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Growth of European anchovy (*Engraulis encrasicolus*) in the Bay of Biscay (NE Atlantic) under different environmental factors: implications for recruitment.

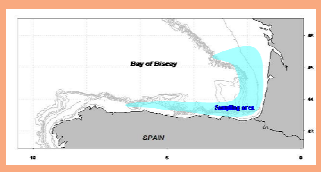
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OBJECTIVE

The objective of this study was to evaluate the consequences of the variability of growth and developmental rates during early life stages on the recruitment success of Anchovy in the Bay of Biscay, by comparing the growth history of recruits (juveniles at age 0).

MATERIAL & METHODS



For the present study, **anchovy juveniles were sampled** in September- October between 2006 and 2009 at different locations of the southern part of the Bay of Biscay during acoustic and bottom trawl surveys. A total of 359 otoliths (43-121 mm standard length (SL)) were examined using daily increments formation in the otolith microstructure. Daily ages were determined as the number of daily growth increments after hatching (Cermeño et al., 2003; Aldanondo, at al. 2008). The birthdate distribution was estimated by subtracting the number of otolith growth increments from the date of capture. Then, individual mean growth rates from hatching to capture were calculated by dividing SL minus 2.97 mm by the daily ages (Takasuka et al., 2003). Juveniles were split into cohorts fortnightly to analize growth patterns depending on their bak-calculated day of hatching. The distance between consecutive increments was measured (IW) to estimate growth rates and to compare average increments between subcohorts at 20-40 days (IW20-40), and 30-40 days (IW30-40).

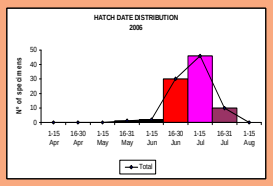
Meteorological and hydrological data: A local measurement of wind representative of the Central Cantabrian Sea was provided by the Spanish Agency of Meteorology from the station located at Santander airport at 43º27'N-03º47'W. Weekly series of Sea Surface Temperature are the Optimum Interpolation analysis NOAA_OI_SST provided on a one-degree grid by the NOAA/OAR/ESRL (Reynolds et.*al.*, 2002)

RESULTS

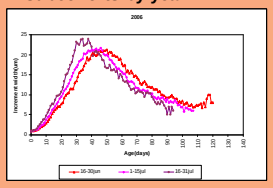
ANCHOVY JUVENILE GROWTH 2006-2009

Hatch Date fornigtly distribution of anchovy juveniles by year

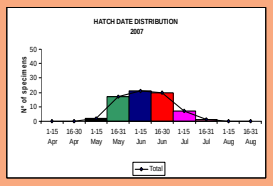
Daily increment widths of the main subcohorts by year



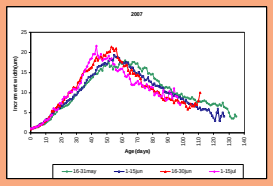
In 2006, three main modal groups, defining three main subcohorts hatched in 16-30 June, 1-15 July and 16-31 July.



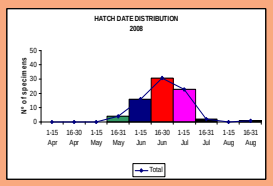
Three subcohorts showed significant differences for IW20-40 (K-S-test, P<0.05).



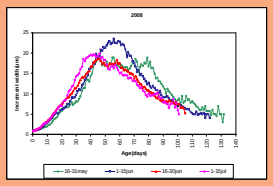
In 2007, four main modal groups, defining four subcohorts hatched in 16-31 May, 1-15 June, 16-30 June and 1-15 July.



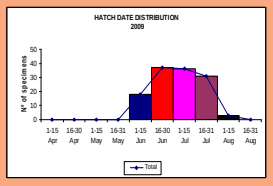
For IW20-40 two subgroups were distinguished, 16-31 May and 1-15 June on the one hand and 16-30June and 1-15 July on the other, showed significant differences between the two subgroups (K-S-test, P<0.05)



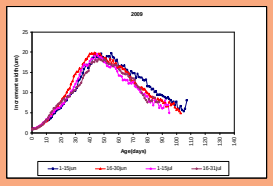
In 2008, four main modal groups, defining four subcohorts hatched in 16-31 May, 1-15 June, 16-30 June and 1-15 July.



For IW30-40 two subgroups were distinguished, 16-31 May and 1-15 June on the one hand, and 16-30 June and 1-15 July on the other, showed significant differences between the two subgroups (K-S-test, P<0.05)

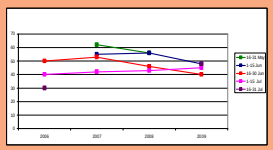


In 2009, four main modal groups, defining four subcohorts hatched in 1-15 June, 16-30 June, 1-15 July and 15-31 July.



For IW 20-40 two subgroups were distinguished, 1-15 June on the one hand and 16-30 June, 1-15 July and 16-31 July on the other, showed significant differences between the two subgroups (K-S-test, P<0.05)

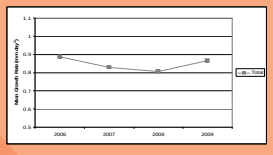
Maximun growth at age by subcohort and year



For all years analyzed, **later born juveniles grow faster in the stage prior to metamorphosis** (larval stage) and then, once go to the juvenile phase, this growth is reversed (grow less in the juvenile phase the later born). However, in 2009 those born later juveniles have slower growth in both larval and juvenile phases.

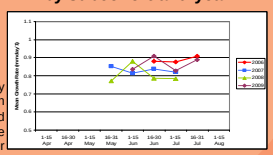
	2006	2007	2008	2009
16-31 May		62	57	
1-15 Jun		55	56	48
16-30 Jun	55	53	46	40
1-15 Jul	48	42	43	45
16-31 Jul	34			48

Mean Growth Rate (mm day^{-1}) by year



The **mean daily growth** rate by year was similar in 2006 and 2009 (0.88 mm day^{-1} and 0.86 mm day^{-1}, respectively). The lowest was found in 2008 (0.80 mm day^{-1}).

Mean Growth Rate (mm day^{-1}) by subcohort and year



By subcohorts the highest mean daily growth rate was found in individuals born later in 2006 and 2009 (0.90 mm day^{-1} and 0.88 mm day^{-1}, respectively) and the lowest was found in subcohorts born later in 2007 and 2008 (0.81 mm day^{-1} and 0.78 mm day^{-1}, respectively)

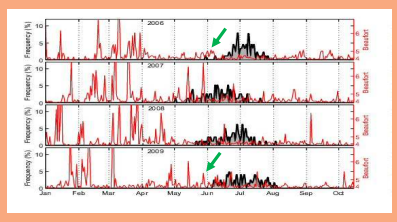
ENVIRONMENTAL FACTORS 2006-2009

The birth-date distribution in 2006 and 2009 suggest that the juvenile population largely consisted of individuals born in June-July, and that anchovy produced earlier in the season, during the peak spawning in May, did not survive.

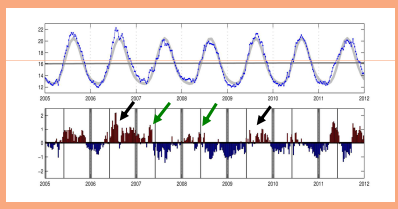
The causes of this low or null survival from the early spawns in 2006 and 2009 could be related to the particular meteorological and oceanographic conditions present around May and first week of June.

In May 2007 the wind was strong but in short pulses, and May 2008 was characterized by absence of wind. Also 2007 and 2008 was characterized by a warm spring (before June), especially in 2007. This possibly allowed the presence of surviving juveniles born in May.

In 2006 and 2009 the SST was above average in the second half of the year. This probably favored the highest growth in the subcohorts born in June and July in these years with respect to 2007 and 2008.



Wind speed cubed (proportional to turbulent kinetic energy added to the water column) at Santandermeteorological station together with hatching date of juveniles



SST anomalies in the Central Cantabrian Sea from the NOAA_OI_SST series. The overall series since 1981 yields an overall trend of 0.23 ºC/decade which is removed from the anomaly.

DISCUSSION

•The estimated **birth-date** of juveniles (May-June-July) concentrated mainly **in early July** for the **years 2006 and 2009** (mean 4thJuly) and in **June** for **2007 and 2008** (means 10th and 24th June, respectively), fell within the spawning period of the species in the Bay of Biscay, extending from March to August (Motos, 1996; Bellier et *al.*, 2007).

•The **general pattern of daily micro- increment width** development in juveniles involved an **increasing** trend until **maximum values over 22.27 µm day^{-1}** were reached **between 56-62** days after hatching, **followed by a later decreasing phase** in which values fluctuated. This is the same pattern found previously in other daily growth studies on anchovy juveniles (Aldanondo et *al.*, 2011). These patterns are probably influenced by endogenous factors, such as decrease in potential growth with age; but they are also modulated by environmental factors, such as temperature and food abundance.

• **Faster growth** (maximum growth achieved in fewer days) in the **subcohorts born later** in every year except 2009 which is the opposite. The age at which maximum growth is presented corresponds to the end of the metamorphosing stage from larva to juvenile, and this is often related to ecological and habitat exchanges .

• For the period 2006-2009, the **lowest growth** was recorded **in 2008** (0.80 mm day^{-1}) and **highest in 2006** (0.88 mm day^{-1}). Previous studies (Aldanondo et al. 2008) show a highest growth in 2004 (0.95 mm day^{-1}) and lowest growth in 2005 (0.73 mm day^{-1} in 2005).

•There are **temporal variability in growth** (inter and intra-annual) of juvenile anchovy in the Bay of Biscay. The results of this study suggest that **temperature and wind stress play a crucial roles in the recruitment process** of the Bay of Biscay anchovy, by both determining larval survival and modulating juvenile growth.

•Further analysis is needed to study spatial and temporal growth (i.e. consider the position of juveniles in the water column, its distance to coast, etc.) included environmental factors taken at other locations of the Bay of Biscay.

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