue whiting estimates of discards in the crustacean fishery for the period of 2004-2011 ranged between 23% and 40% (in metric tonnes). For the same period the frequency of occurrence in the demersal fish fishery was around zero for the most of the years, in the years were it was significant (2004, 2006, 2010) was ranged between 43% and 38% (in metric tonnes). In 2014, discards were 39% of the total catches for blue whiting in the Portuguese coast

In general, discards are assumed to be minor in the blue whiting directed fishery. Discard data are provided by the Denmark, Netherlands, UK (England and Wales), Spain and Portugal to the working group. The discards rates of blue whiting in Denmark, Netherlands, UK (England and Wales) fisheries are low and were not used in the assessment. The discards of Portugal and Spain which constitute respectively 39 and 20% of the total catches were considered in this year assessment.

B.3. Surveys

A number of surveys are (or have been) carried out which provide data on blue whiting abundance in different areas of their distribution. One survey is used to tune the assessment. The remaining surveys are not used in the assessment but data are updated on an annual basis and could be incorporated at a later stage should further work suggest their inclusion would lead to an improvement in the assessment.

Surveys Used in the assessment

1. International Blue Whiting spawning stock survey (IBWSS)

The IBWSS is carried out in March-April on the spawning grounds to the west of the British Isles and was established in its current form in 2004. Five countries participate annually in the survey; the Russian Federation, Norway, Faroes, the Netherlands and Ireland. The survey is internationally coordinated through the Working Group of International Pelagic Surveys (WGIPS).

The design of the IBWSS has traditionally been aimed at reducing the effects of double counting of the northward migrating spawning aggregation. Consideration is also given to the start and end times of the survey window to assure a synoptic coverage while taking into account vessel availability in the different countries and temporal occurrence of spawning aggregations. The spatial confines of the survey, although not fixed, are defined as core spawning areas and secondary target areas as suggested in 2005. The overall design uses stratified transects with a random start (random latitude) to ensure transect coverage is not replicated but randomised between years. The survey procedures are described in the "Manual for Acoustic Surveys on Norwegian Spring-spawning Herring in the Norwegian Sea and Acoustic Surveys on Blue whiting in the Eastern Atlantic" (ICES, 2008). The main problem affecting the outcome of the survey relates to adverse weather conditions encountered in the Northeast Atlantic at the time of the survey. This survey was first used as a tuning series in the assessment in 2007 with ages 3-8.

During the 2011 WGWIDE working group meeting it was decided to exclude the 2010 values from the IBWSSS time series on the basis of a recommendation from WGNAPES. During the 2010 survey, poor weather and a mismatch between vessels led to a gap in coverage in north Porcupine and south Hebrides (ICES CM2010/SSGESST:20). It was agreed within WGNAPES in 2010 that the gap in area coverage occurred in an area of concentrated fishing effort and thus contained a high but un-quantified biomass. Mean acoustic density for the un-surveyed rectangles within the core spawning area was determined by means of interpolation from surrounding surveyed rectangles following established methods. It was also agreed that the gap in coverage had no doubt resulted in an underestimate of the stock. However, the revised estimate was recommended to be accepted by WGWIDE in 2010 as the best available. In WGNAPES 2011(ICES CM2011/SSGESST:16) the time series was reviewed and the problems in the 2010 IBWSS was considered. The updated survey time series, including the 2011 survey, show a decline in the observed stock but the rate of decline is not as abrupt if the 2010 estimate is excluded. Due to the large uncertainties in the estimate from 2010, WGNAPES recommended to exclude the 2010 data from the time series in the assessment.

The original TS-length relationship applied for blue whiting was considered too low and tended to overestimate the abundance of fish. This original relationship was based on measurements taken from a juvenile cod in the 1970s and was applied as the best estimate available at the time. Acoustic abundance estimates of blue whiting have so far tended to be considerably higher than those based on the assessment. The Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES) met in 2012. The objectives of the workshop were to implement a new TS-Length relationship proposed by Pedersen *et al*. (2011). This latest research used in-situ acoustic measurements and was taken over several years, utilizing several different observation platforms. As the measurements were taken during the spawning stock survey they are not only species-specific but also time and area specific, something which was not achieved with the old TS-length relationship. Recalculating the survey index resulted in an expected downward shift to around 32% of the original TSB. When recalculating the survey index all previous settings were retained to ensure continuity and comparability across the index. During the review of survey data an error was observed in the presented 2009 blue whiting estimate relating to abundance at age data. This error was corrected in the data in 2012.

2. International ecosystem survey in the Nordic Seas (IESNS)

An international ecosystem survey is carried out annually in the Nordic Seas from late April to early June aimed at observing the pelagic ecosystem in this area. This survey focuses on Norwegian spring spawning herring, blue whiting, zooplankton and hydrography.

The survey area was split into three subareas which are as follows:

Area I - Barents Sea

Area II - northern and central Norwegian Sea

Area III - Southwestern area, i.e. Faroese and Icelandic zones and Southwestern part of the Norwegian Sea

The survey is coordinated by WGIPS. Ages 1-2 from this survey were used as recruitment indices, but WKPELA2012 decided not to use any recruitment series in the assessment.

3. Norwegian survey on the spawning grounds

The Norwegian survey on the spawning grounds for blue whiting, west of the British Isles, provides the longest time series covering a significant part of the blue whiting stock, and is an important time series for tuning the assessment. This survey was carried out from 1991-2006. The time series from 1991 – 2003, ages 3-8 is currently used to tune the assessment. This survey was replaced by the International spawning stock survey.

<u>Surveys not used in the assessment but provide information</u>

4. Norwegian bottom trawl survey in the Barents Sea

Norway has conducted bottom trawl surveys targeting cod and other demersal fish in the Barents Sea since late 1970s. From 1981 onwards there have been systematically designed surveys carried out during the winter months (usually late January ‐ early March) by at least two Norwegian vessels; in some years the survey has been conducted in co ‐ operation with Russia. Blue whiting is a regular bycatch species in these surveys, and has in some years been among the numerically dominant species (Heino *et al,* 2003). This survey is presently giving the first reliable indication of year class strength of blue whiting. The survey is not used in the assessment because of it coverage at the edge of the distribution area, but it is used for recruitment predictions. The indices of 1 group blue whiting are presented in Table D1.

5. Spanish bottom trawl survey

Bottom trawl surveys have been conducted off the Galician (NW Spain) coast since 1980, following a stratified random sampling design and covering depths down to 500 m. The survey is directed to a mixture of species. Since 1983, the area covered in the Spanish survey was extended to completely cover Spanish waters in Division VIIIc. A new stratification has been established since 1997. The survey is not used in the assessments as it is only representative for a small part of the stock area. The mean catch and standard error of these bottom trawl surveys are presented in Table D2 and Figures E7. The stratified mean catch is presented in Figure D8.

6. Portuguese bottom trawl survey

Bottom trawl surveys have been conducted off the Portuguese coast since 1979, following a stratified random sampling design and covering depths down to 500 m. The area covered in the Portuguese survey was extended in 1989 to the 750 m contour. The survey is not used in the assessments as it is only representative for a small part of the stock area. The mean catch and standard error of these surveys is presented in Table D3.

7. French bottom trawl survey

Bottom trawl surveys have been carried out since 1987 in the Bay of Biscay and 1997 in the Celtic Sea following a random stratified sampling design and covering depths down to 700 m; both areas are covered in October-November. Estimates of aged 0 blue whiting using a cut off of 18 cm and raised to the total survey areas are presented in Table D5.

8. Irish bottom trawl survey

The current bottom trawl survey has been carried out since 2003 in October-November around Ireland using a stratified design (the design changed in 2005). Estimates of age 0 using a 18 cm cut off point are shown in Table D6.

7. Other Surveys

Several other surveys have in the past provided data to the Working Group. In recent years however these data have not been updated. Historical results from the following surveys are presented in WGNPBW working group reports.

- Norwegian Sea summer survey carried out in 1981 – 2001, 2005 – 2007. The stock estimates in numbers at age are given in the 2007 report.
- Faroes plateau spring bottom trawl survey carried out in March 1996–2008. The survey is aimed at cod, haddock and saithe, but varying amounts of blue whiting are caught as bycatch each year.
- Faroes plateau autumn bottom trawl survey carried out in August- September 1994–2008. The survey is aimed at cod, haddock and saithe, but varying amounts of blue whiting are caught as bycatch each year.

B.4. Commercial CPUE

Spanish pair trawl CPUE

The Spanish pair trawls CPUE series was used for several years as a tuning fleet in the blue whiting assessment. Following a recommendation of the methods working group (ICES, 2003) the use of this CPUE data was discontinued because this fleet represents only a small part of the landings caught in a small part of the distribution area. This data series runs from 1983-2003 and has not been updated since then. The age stratified CPUE data are shown in Table 4 and Figure 9 and show a slight declining trend in CPUE.

Norwegian CPUE

CPUE data in the spawning area was collected from the Norwegian commercial fleet 1982–2003. The time series has not been updated in recent years. The data are not considered to be representative for the development of the stock and are not used in the assessment.

B.5. Other relevant data

None.

C. Assessment Method and Data

Model used:

The State-space Assessment Model (SAM), analytical assessment.

At the Benchmark (WKPELA, 2012) the state-space models SAM model was chosen as the assessment model for blue whiting. SAM offers a flexible way of describing the entire system, with relative few model parameters. Compared to the previously used SMS model, SAM models fishing mortality from random walk, whereas SMS assumes a separable model for fishing mortality and thereby a rather stable exploitation pattern. Model diagnostics from both models for are similar; however SAM gives a slightly better fit to catch data as it allows variations in exploitation pattern from year to year. The assessment output from the two models is almost identical, such that the perception of the stock remains unchanged using SAM.

Software used:

Source code for the SAM model and all scripts are freely available at http://130.226.135.24/bluewhiting [Username: guest; Password: guest]. This web-page does also provide the latest assessment, including input and output.

Model Options chosen:

The blue whiting assessment makes use of one survey index (International Spawning Ground survey, IBWSSS) is used, and the total catch-at-age data. Fishing mortality random walks are allowed to be correlated.

The table below present the SAM configuration options (file model.cfg). In the file text following a hash-mark ("#") is a comment

```
# Min, max age represented internally in model
 1 10
# Max age considered a plus group? (0 = No, 1= Yes)

# Coupling of fishing mortality STATES
# 1 2 3 4 5 6 7 8 9 10 # Age
  1 2 3 4 5 6 7 8 9 9 # catch
  0 0 0 0 0 0 0 0 0 0 # IBWSSS

# Use correlated random walks for the fishing mortalities
# ( 0 = independent, 1 = correlation estimated)

# Coupling of catchability PARAMETERS
# 1 2 3 4 5  6  7  8 9 10 # Age
  0 0 0 0 0  0  0  0 0  0 # catch
  0 0 1 2 3  3  3  3 0  0 # IBWSSS

# Coupling of power law model EXPONENTS
# 1 2 3 4 5 6 7 8 9 10 #
  0 0 0 0 0 0 0 0 0 0 # catch
  0 0 0 0 0 0 0 0 0 0 # IBWSSS

# Coupling of fishing mortality RW VARIANCES
# 1 2 3 4 5 6 7 8 9 10 #
  1 1 1 1 1 1 1 1 1 1 # catch
  0 0 0 0 0 0 0 0 0 0 # IBWSSS

# Coupling of log N RW VARIANCES
# 1 2 3 4 5 6 7 8 9 10 #
  1 2 2 2 2 2 2 2 2 2

# Coupling of OBSERVATION VARIANCES
```

```
# 1 2 3 4 5 6 7 8 9 10 #
  1 2 3 3 3 3 3 3 4 4 # catch
  0 0 5 6 6 6 7 7 0 0 # IBWSSS

# Stock recruitment model code (0=RW, 1=Ricker, 2=BH)
 0
# Years in which catch data are to be scaled by an estimated parameter
(mainly cod related)
 0
# Fbar range
 3 7

# so called checksum
123 123
```

The options for "Coupling of fishing mortality STATES" show that random walk for F is independent by age for the ages 1-8, and combined for age 9 and 10.

It is assumed that F at age is correlated to some degree estimated by the models. Therefore the option for "Use correlated random walks for the fishing mortalities" is set to 1.

The `"Coupling of catchability PARAMETERS"` specifies the grouping of ages with respect to survey catchability. For the IBWSSS survey there is assumed an age dependent catchability for age 3 and 4, and a combined (the same) catchability ages 5-8.

In the IBWSSS a linear relation between CPUE and stock size is assumed, such that the options for `"Coupling of power law model EXPONENTS"` are all set to 0.

The variance for the random walk for F (`"Coupling of fishing mortality RW VARIANCES ")` is assumed the same for all ages.

The `"Coupling of OBSERVATION VARIANCES"` specifies the options for observation noise for both catches and survey indices. For catches the observation variance is age dependent for age 1 and 2. For ages 4-8 the variance is assumed the same, and different from the variance for ages 9-10. For the IBWSSS survey the variance is the the same within the groups of age 3, 4-6, and 7-8.

There is no obvious relation between SSB and recruitment, but recruitment seems to be correlated between years. To reflect this, the `"Stock recruitment model code"` is set to 0=Random Walk.

SAM is a new model which has not been applied to blue whiting before. Small changes in model structure may be applied following the first WGWIDE assessment of the stock using this model. In particular, to be able to effectively handled large changes in F in the terminal year (as may happen with the low 2011 TAC) an alternative variance distribution may be required for the random walk on F (e.g. t-distribution).

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1981 –	1-10	Yes
Canum	Catch at age in numbers	1981 –	1-10	Yes
Weca	Weight at age in the commercial catch	1981 –	1-10	Yes
West	Weight at age of the spawning stock at spawning time.	1981 –	1-10	Yes
Mprop	Proportion of natural mortality before spawning	1981 –	NA	No
Fprop	Proportion of fishing mortality before spawning	1981 –	NA	No
Matprop	Proportion mature at age	1981 –	1-10	No
Natmor	Natural mortality	1981 –	NA	No

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	International Spawning Stock Survey	2004 – assessment year + 1	3-8

Models used for exploratory assessments

Previous WGWIDE working groups have conducted alternative assessments (e.g. TISVPA and XSA) in addition to the accepted assessment as a check on model assumptions and how the different model platforms handle the data. At future meetings exploratory analyses, potentially also including recruitment indices, will be encouraged. Advice will be based on the outputs of the SAM model.

D. Short-Term Projection

Model used, before 2014:

At the Benchmark in 2012 it was concluded that due to the uncertainty in the final year estimates of fishing mortality and stock numbers, the standard (deterministic) short-term forecast is considered inappropriate for this stock. Therefore, stochastic projections are performed, from which short-term projections are extracted. The stochastic projections are carried out by starting at the final year's estimates, using the variance-covariance matrix of those estimates. To run the short term forecast 1000 samples are generated from the estimated distribution of the final year's estimates. Those 1000 replicates are then simulated forward according to the model and subject to different scenarios.

Issues with the stochastic forecast:

Compared to a deterministic forecast the stochastic forecast gives slightly higher estimates of TAC and SSB. For e.g. the TAC advice for 2015 is estimated 4-5% higher and SSB in 2016 8-9% higher. The difference is due to the assumed log-normal distributed stock number. The median of the projected stock N is unbiased compared to the stock N from a deterministic forecast, but the median of quantities like yield and SSB, which is the sum of several age groups N weighted by e.g. F, mean weight and proportion mature, will be higher. The difference increases by increasing uncertainty of the initial stock numbers used for the forecast.

Model used, since 2014:

Since 2014 a deterministic version of the short term forecast has been applied for advice. The MSE evaluation (ICES advice 2014, ICES advice 2015) used a deterministic forecast in the evaluation. The conclusion, that a given HCR is precautionary is sensitive to the choice of forecast model. With a TAC estimated 4-5% lower in the MSE than actually applied in the MSE will give a too high target F for precautionary management. Therefore the WGWIDE concluded in 2014 to use to use a deterministic forecast.

Software used:

Source code for the SAM model and all scripts including forecast script are freely available at https://www.stockassessment.org [Username: guest; Password: guest].

The default forecast.R script has been modified to handle both stochastic and deterministic forecast: The top two lines

```
determenistic<-TRUE
if (determenistic)nosims<-2 else nosims<-1000
```

has been inserted, which allow setting deterministic<-TRUE or FALSE. The script has further been modified such that when deterministic==TRUE, the variance - covariance matrix is set to 0 (deterministic forecast). The number of simulations (nosims) is maintained at 2 (1 would be sufficient) such that the same data structure can be used for both types of forecast.

Initial stock size: Final year's estimates.

Maturity: The proportion mature for this stock is assumed constant over the years. The maturity ogive used in the short term forecast is the same as the ogive used in the assessment.

F and M before spawning: These values are both 0, spawning is assumed to take place the 1st January.

Weight at age in the stock and weight at age in the catch: Weight at age in the catch and weight at age in the stock are the same and for the short term forecast are calculated as three year averages.

Exploitation pattern: This is based on F in the year where the final three years of data calculated from the most recent assessment.

Natural Mortality: Natural mortality is assumed to be 0.2 across all ages. Maturity:

Intermediate year assumptions: TAC is landed fully.

Stock recruitment model used: None. The benchmark in 2012 concluded that the available survey indices should be used in a qualitative way to estimate recruitment, rather than using them in a strict quantitative model framework. The WGWIDE has followed this recommendation and investigated several survey time series indices with the potential to give quantitative or semi-quantitative information of blue whiting recruitment.

Survey used

1) The International Ecosystem Survey in the Nordic Seas (IESNS) only partially covers the known distribution of recruitment from this stock but catches include juveniles as well.
2) The International Blue Whiting Spawning Stock Survey (IBWSS) is not designed to give a representative estimate of immature blue whiting. However, the 1-group and the 2-group indices appear to be fairly consistent with corresponding indices from older ages
3) The Norwegian bottom trawl survey in the Barents Sea (BS-NoRu-Q1(Btr)) in February-March shows in some years a high catch rates of 1-group blue whiting was present. This 1-group index should be used as a presence/absence index, in the way that when blue whiting is present in the Barents Sea this is usually a sign of a strong year-class, as all known strong year classes have been strong also in the Barents Sea.
4) The Icelandic bottom trawl survey (March) has a time series from 1996 to present. This survey is aimed at demersal species, but blue whiting juveniles are caught as bycatch. Some signals in recruitment are evident in the time series.
5) The Faroese Plateau spring (March) bottom trawl survey has a time series from 1994 to present. While this survey is not specifically aimed at blue whiting, nor has it been used in any assessments, there are some signals in recruitment evident in the time series.

The survey series were standardized by dividing with their mean. An example is shown in Figure E1.

Method for estimating recruitment:

Based on the available CPUE indices, recruitment (age 1) in the intermediate year and in the previous year are estimated by a qualitative evaluation. As an example: if the indices of the corresponding year classes are much higher than average a high percentile (e.g. 75%) of the historical recruitment as estimated by the SAM model is used.

Even though it is a qualitative evaluation, the precise method needs to be described better; however a more formal approach has not been decided on yet.

E. Medium-Term Projection

Medium term projections were carried out as part of the management plan evaluation simulations at a meeting in May 2008 (Anon, 2008). These simulations were updated at WGWIDE in September 2008. HCS (Skagen, 2008) with some minor modifications were made to cover the needs of the blue whiting simulations. As a control, some simulations were repeated with the SMS software which is also used to assess the stock of blue whiting and was used for evaluation of the management plan presently in use (ICES, 2008a).

Since 2012 a series of management plan evaluation have been conducted using HCS and ad hoc developed software.

F. Long-Term Projections

Long term projections are not carried out for this stock.

G. Biological Reference Points

The Workshop on Limit and Target Reference Points (WKREF) considered the biological reference points for Blue Whiting at a meeting in Gdynia, Poland in January in 2007 (ICES, 2007b). The original reference points for this stock were set in 1998, before the era of high productivity became apparent. The group examined the consequences of these new observations on the reference points by first splitting the time‐series into two productivity regimes (low productivity from 1981–1994, and high productivity from 1995–2005). Standard methods (i.e. using the guidelines from the Study Group on Precautionary Reference points, SGPRP (ICES, 2003b) were then used to re‐estimate the reference points, which were found to be comparable to the current values. A new probabilistic approach for estimating B_{lim} was also employed, but again, the result was found to be comparable with the current values. The group concluded that there was no basis for revising the current reference points. WKREF also noted that there may be no need for different B_{lim} values in different productivity regimes.

A stochastic equilibrium analysis made during the Working Group established by the Blue Whiting Coastal States on Blue Whiting management strategies (Anon, 2008) indicates a high risk of stock collapse with an F from approximately 0.3 and upwards given the "low recruitment" regime as observed in 1981–1996. F_{max} is poorly defined and a very limited increase in yield is obtained for F in the range 0.18 to 0.30. $F_{0.1}$ was estimated at 0.18. Sensitivity analysis of a change in exploitation pattern showed that these conclusions are robust with respect to the choice of exploitation pattern. A yield per recruit analysis was conducted using MFYPR which also calculated $F_{0.1}$ as 0.18.

At the WKPELA 2012 meeting the precautionary approach fishing mortality reference points for this stock were removed. A major problem was that fishing at F_{pa} implied a high probability of bringing the stock below B_{pa}, in other words the present combination of F_{pa} and B_{pa} is inconsistent, likewise for F_{lim} and B_{lim}.

As a response to a special request from NEAFC, ICES re-evaluated in May 2013 (ICES advice, 2013) the reference points for the stock. ICES concluded that Blim and Bpa should remain unchanged. Fpa and Flim were undefined. Equilibrium stochastic simulations have been used to give a new value for Flim = 0.48. On the basis of this and the uncertainty in the assessment, a corresponding value for Fpa = 0.32 was derived. Currently MSY advice is based on a management strategy evaluation which used F0.1 as a proxy for FMSY and an MSY Btrigger = Bpa. The new simulations provide estimates of FMSY = 0.30. There are no scientific reasons to reduce MSY Btrigger below Bpa, and no estimates of MSY Btrigger are above Bpa. Under these circumstances it is proposed that Bpa be retained as MSY Btrigger for the MSY framework.

In a new request from NEAFC, June 2013, ICES was requested to confirm the suggested reference points, more specifically to confirm:

a) That the value of F0.1 is considered to be 0.22 rather than 0.18, as stated in the advice of September 2012 b) That the value of Fmsy is considered to be 0.30 rather than 0.18, as stated in the advice of September 2012

ICES confirmed (ICES advice October 2013) that the value of F0.1 is currently estimated to be 0.22. ICES advised that the value of FMSY is considered to be 0.30 and this replaces the F0.1 proxy for FMSY of 0.18 from the advice of September 2012.

The present reference points and their technical basis are:

Reference point	Blim	Bpa	Flim	Fpa
Value	1.5 mill t	2.25 mill. t	0.48	0.32
Basis	Bloss	Blim* exp(1.645* σ), with σ= 0.25.	Equilibrium stochastic simulations, (ICES advice, 2013)	Based on Flim and assessment uncertainties (ICES advice, 2013)

Reference point	FMAX	F0.1	FMSY	MSY Btrigger
Value	NA	0.22	0.30	2.25 mill. t
Basis	FMAX is poorly defined	Yield per recruit (ICES advice, 2013 and WGWIDE, 2013)	Equilibrium stochastic simulations, (ICES advice, 2013)	Bpa

The result from an additional request for advice on options for a revised long-term management strategy on blue whiting from NEAFC, July 2016 were not ready during WGWIDE 2015.

H. Other Issues

Changes in Blue Whiting Mean Weights over time

Possible causal relations for the visible reductions in mean weight at age were investigated by WGWIDE in 2008. Several aspects relating to the biology of fish stocks such as recruitment, growth or natural mortality, are influenced by ecosystem conditions. Some of these conditions were suggested as possible reasons for the change in mean weight at age. These include the following:

Density dependant competition– too many fish competing for the same food resource.

Changes in plankton abundance would impact on the amount of food available for blue whiting.

External environmental factors, such as temperature and salinity. Spawning is effected by both of these environmental variables.

An in depth analysis of the causes of these changes in mean weights, which would be needed for any kind of forecast is outside the scope of this working group (ICES, 2008a)

Possible effects of protecting juvenile Blue Whiting

The modern blue whiting fishery developed during the second half of the 1970s when the landings increased from around 100 000 tonnes to above 1 million tonnes. The majority of the catches have since been taken on the spawning grounds west of the

British Isles. A small but fairly constant fraction of the catches are taken in the southern areas and in the North Sea (Norwegian trench) and a variable fraction in the Norwegian Sea (Figure D10). The proportion of landings taken in the Norwegian Sea increased after the strong year classes from 1995 onwards led to increased densities of (young) blue whiting in this area, but is now decreasing and was in 2007 around the pre-2000 level.

Landings from the Norwegian Sea and the North Sea are generally comprised of a higher proportion of juvenile fish compared to landings from the spawning area, though this proportion varies between years. A measure to reduce the exploitation of juveniles could therefore, in theory, be to close the fishery in these areas (or a temporal closure of the fishery outside the spawning season). However, it is impossible to estimate the resulting reduction in juvenile fishing mortality of such measures since juveniles are also exploited in the spawning ground fishery.

The effects on the yield per recruit curve of applying three different exploitation patterns on ages 1–2 were explored using the standard ICES software MFYPR; (1) zero exploitation, (2) "high" exploitation and (3) the constant F selection pattern used in SMS from 1999 onwards. The "high" exploitation pattern which gave the highest relative fishing mortality on ages 1–2 during the last 15 years was derived from the XSA assessment. The SMS exploitation pattern was used on ages older than 2 years. Figure D11 shows the three F selection patterns used and the resulting yield per recruit curves. The difference between the curves is marginal with similar values for $F_{0.1}$ derived. The conclusion is that the effect on yield of protecting juveniles is likely to be very small. A separate clause for the protection of juveniles in the management plan is not needed (ICES, 2008a).

H.1 Management and ICES advice

Management plans

A management plan was agreed for this stock between the four coastal states (Norway, Faroe Islands, Iceland, and EU) in December 2005. The text for the agreed plan is given below. This management agreement aims to maintain the SSB of the blue whiting stock at levels above 1.5 million tonnes (B_{lim}) and the fishing mortality rates at levels of no more than 0.32 (F_{pa}). To achieve this, the TAC is reduced by at least 100 000 t a year until the fishing mortality is reduced to 0.32 (F_{pa}). The plan states that if the spawning stock falls below 2.25 million t unspecified actions to obtain a safe and rapid recovery to this level should be taken. ICES has evaluated this management plan in 2006 and found it not to be in accordance with the precautionary approach in a period of low recruitment.

<u>Text for the 2005 management plan for Blue Whiting</u>

1) *The Parties agree to implement a multi-annual management arrangement for the fisheries on the blue whiting stock which is consistent with the precautionary approach, aiming at constraining harvest within safe biological limits, protecting juveniles, and designed to provide for sustainable fisheries and a greater potential yield, in accordance with advice from ICES.*

2) *The management targets are to maintain the Spawning Stock Biomass (SSB) of the blue whiting stock at levels above 1.5 million tonnes (Blim) and the fishing mortality rates at levels of no more than 0.32 (Fpa) for appropriate age groups as defined by ICES.*

3) *For 2006, the Parties agree to limit their fisheries of blue whiting to a total allowable catch of no more than 2 million tonnes.*

4) *The Parties recognise that a total outtake by the Parties of 2 million tonnes in 2006 will result in a fishing mortality rate above the target level as defined in Paragraph 2. Until the fishing mortality has reached a level of no more than 0.32, the Parties agree to reduce their total allowable catch of blue whiting by at least 100 000 tonnes annually.*

5) *When the target fishing mortality rate has been reached, the Parties shall limit their allowable catches to levels consistent with a fishing mortality rate of no more than 0.32 for appropriate age groups as defined by ICES.*

6) *Should the SSB fall below a reference point of 2.25 million tonnes (Bpa), either the fishing mortality rate referred to in Paragraph 5 or the tonnage referred to in Paragraph 4 shall be adapted in the light of scientific estimates of the conditions then prevailing. Such adaptation shall ensure a safe and rapid recovery of the SSB to a level in excess of 2.25 million tonnes.*

7) *This multi-annual management arrangement shall be reviewed by the Parties on the basis of ICES advice*

The stock is currently in a period of low recruitment. In July 2008 a new draft management plan was proposed by the Coastal States. ICES has evaluated the draft management plan and considers it precautionary if fishing mortality in the first year is immediately reduced to the fishing mortality that is implied by the HCR. The text of this plan is also presented below.

Text for the 2008 management plan for Blue Whiting

1) The Parties agree to implement a long term management plan for the fisheries on the Blue Whiting stock, which is consistent with the precautionary approach, aiming at ensuring harvest within safe biological limits and designed to provide for fisheries consistent with maximum sustainable yield, in accordance with advice from ICES.
2) For the purpose of this long term management plan, in the following text, "TAC" means the sum of the coastal State TAC and the NEAFC allowable catches.
3) As a priority, the long term plan shall ensure with high probability that the size of the stock is maintained above 1.5 million tonnes (B_{lim}).
4) The Parties shall aim to exploit the stock with a fishing mortality of 0.18 on relevant age groups as defined by ICES.
5) While fishing mortality exceeds that specified in paragraph 4 and 6, the Parties agree to establish the TAC consistent with reductions in fishing mortality of 35% each year until the fishing mortality established in paragraph 4 and 6 has been reached. This paragraph shall apply only during 2009 and 2010.
6) For the purposes of this calculation, the fishing percentage mortality reduction should be calculated with respect to the year before the year in which the TAC is to be established. For this year, it shall be assumed that the relevant TAC constrains catches.
7) When the fishing mortality in paragraph 4 has been reached, the Parties agree to establish the TAC in each year in accordance with the following rules:

   In the case that the spawning biomass is forecast to reach or exceed 2.25 million tonnes (SSB trigger level) on 1 January of the year for which the TAC is to be set, the TAC shall be fixed at the level consistent with the specified fishing mortality.

In the case that the spawning biomass is forecast to be less than 2.25 million tonnes on 1 January of the year for which the TAC is to be set (B), the TAC shall be fixed that is consistent with a fishing mortality given by:

$$F = 0.05 + [(B - 1.5)(0.18 - 0.05) / (2.25 - 1.5)]$$

In the case that spawning biomass is forecast to be less than 1.5 million tonnes on 1 January of the year for which the TAC is to be set, the TAC will be fixed that is consistent with a fishing mortality given by F = 0.05.

8) When the fishing mortality rate on the stock is consistent with that established in paragraph 4 and the spawning stock size on 1 January of the year for which the TAC is to be set is forecast to exceed 2.25 million tonnes, the Parties agree to discuss the appropriateness of adopting constraints on TAC changes within the plan.
9) The Parties, on the basis of ICES advice, shall review this long term management plan at intervals not exceeding five years and when the condition specified in paragraph 4 is reached

In 2012 options for a new management plan will be explored.

ICES advice

In 2003, ICES stated that both estimates of SSB and fishing mortality were high but uncertain. Nevertheless, the spawning stock biomass in 2003 was likely to be above B_{pa}. Therefore, based on the most recent estimates of fishing mortality and SSB, ICES classified the stock as likely to be harvested outside safe biological limits ($F>F_{lim}$). The incoming year classes seemed to be strong. ICES recommended that catches should be less than 925 000 tonnes in 2004 in order to achieve a 50% probability that the fishing mortality in 2004 is less than F_{pa} (=0.32). This would also assure a high probability that the spawning stock biomass in 2005 to be above B_{pa} (ICES, 2005).

In 2004 ICES concluded from the most recent estimates of fishing mortality and SSB, that the stock had full reproductive capacity, but was harvested unsustainably. Although the estimates of SSB and fishing mortality were not considered precise, it was certain that SSB was above B_{pa} and the estimated fishing mortality well above F_{lim}. Recruitments in the last decade appeared to be at a much higher level than earlier. The unimplemented management plan implied catches of less than 1.075 million t in 2005 which was expected to keep fishing mortality less than 0.32 with 50% probability. This would also have assured a high probability that the spawning stock biomass in 2006 would be above B_{pa}. ICES recommended that measures be taken to protect juveniles (ICES, 2005).

In 2005 ICES advised that fishing within the limits of the management plan (F=0.32) implied catches of less than 1.5 million t in 2006. This would result in a high probability that the spawning stock biomass in 2007 would be above B_{pa}. The present fishing level was well above levels defined by the management plan and should be reduced. The primarily approach to reduce catch of juveniles is to reduce overall fishing mortality. Catches of juveniles in the last 4 years were much greater than in earlier periods. If an overall reduction of fishing mortality cannot be achieved then specific measures should be taken to protect juveniles (ICES, 2006a).

In 2006 ICES stated that the maximum catch in 2007 corresponding to a new agreed management plan is 1.9 million tonnes, which is expected to leave the spawning stock biomass at 2.86 million t, i.e. above B_{pa} in 2008, but would lead to an F above F_{lim} in 2007. Fishing mortality is estimated at 0.48 and was above the fishing mortalities expected to lead to high long-term yields and low risk of depletion of production potential. Fishing at F_{pa} implies catches of less than 980 thousand t in 2007. This was expected to result in a spawning stock biomass in 2008 well above B_{pa}. The newly agreed management plan was evaluated by ICES and was not considered in accordance with the precautionary approach. ICES concluded that the exploitation boundaries for this stock should be based on the precautionary limits (ICES, 2007a).

In 2007 ICES classified the stock as having full reproductive capacity, but being harvested at increased risk. SSB increased to a historical high in 2003, but has decreased since then. The estimated fishing mortality was well above F_{pa}. Recruitment in the last decade appears to be at a much higher level than prior to 1996. The 2005 and 2006 year classes were estimated at the pre 1996 level. ICES has evaluated the present management plan in 2006 and found it not to be in accordance with the precautionary approach. ICES concluded that the exploitation boundaries for this stock should be based on the precautionary limits. The advice for 2008 is a maximum TAC at 835 000 t based on an F at F_{pa} (ICES, 2008a).

The 2008 advice for Blue whiting states that based on the most recent estimates of fishing mortality and SSB, ICES classifies the stock as having full reproductive capacity, but being harvested at increased risk. SSB increased to a historical high in 2003, but has decreased since then and is expected to be just above B_{pa} in 2009. The estimated fishing mortality is well above F_{pa}. Recruitment of the 2005 and 2006 year classes are estimated to be in the very low end of the historical time-series. Surveys indicate that the 2007 year class could also be low.

In 2009 ICES advised that based on the most recent estimates of SSB (in 2009) and, fishing mortality (in 2008), ICES classifies the stock as having full reproductive capacity and being harvested sustainably (F=0.29). Year classes 2005-2008 are among the lowest observed. Due to recent low recruitment, SSB has declined from its historical peak in 2003-2004 of more than 7 million tonnes to 3.6 million tonnes at the beginning of 2009, and the decline is expected to continue in the short-term.

In 2010, following a sharp downward revision in the perceived abundance of the stock in the assessment, the TAC for blue whiting in 2011 was significantly lower than in 2010. This downward revision in the assessment estimates of abundance was driven predominantly by the low values of the 2010 IBWSSS acoustic survey. In 2011 these values were removed from the assessment of the stock (see Section B.3) resulting in an upward revision of abundance estimates. This lead in turn to a sharp increase in the TAC for 2012 compared with the low 2011 TAC.

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Table D1: 1-group indices of blue whiting from the Norwegian winter survey (late January-early March) in the Barents Sea. (Blue whiting <19cm in total body length which most likely belong to 1-group.)

	Catch Rate	
Year	All	<19cm
1981	0.13	0
1982	0.17	0.01
1983	4.46	0.46
1984	6.97	2.47
1985	32.51	0.77
1986	17.51	0.89
1987	8.32	0.02
1988	6.38	0.97
1989	1.65	0.18
1990	17.81	16.37
1991	48.87	2.11
1992	30.05	0.06
1993	5.8	0.01
1994	3.02	0
1995	1.65	0.10
1996	9.88	5.81
1997	187.24	175.26
1998	7.14	0.21
1999	5.98	0.71
2000	129.23	120.90
2001	329.04	233.76
2002	102.63	9.69
2003	75.25	15.15
2004	124.01	36.74
2005	206.18	90.23
2006	269.2	3.52
2007	80.38	0.16
2008	16.72	0.01
2009	3.74	0
2010	3.19	0.10

Table D2: Stratified mean catch (Kg/haul and Number/haul) and standard error of Blue Whiting in bottom trawl surveys in Spanish waters (Divisions VIIIc and IXa north). All surveys in September-October.

Kg/haul	30-100 m		101-200 m		201-500 m		TOTAL 30-500 m	
Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1985	9.50	5.87	119.75	45.99	68.18	13.79	92.83	28.24
1986	9.74	7.13	45.41	12.37	29.54	8.70	36.93	7.95
1987	-	-	-	-	-	-	-	-
1988	2.90	2.59	154.12	38.69	183.07	141.94	143.30	45.84
1989	14.17	12.03	76.92	17.08	18.79	6.23	59.00	11.68
1990	6.25	3.29	52.54	9.00	18.80	4.99	43.60	6.60
1991	64.59	34.65	126.41	26.06	46.07	18.99	97.10	17.16
1992	6.37	2.59	44.12	6.64	29.50	6.16	34.60	4.23
1993	1.06	0.63	14.07	3.73	51.08	22.02	22.59	6.44
1994	8.04	5.28	37.18	8.45	25.42	5.27	29.70	5.19
1995	19.97	13.87	36.43	4.82	15.97	4.10	28.52	3.66
1996	7.27	3.95	49.23	7.19	92.54	17.76	54.52	6.36
Kg/haul	70-120 m		121-200 m		201-500 m		TOTAL 70-500 m	
Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1997	17.87	7.35	44.68	10.52	57.14	16.60	42.62	7.29
1998	14.13	4.17	42.78	8.13	78.88	22.01	47.14	7.58
1999	93.01	14.60	112.39	19.92	169.21	50.26	124.66	17.85
2000	62.39	12.00	91.99	14.75	58.72	24.94	76.19	10.61
2001	8.35	3.31	50.18	10.09	52.41	16.71	42.02	7.02
2002	31.40	5.02	69.00	13.41	36.75	12.07	51.80	7.64
2003	42.52	12.22	71.40	11.01	46.43	11.42	58.13	6.92
2004	2.80	2.11	14.05	7.79	59.51	21.41	24.76	7.31
2005	50.63	16.15	95.17	19.28	40.06	8.88	69.94	10.57
2006	14.28	7.01	70.79	12.60	115.08	39.88	71.64	13.18
2007	4.76	3.75	39.10	23.21	21.69	4.41	26.86	11.74

Table D3 Stratified mean catch (Kg/haul) and standard error of bottom trawl surveys in Portuguese waters (Division IXa).

		20-100 m		100-200 m		200-500 m		500-750 m		TOTAL	
Year	Month	y	sy	y	sy	y	sy	y	sy	y	sy
1990	July	**2**	2	**153**	103	**242**	42	**50**	5	**96**	35
	October	**11**	5	**90**	28	**762**	234	**42**	10	**153**	35
1991	July	**1**	1	**140**	40	**268**	38	**64**	18	**98**	15
	October	**8**	5	**83**	18	**259**	53	**121**	27	**91**	11
1992	February	**7**	7	**43**	35	**249**	21	**73**	3	**68**	12
	July	**1**	1	**29**	18	**216**	43	**27**	5	**47**	9
	October	**1**	1	**22**	7	**208**	44	**80**	3	**54**	7
1993	February	**0**	0	**19**	14	**105**	31	**36**	0	**42**	10
	July	**0**	0	**3**	3	**151**	28	**55**	5	**34**	4
	November	**0**	0	**90**	0	**189**	43	**6**	1	**86**	9
1994	October	**0**	0	**374**	30	**283**	32	**49**	7	**174**	11
1995	July	**0**	0	**18**	14	**130**	20	**52**	3	**35**	5
	October	**18**	15	**103**	21	**328**	91	**31**	12	**94**	16
1996	October	**25**	24	**12**	2	**36**	6	**25**	7	**22**	8
1997	June	**0**	0	**3**	3	**116**	42	**45**	12	**27**	7
	October	**2**	1	**54**	20	**77**	13	**7**	2	**32**	8
1998	July	**0**	0	**8**	5	**105**	17	**38**	3	**25**	3
	October	**1**	1	**384**	87	**427**	101	**20**	2	**212**	36
1999	July	**1**	0	**60**	21	**66**	19	**25**	2	**37**	9
	October	**0**	0	**69**	16	**80**	20	**18**	8	**41**	7
2000	July	**23**	13	**109**	34	**116**	10	**63**	6	**75**	13
	October	**11**	4	**155**	53	**196**	22	**54**	4	**99**	19
2001	July	**18**	7	**238**	37	**305**	116	**57**	14	**152**	23
	October	**106**	6	**474**	224	**294**	66		0	**295**	97
2002	October	**19**	12	**176**	81	**180**	24		0	**116**	34
2003	October	**24**	10	**114**	14	**119**	30	**34**	6	**76**	8
2004	October	**0**	0	**44**	10	**380**	27			**84**	15
2005	October	**0**	0	**25**	7	**407**	239			**81**	42
2006	October	**1**	1	**154**	59	**196**	32			**95**	26
2007	October	**1**	1	**136**	66	**141**	25			**91**	32

Table D4: Age stratified CPUE from the Spanish surveys

Numbers	age							
	1	2	3	4	5	6	7	total
1982								
1983		7196	16392	9311	7476	6326	1718	48419
1984		13710	27286	14845	4836	1755	1750	64182
1985		14573	23823	14126	6256	1232	217	60227
1986		3721	14131	14745	7113	1278	505	41493
1987		25328	13153	6664	2938	1029	166	49278
1988		7778	21473	18436	6391	1300	781	56159
1989		15272	18486	17160	8374	3760	1003	64055
1990		21444	19407	5194	1803	1357	451	49656
1991		15924	15370	4989	2329	1045	440	40097
1992		10007	24235	9671	4316	1194	462	49885
1993		4036	13991	22493	7979	1354	658	50511
1994		543	6066	15917	7474	2990	1055	34045
1995		9090	14409	6833	4551	1990	623	37496
1996		3905	14557	14449	3931	3639	1834	42315
1997		8742	15875	11134	3698	1046	450	40945
1998		5884	13236	9803	10844	5229	1153	46149
1999		2048	10268	20242	9833	6287	3047	51725
2000		6207	15518	13987	5375	1264	1414	43765
2001		16223	16488	6830	1620	1148	162	42471
2002		10520	13725	10265	3385	336	69	38300
2003		9069	10461	6517	3983	1932	737	32699

Table D5. Stratified total numbers of blue whiting in French bottom trawl survey. NA no survey.

Year	Bay of Biscay	Celtic Sea	Variance (Biscay)	Variance (Celtic Sea)
1987	1313935981.7	NA	36528215960600000	NA
1988	1232403510.386	NA	104181056815335824	NA
1989	386898631.53	NA	10803455685233600	NA
1990	939550666.3	NA	28702880627300000	NA
1991	252039532.47	NA	3035806271405160	NA
1992	588546250.7	NA	9508732598060000	NA
1994	5518146422	NA	4.069619255e+17	NA
1995	2198718815.9	NA	87909759110826000	NA
1997	2085015191.84	7563919067.5	223112995134135808	3269641296923777024
1998	2429940410	847781802.11	2.69773734417e+17	10432317514100000
1999	5332275585.6	4400073060	583976280075900032	8.491756792e+17
2000	3961897973	2945777150	2.8070907774e+17	1.0197334661e+17
2001	1315527385.4	1057830493.98	26628615465300000	30077478942323000
2002	3047994204.6	3656904157.62	208792419841729984	171254737153962912
2003	1308226336.15	1420863842.72	45621762165804800	13006693795190300
2004	1745829772.682	1120840204.85	187350873468851904	285938881215680000
2005	751195629.6	708676111.01	21756850596703000	15983137256765540
2006	7653085198.4	2768183161.2	1027720375481849984	465222574238270016
2007	2921175740.7	1235860328	62665823860790000	71468526200790000
2008	30957020.3	774364861.67	158326076200000	221764902757548992
2009	8332657852.96	9042511712.72	857103189073946496	2457647244348636160
2010	3323790245.4	2078662996.81	160121742822700000	134645834507700000

Table D6. Stratified mean numbers per haul of blue whiting in Irish bottom trawl survey (18 cm cutoff to determine age 0).

Year	Mean number per haul	SE_
2005	1653	659
2006	3143.8	1463.3
2007	941.5	225.4
2008	1225.7	269.5
2009	5698.2	976.6
2010	1415	394.7

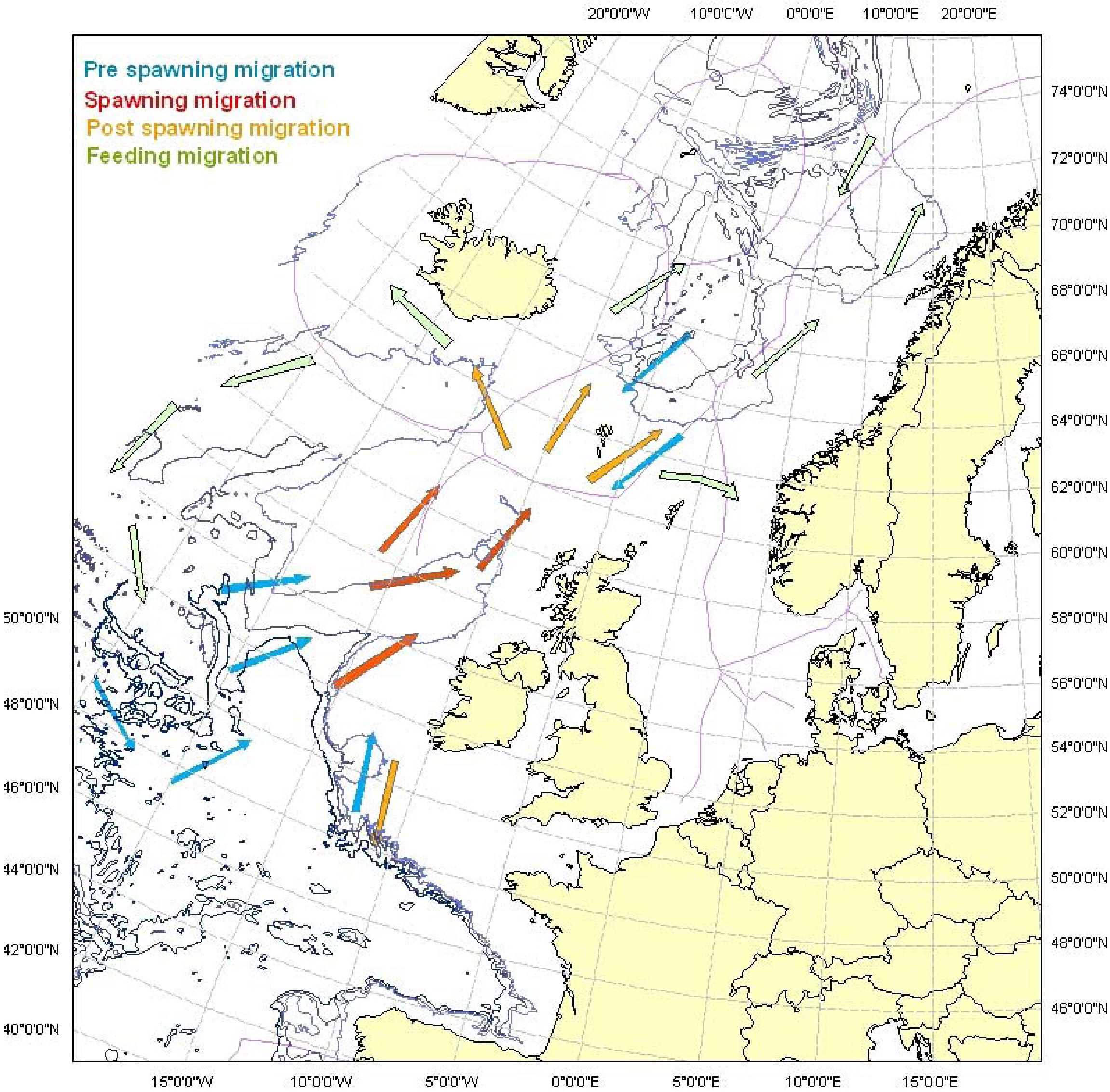

Figure D1. Migration routes for the blue whiting in the Northern Atlantic. Tangen and Sveinbjörnsson (Source: Worsoe Clausen, *et al* 2005)

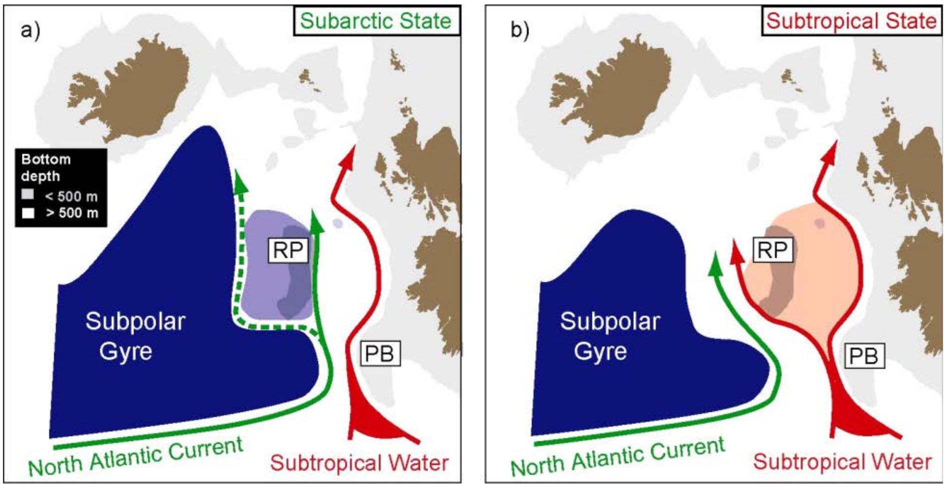

Figure D2: Outline of the source flows to the blue whiting spawning grounds in the Rockall Region. (a) A strong subpolar gyre (SPG) results in strong influence of cold subarctic water near the Rockall Plateau. (b) A weak gyre results in warm subtropical dominance near the plateau (based on Hátún *et al.* 2005). Abbreviations - RP: Rockall Plateau and PB: Porcupine Bank (Source: Hatun *et al.* 2009a).

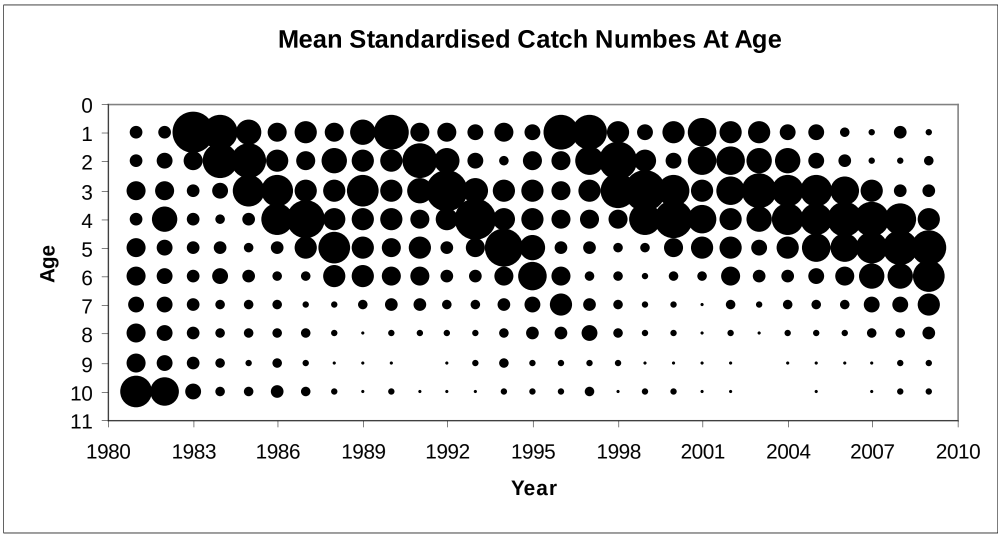

Figure D3: Catch numbers at age mean standardised by year 1981 - 2009

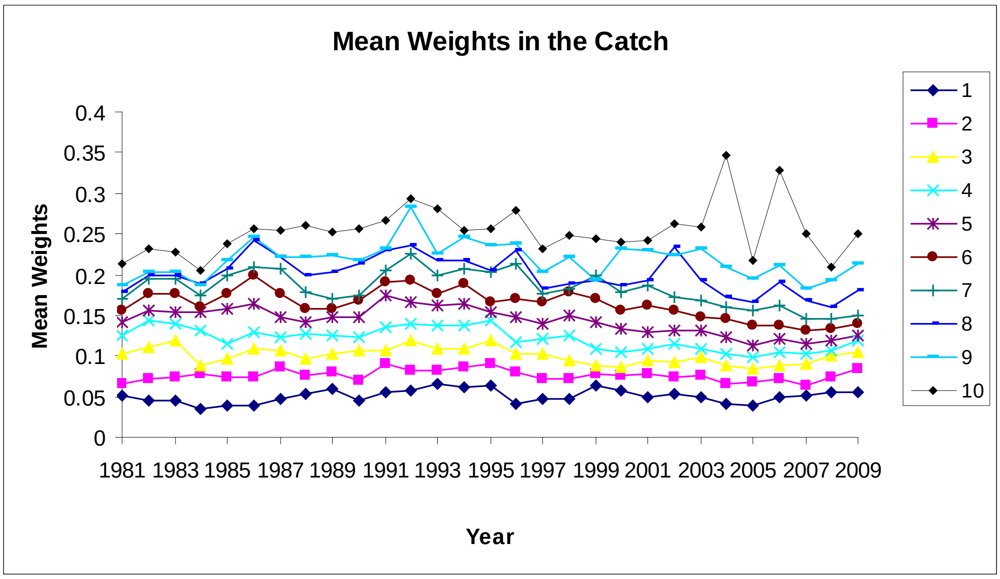

Figure D4: Mean weight in the catch 1981-2009

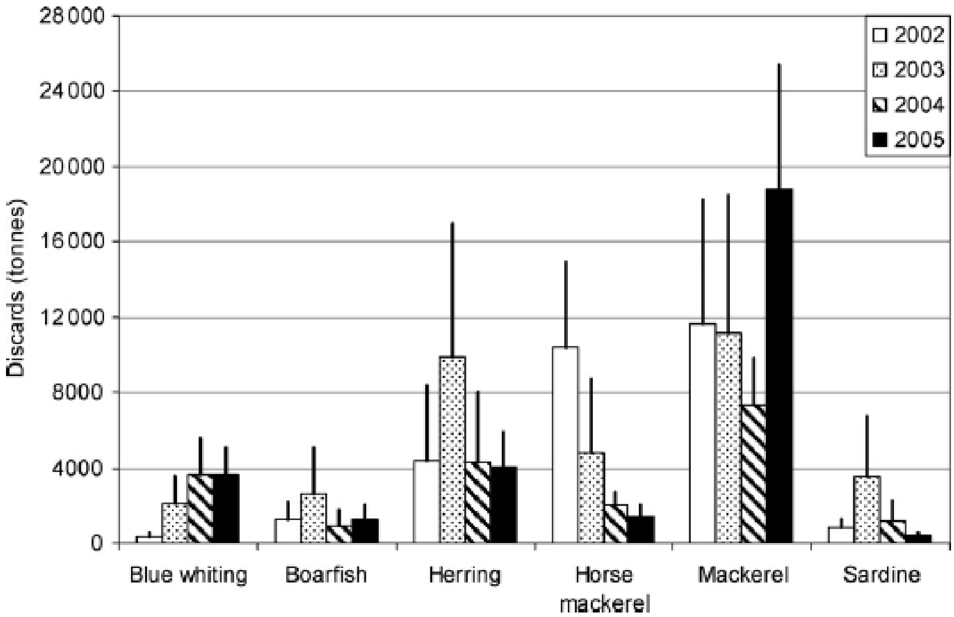

Figure D5: Biomass discarded by the Dutch freezer trawler fleet annually (raised using total number of trips) for the six most discarded species. The vertical lines represent the standard error on the estimates. (From Borges *et al* 2008)

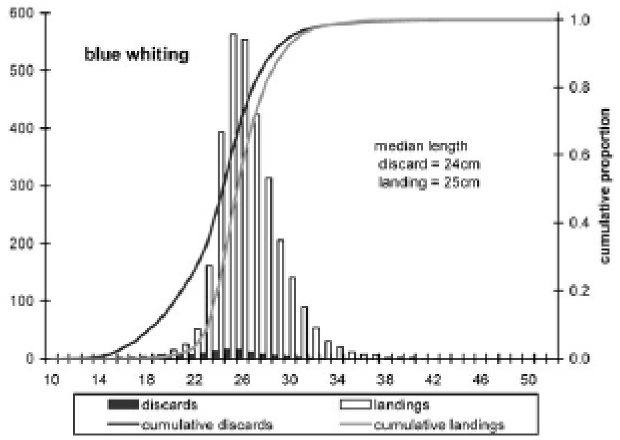

Figure D6: Length frequencies of discarded (filled histograms) and landed blue whiting (white histograms) by the Dutch fleet between 2002 and 2005. (From Borges, *et al* 2008)

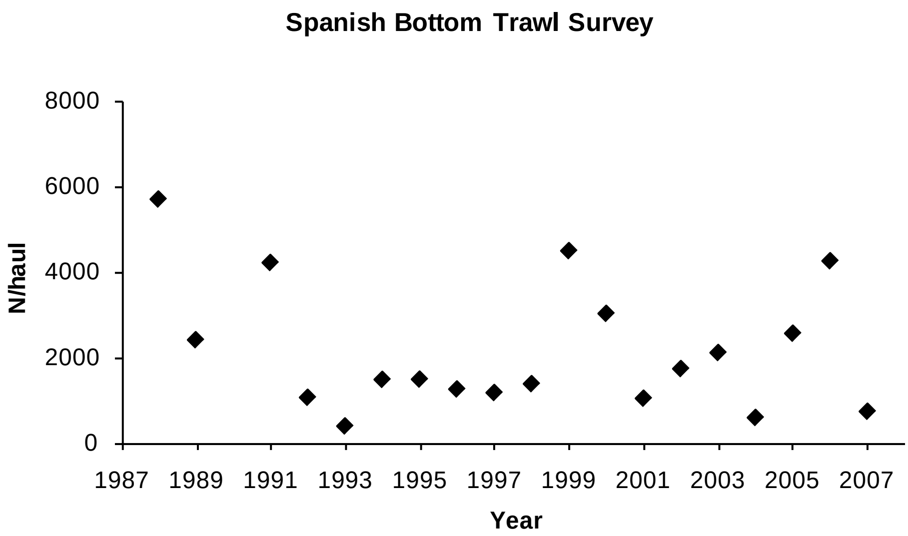

Figure D7. Mean catch rates (Kg/haul and Number/haul) of blue whiting in Spanish bottom trawl survey.

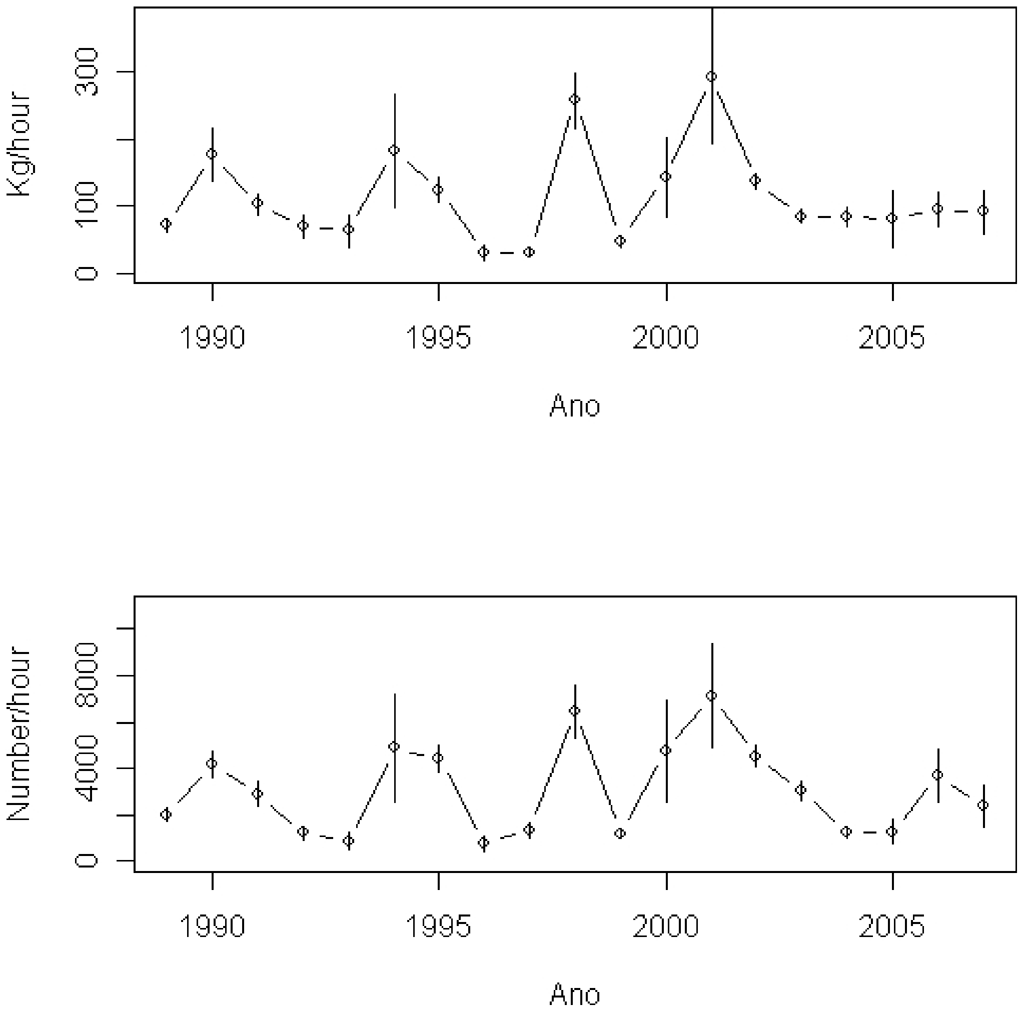

Figure D8: Stratified mean catch (Kg/haul and Number/haul) and standard error of blue whiting in bottom trawl surveys in Spanish waters (Divisions VIIIc and IXa north). All surveys in September –October

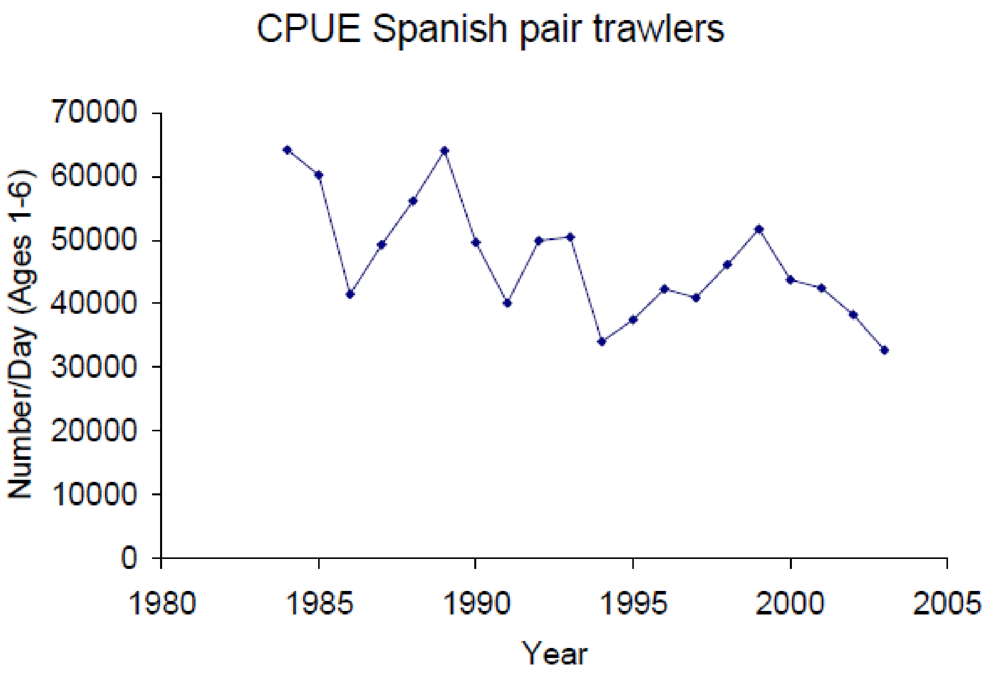

Figure D9: Blue Whiting CPUE from Spanish Pair Trawlers in ICES Div VIIIc and IXa (North)

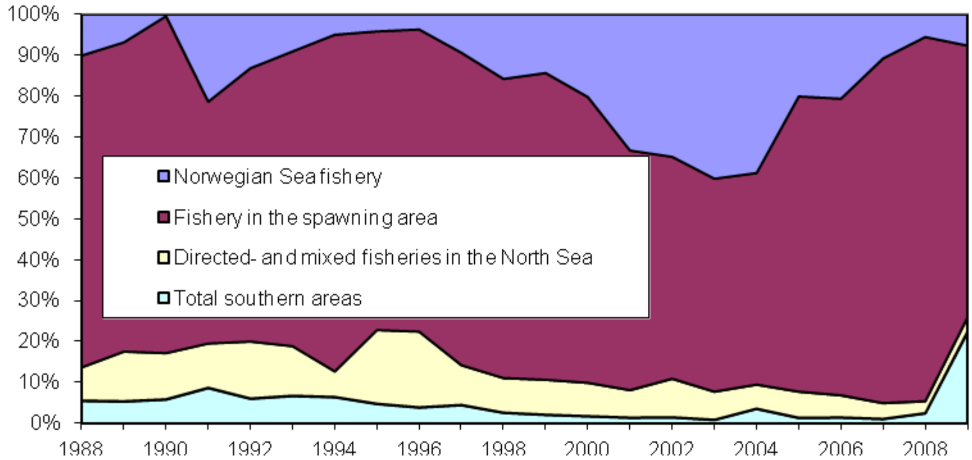

Figure D10: Development of Blue Whiting fisheries in different areas

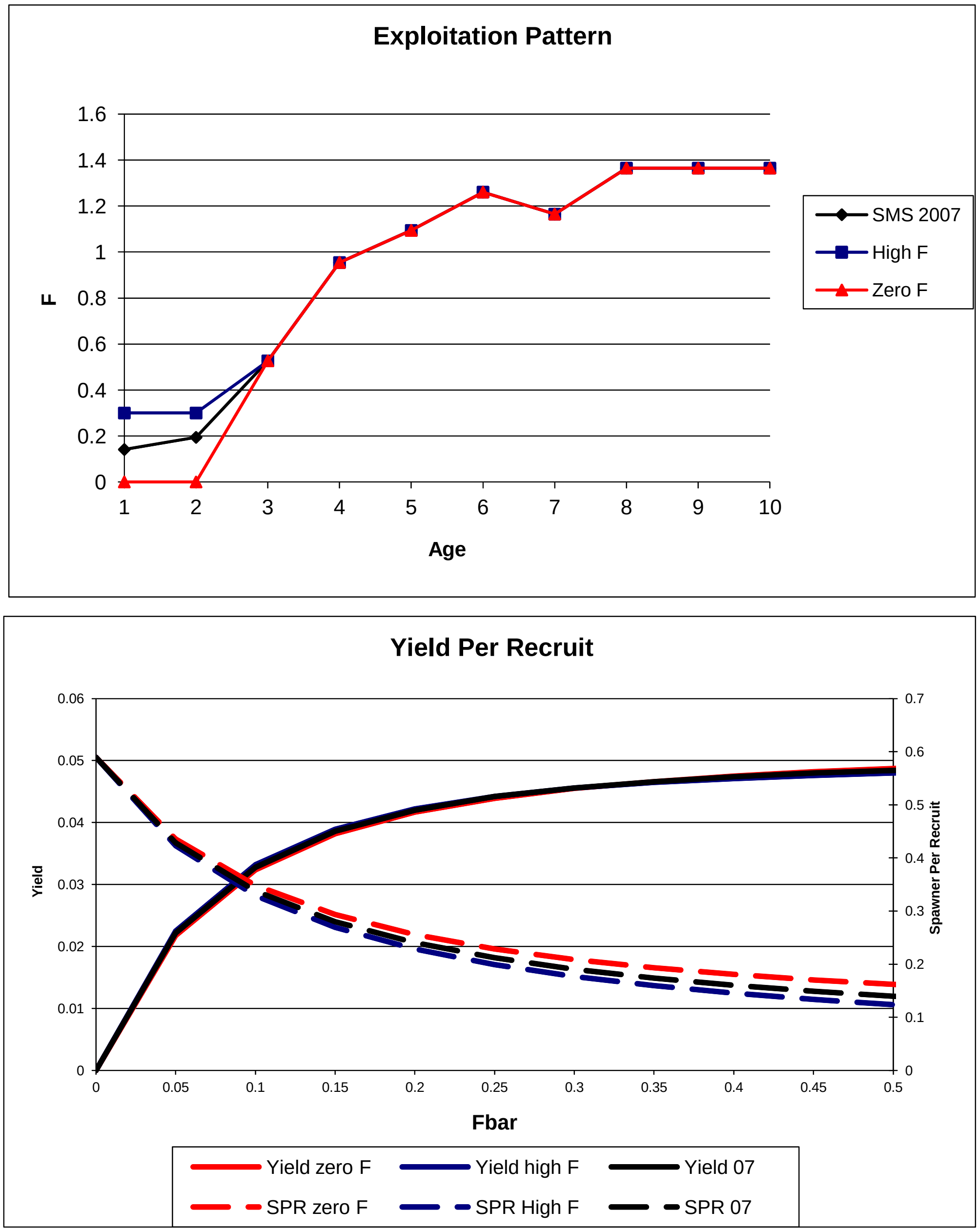

Figure D11: Blue Whiting exploitation pattern (upper) and yield per recruit curves (lower)

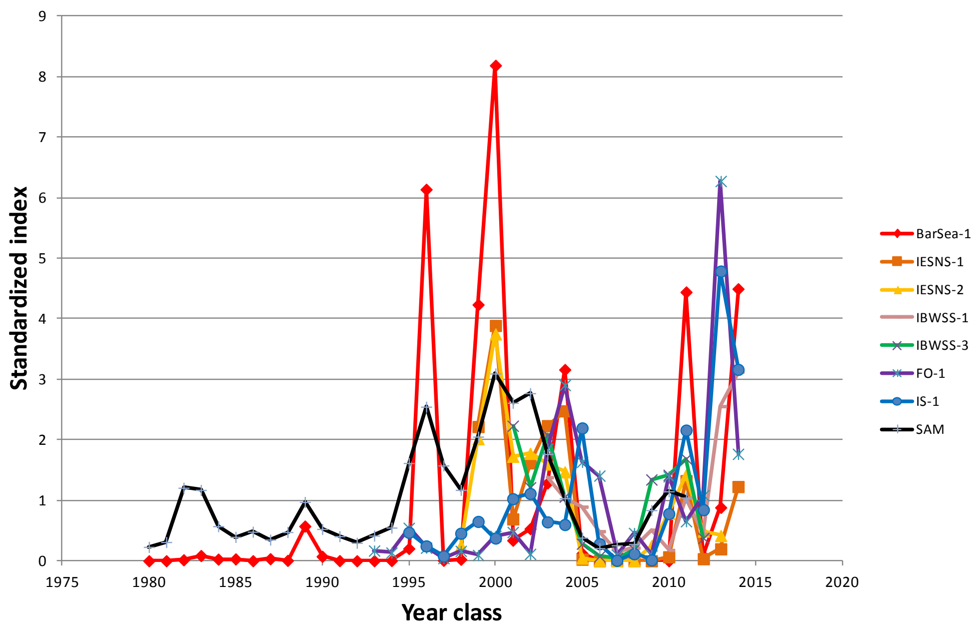

Figure E1. Blue whiting young fish indices from five different surveys and recruitment index from the assessment, standardized by dividing each series by their mean. BarSea - Norwegian bottom trawl survey in the Barents Sea, IESNS: International Ecosystem Survey in the Nordic Seas in May (1 and 2 is the age groups), IBWSS: International Blue Whiting Spawning Stock survey (1 and 3 is the age groups), FO: the Faroese bottom trawl surveys in spring, IS: the Icelandic bottom trawl survey in spring, SAM: recruits from the assessment.