9206

Bol Inst Esp Oceanogr 8(1). 1992: 115-121

First attempt to determine birthdates and environmental relationship of juvenile sardine, *Sardina pilchardus* (Walb.), in the region of Vigo (NW Spain) during 1988

F. Álvarez[1] and *J. L. Butler*[2]

[1] Instituto Español de Oceanografia. Centro Oceanográfico de Baleares. Muelle de Pelaires, s/n. 07080 Palma de Mallorca, España.
[2] Southwest Fisheries Science Center. NMFS. NOAA. La Jolla. CA 92038, USA.

ABSTRACT

The birthdate of juvenile sardine, Sardina pilchardus, *from the Vigo region was determined from the number of daily increments in the otoliths. The majority of the fish were born during the first part of May to early June, which corresponds to the beginning of a period of calm weather.*

Key words: Sardine, juvenile, birthdate, weather conditions, Spain.

RESUMEN

Relación entre fechas de nacimiento de juveniles de sardina, *Sardina pilchardus* (Walb.), y parámetros medioambientales en la región de Vigo (NO de España) durante 1988. Primera aproximación.

Se ha determinado el día de nacimiento de juveniles de sardina Sardina pilchardus *del área de Vigo a partir del número de incrementos diarios en los otolitos. La mayoría de juveniles han nacido en el período comprendido entre la primera parte de mayo y principios de junio, que corresponde al principio de un periodo de calma.*

Palabras clave: Sardina, juveniles, nacimientos, medioambiente, España.

INTRODUCTION

Lack of scientific understanding of the mechanisms controlling recruitment variability is widely recognized as the key problem area in fishery science at the present time. Marine fishes are generally known for their high mortality in the early life stages, and this is considered one of the main factors affecting population size. This feature led to the critical period hypothesis (Hjort, 1914, 1926) and its later variants, such as the match-mismatch hypothesis (Cushing, 1981), stability hypothesis (Lasker, 1981), larval transport hypothesis (Parrish, Nelson and Bakun, 1981) and retention hypothesis (Iles and Sinclair, 1982). Much of the recent research on the recruitment problem has been structured from these theories. On the other hand, the observation of microincrements in the otoliths of fishes (Pannella, 1971, 1974) and its daily nature (Brothers, Mattews and Lasker, 1976) have supposed a remarkable discovery in fisheries research.

The age and birthdate of fishes can be estimated with precision using this methodology. Reviews of the technique of microincrements have emphasized the necessity of validation of the 1:1 nature of increments and age in days (Campana and Neilson, 1985; Jones, 1986). The daily nature of microincrements in the otoliths of *Sardina pilchardus* has been demostrated by Ré (1984) from edge analysis. Birthdates of juvenile fishes were first calculated by Methot (1983), showing that these birthdates can be used to determine periods of high survival of pelagic fish spawn. Comparison of the survival index to short-term variability in environmental processes and conditions may reveal linkages and causal mechanisms.

It is the basic hypothesis of the Sardine Anchovy Recruitment Program (SARP) that the technique of daily microincrements can be used to investigate the process of recruitment in clupeoid fishes. In this paper, we present the first attempt to determine the birthdates of juvenile sardine off NW Spain and its possible relationship to environmental variables, such as calm weather.

MATERIAL AND METHODS

Only two samples of young sardine were obtained from the purse seine fishery in Vigo, on September 24 and 29, 1988. The total length of 95 and 96 individuals were measured, respectively (fig. 1, 2). The sagitta (hereafter otoliths) were removed, cleaned and mounted on microscope slides with Eukitt mounting medium. Otoliths from 25 randomly-selected fish from each sample were used. Total length of these 50 fishes ranged from 7.5-9.5 cm (fig. 3).

Daily microincrements in the otoliths were accurately read and recorded, using a compound microscope with 5, 16, 40 and 63 X objetives illuminated with polarized light. A closed circuit television camera was mounted on top of the microscope and the image was relayed to a video monitor. A digitizer with a precision of 0.13 μm interfaced with the monitor and a microcomputer (Methot, 1981). To reveal the inner microstructure, otoliths were ground with wet grit sandpaper.

A series of readings along the counting path running from the focus to the postrostral margin was made. Between succesive readings, the otolith was polished to improve the resolution and reveal more microincrements until the entire path was analyzed. Occasionally, the microstructure of daily increments was difficult to resolve within short (40-60 μm) segments of the otolith. In these cases, their number and width were interpolated by averaging the widths of the rings inmediately preceding and following that segment, and dividing the mean into the segment length.

Usually such averaging involved only about 10% of the total microincrements observed. In most cases (70%), only one otolith was used, unless it was damaged or destroyed due to the destructive nature of the preparation method.

To interpolate the number of microincrements near the focus, we assumed that the width of the first microincrement was 1.5 μm and the distance from the focus to the first microincrement was 8 μm. We based this assumption on the average measurements of these parameters. To estimate the time between hatching and first feeding, we used embryonic growth rates determined in rearing conditions (Miranda, Cal and Iglesias, 1990) and the temperatures recorded at three stations off the Ría de Vigo during the month of May. These temperatures ranged from 14.7 to 16.5° C (mean 15.3° C). At 15° C, sardine eggs hatch in 4 days and the eyes become pigmented 8 days after fertilization. Thus, 4 days were added to the number of daily microincrements in the otoliths to calculate the day of hatching.

Data on environmental conditions were estimated from geostrophic winds in a station located in front of the Ría de Vigo at 42° N. The data set is made up of 6 hourly observations and contains a north-south component and an east-west component (Smith and Bakun, 1989).

RESULTS

The birthdates or day of hatching of the 50 fish studied ranged from 130 to 160 Julian days of 1988, corresponding to May 10 to June 9. The mean birthdate was May 25. These birthdates corresponded to the beginning of a period of calm weather (fig. 4).

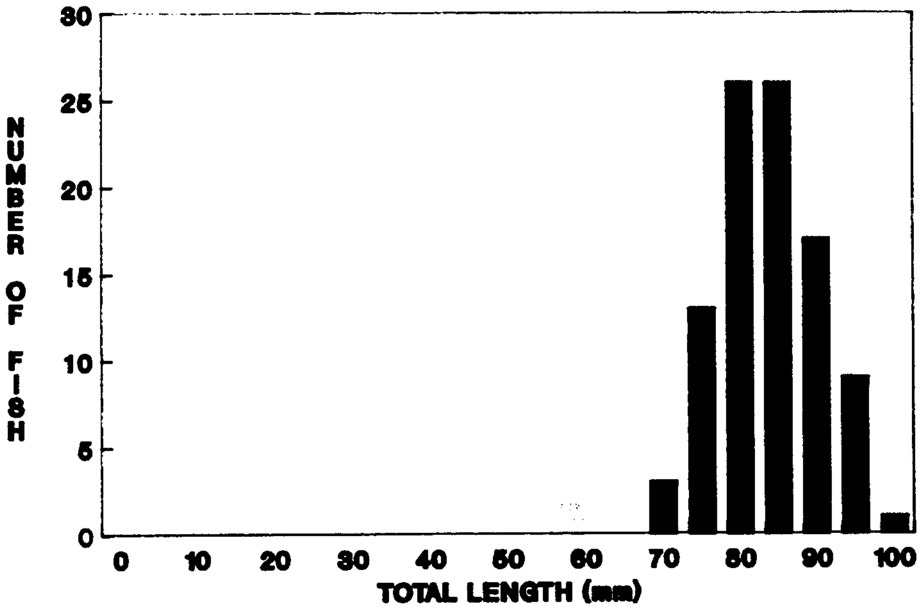

Fig. 1.—Size distribution of sardine juveniles sampled on September 24, 1988 (n = 95).

Fig. 1.—Distribución de tallas de juveniles de sardina muestreados el 24 de septiembre de 1988 (n = 95).

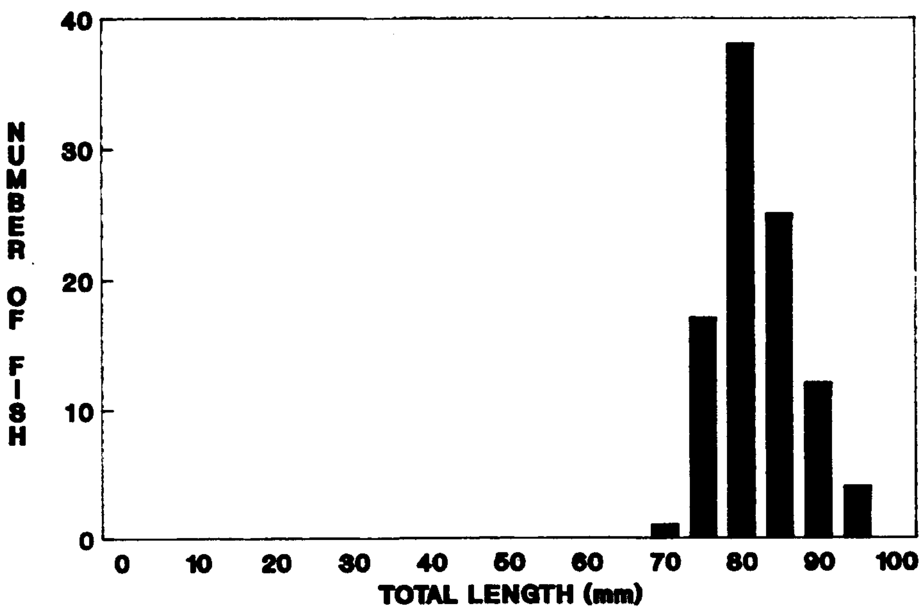

Fig. 2.—Size distribution of sardine juveniles sampled on September 29, 1988 (n = 96).

Fig. 2.—Distribución de tallas de juveniles de sardina muestreados el 29 de septiembre de 1988 (n = 96).

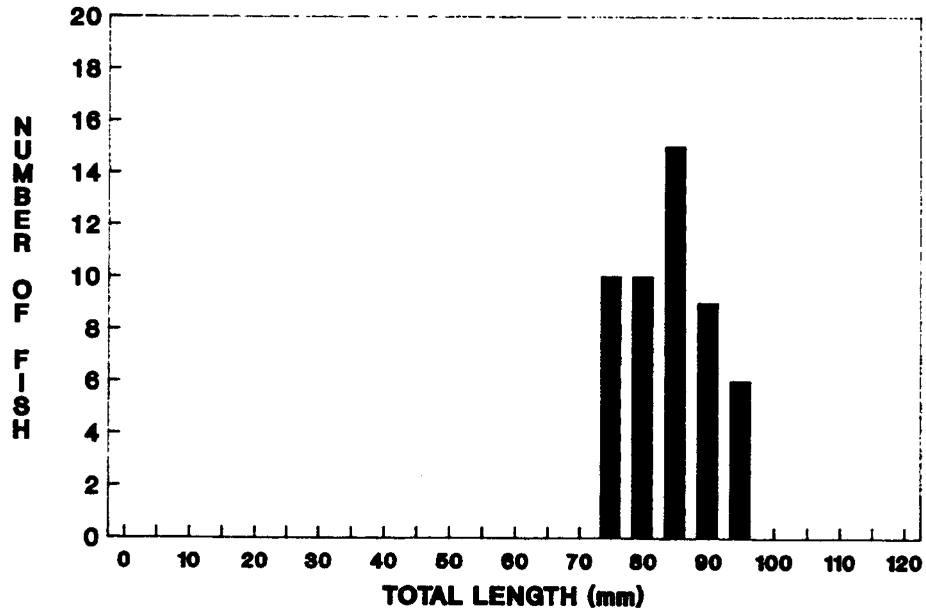

Fig. 3.—Size distribution of sardine juveniles for which age was determined (n = 50).

Fig. 3.—Distribución de tallas de juveniles de sardina a los que se determinó la edad (n = 50).

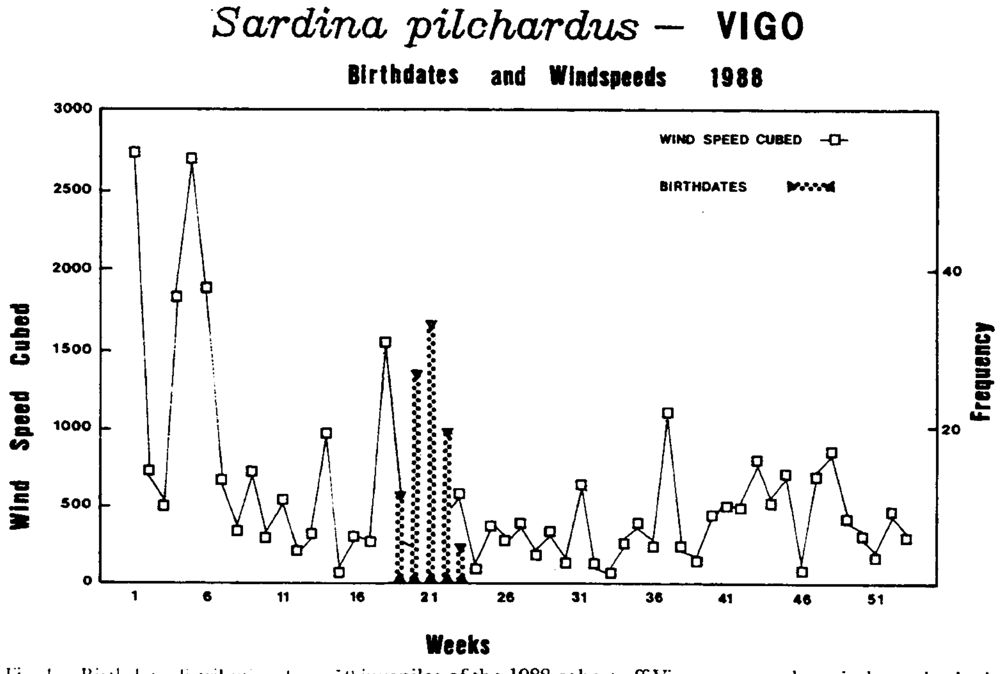

Fig. 4.—Birthdate distribution from 50 juveniles of the 1988 cohort off Vigo, compared to wind speed cubed from the same year. Wind data from Smith and Bakun (in press).

Fig. 4.—Comparación entre las fechas de nacimiento de 50 juveniles de la cohorte de 1988 en la región de Vigo y el cubo de la velocidad del viento del mismo año. Datos del viento de Smith y Bakun (en prensa).

DISCUSSION AND CONCLUSIONS

Recruitment variability in the sardine stock of the Atlantic Iberian Peninsula has been quantified during the past decade (Porteiro, Álvarez and Pérez, 1988; Anon, 1990). Recruitment was poor in 1988. Sampling difficulties arose due to low juvenile catches by the purse seine fleet based in Vigo port.

Sardine presents a protacted spawning season, from early autum to the end of spring (Andreu, 1955; Ferreiro and Labarta, 1982; Pérez, Porteiro and Álvarez, 1985).

A recent work based on ichthyoplankton samples collected on a monthly basis at three locations off the N-NW Iberian Peninsula from 1987-1989 pointed out that spawning can last practically all year round, with the main spawning period in spring (April-May) (Solá *et al.*, 1990).

On the other hand, studies by Hunter and Goldberg (1980) and Hunter and Leong (1981) changed concepts about the reproductive biology of batch or multiple-spawning fish, and gave rise to a large number of studies on the reproductive biology of small, schooling, batch-spawning clupeiform fish in different ecosystems (Alheit, 1991). These aspects were investigated in the Iberian Atlantic sardine, and estimations of relative batch fecundity, spawning frecuency and daily specific fecundity were obtained (Pérez *et al.*, 1989; García *et al.*, 1991).

This spawning strategy could be interpretated as an adaptation to an unpredictable environment such as the upwelling system, which is well known in the Atlantic waters of the Iberian Peninsula (Wooster, Bakun and McLain, 1976; Fraga, 1981; Cabanas *et al.*, 1988). To ensure that at least some of the eggs and larvae survive to be recruited, mature fish spawn intermittently in batches over a protracted spawning season, improving the chances that at least some eggs or larvae are present when an unpredictable "survival window" is opened (Peterman and Bradford, 1987; Curry and Roy, 1989). Our data would indicate that the birthdates correspond to the beginning of a period of calm weather, and they are consistent with the Lasker hypothesis (1981) that first-feeding larvae require adequate food supplies for growth and survival. In a later work on the possible causes of variability in this stock, based on the monthly capture of juveniles in southern Galicia ports and their birthdates and environmental parameters (Robles, Porteiro and Cabanas, 1991), some links between recruitment anomalies and those parameters have been identified. So, variations in recruitment can be explained on the basis of fluctuations in "environmental windows" during the periods of spawning and larval drift. Weak upwelling and abundant food would determine the success of spawning. Our results should also be in accordance with this conclusion.

However, it should be pointed out that Robles, Porteiro and Cabanas (1991) have carried out a qualitative attempt to explain the relationships studied, and our results are based on a very limited number of samples.

Smaller, and hence younger, recruits may not be represented in these samples. Thus, recruits from the calm period lasting into July may not be represented. To carry out a complete test of the hypothesis under study in SARP, birthdates distribution of unbiased samples of the survivors of the larval stage, the recruits, should be compared with the seasonal distribution of spawning, determined from ichthyoplankton surveys conducted throughout the spawning season over the entire habitat at short intervals. The reason is that larval production can vary on small space scales as well as on small temporal scales. Because of the extensive ship time and other operational resources required, no fully elaborated SARP "within year" exercise, incorporating a full suite of environmental and biological aspects, has been completed to date. Nevertheless, the EUROSARP cooperative project will be implemented in the period 1990-1992 with EEC funds. The project concentrates on North Sea spratt *(Sprattus sprattus)*, sardine off the Iberian peninsula and anchovy *(Engraulis encrasicolus)* in Portuguese estuaries. The project includes the "high temporal resolution" exercise as well "high spatial resolution" studies (Bakun, Alheit and Kullenberg, 1991), and is expected to provide very valuable insights into the recruitment processes of clupeoid fishes.

ACKNOWLEDGEMENTS

This work was carried out with funds from the Instituto Español de Oceanografía and the Joint Committee of the U.S.-Spanish Treaty of Friendship and Cooperation.

REFERENCES

Alheit, J. 1991. Recent advances in the application of the daily egg production method to clupeoid fish. *ICES C. M.* 1991/H:38.

Andreu, B. 1955. The sexuality of sardines. In: *General Fisheries Council for the Mediterranean. Technical paper* n.° 1.

Anon. 1990. Report of the Working Group on the Assessment of the Stocks of Sardine, Horse Mackerel and Anchovy. *ICES C. M.* 1990/Assess: 24.

Bakun, A., J. Alheit and G. Kullenberg. 1991. The Sardine-Anchovy Recruitment and development. *ICES C. M.* 1991/L:43.

Brothers, E. B., C. P. Mattews and R. Lasker. 1976. Daily growth increments in otoliths from larval and adult fishes. *Fish Bull US* 74: 1-8.

Campana, S. and J. Neilson. 1985. Microstructure of fish otoliths. *Com J Fish Aquat Sci* 42: 1014-1032.

Cabanas, J. M. 1988. Hydrographic conditions off the Galician coast, NW of Spain, during an upwelling event. (In this volume.)

Curry, P. and C. Roy. 1989. Optimal environmental window and pelagic fish recruitment success in upwelling areas. *Com J Fish Aquat Sci* 46: 670-680.

Cusing, R. 1981. *Marine ecology and fisheries.* Cambridge University Press: 278 pp.

Fraga, F. 1981. Upwelling off Galician coast, NW Spain. In: *Coastal Upwelling.* F. A. Richards (ed.): 176-182. American Geophysical Union. Washington, D.C.

Ferreiro, M. J. and U. Labarta. 1982. Distribution and abundance of sardine eggs, *Sardina pilchardus,* from the Ría de Vigo (Galician coast, NW Spain). 1979-1980. *ICES C.M.* 1982/H: 57.

García, A., N. Pérez, C. Porteiro and P. Carrera. 1991. Estimates of the sardine spawning stock biomass off the Galician and Cantabrian coasts. *ICES C.M.* 1991/H: 35.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe. Rapp P-V *Reun Cons Int Explor Sci Mer* 19: 1-228.

Hjort, J. 1926. Fluctuations in the year classes of important food fishes. *J Cons Int Explor Mer* 1: 5-38.

Hunter, J. R. and S. R. Goldberg. 1980. Spawning incidence and batch fecundity in northern anchovy *(Engraulis mordax). Fish Bull US* 77: 641-652.

Hunter, J. R. and R. Leong. 1981. The spawning energetics of female northern anchovy *(Engraulis mordax). Fish Bull US* 79: 215-230.

Iles, T. D. and M. Sinclair. 1982. Atlantic herring: stock discreteness and abundance. *SCI* 215: 627-633.

Jones, C. 1986. Determining age of larval fish with the otolith increment technique. *Fish Bull US* 84: 91-103.

Lasker, R. 1981. The role of a stable ocean in larval fish survival and subsequent recruitment. In: *Marine Fish Larvae: Morphology, Ecology and Relation to Fisheries.* R. Lasker (ed.): 80-87. University of Washington Press. Seattle.

Methot, R. 1981. *Growth rates and age distributions of larval and juvenile northern anchovy,* Engraulis mordax, *with inferences on larval survival.* Doctoral Thesis. Univ. California, San Diego: 200 pp.

Methot, R. 1983. Seasonal variation in survival of larval northern anchovy, *Engraulis mordax,* estimated from the age distribution of juveniles. *Fish Bull US* 81: 741-750.

Miranda, A., R. Cal and J. Iglesias. 1990. Effect of temperature on the development of eggs and larvae of sardine, *Sardina pilchardus,* in captivity. *J Exper Marine Biol Ecol* 140: 69-77.

Panella, G. 1971. Fish otoliths: daily growth layers and periodical patterns. *SCI* 173: 1124-1127.

Panella, G. 1974. Otolith growth patterns: an aid in age determination in temperature and tropical fishes. In: *The Ageing of Fish.* T. B. Bagenal (ed.): 28-29. Unwin Brothers. Surrey, England.

Parrish, R. H., C. S. Nelson and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California Current. *Biol Oceanogr* 1: 175-203.

Pérez, N., A. García, N. C. Lo and C. Franco. 1989. The egg production method applied to the spawning biomass estimation of sardine, *Sardina pilchardus* (Walb.), on the North Atlantic Spanish coast. (In this volume.)

Pérez, N., C. Porteiro and F. Álvarez. 1985. Some observations on the biology of sardine, *Sardina pilchardus,* off Galicia, NW Spain. *ICES C.M.* 1985/H: 19.

Peterman, R. M. and M. J. Bradford. 1987. Wind speed and mortality rate of a marine fish, the northern anchovy *(Engraulis mordax). SCI* 235: 354-356.

Porteiro, C., F. Álvarez and N. Pérez. 1988. Variaciones en el stock de sardina, *Sardina pilchardus* (Walb.), de las costas atlánticas de la península Ibérica. In: *International Symposium on Long-term Changes in Marine Fish Populations.* (November 18-21, 1986. Vigo, Spain). T. Wyatt and M. G. Larrañeta (eds.): 529-541.

Ré, P. 1984. Evidence of daily and hourly growth in pilchard larvae based on otolith growth increments. *Cybium* 8: 33-38.

Robles, R., C. Porteiro and J. M. Cabanas. 1991. The stock of Atlantic Iberian sardine: possible causes of variability. *ICES, Variability Symp,* n.° 31/Session 3.

Smith, P. and A. Bakun. 1989. Lasker gates between mixing events from the French border region to the Canary islands, 1988-1989, and interannual and seasonal changes of the wind indices 1967-1989. In: *C.M. SARP Seminar on research conducted by the SARP project of Spain and Portugal, 1987-1989* (November 1-3, 1989. La Jolla, California, USA). *NOAA Admin Rep.*

Solá, A., L. Motos, C. Franco and A. Lago de Lanzós. 1990. Seasonal ocurrence of pelagic fish eggs and larvae in the Cantabrian Sea (VIIIc) and Galicia (IXa) from 1987 to 1989. *ICES C.M.* 1990/H: 25.

Wooster, W., A. Bakun and D. R. McLain. 1976. The seasonal upwelling cycle along the eastern boundary of the North Atlantic. *J Mar Res* 34: 131-141.

Received October, 1991. Accepted March, 1992