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Tag and recapture of European hake (Merluccius merluccius L.) off the Northwest Iberian Peninsula: First results support fast growth hypothesis

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Abstract:

In the first tagging experiment of European hake (Merluccius merluccius L.) conducted off the NW Iberian Peninsula to study hake growth in the wild we released 527 live tagged individuals. The survival rate after capture and tagging was 58%. Mortality during capture was positively correlated with depth of capture and negatively correlated with hake size. Fifteen months after tagging, seven individuals (1.3%) had been recaptured with times at liberty ranging from 29 to 466 days. We provide the first direct measurements of growth rates of Southern stock European hake in the wild and compare them with rates obtained from tagging experiments in other regions and with rates derived from conventional otolith age reading. The mean somatic growth rate of all recaptured hake was 0.032 ± 0.016 cm day−1 (sexes combined), while the mean growth rate of the two hake with over 340 days at liberty was 0.052 ± 0.003 cm day−1 (sexes unknown). These results indicate that conventional otolith age reading methods overestimate age and underestimate growth.

Keywords: European hake; Growth rates; Tag-recapture; Age estimation; Northeast Atlantic

1. Introduction

The European hake *Merluccius merluccius L.* is widely distributed throughout the Northeast Atlantic and Mediterranean and reaches greatest density between the British Isles and the Southern Iberian Peninsula (Casey and Pereiro, 1995). It is one of the most valuable and heavily exploited demersal species in Western European fisheries. The status of *M. merluccius* populations in the NE Atlantic is assessed annually by the International Council for the Exploration of the Sea (ICES) on the basis of two separate stocks, the Northern stock and the Southern stock, to the north and south of Cape Breton Canyon (Bay of Biscay) respectively (ICES, 1979). Recent assessments of the status of the Southern stock (Spanish and Portuguese waters) reveal a dramatic decline of the spawning stock biomass that has been attributed to overfishing (ICES, 2006). Despite numerous studies focusing on the biology of *M. merluccius* (see Piñero and Saínza, 2003 for a review), many gaps remain in our knowledge on the species. In particular, there is a lack of knowledge on the growth rate, which is vital for population assessment using age-based models. Problems with hake otolith interpretation and age estimation have to date hindered efforts to produce reliable age length keys for age-based models (Piñeiro and Saínza, 2003).

One of the most reliable methods of validating the growth of fishes is tagging and recapturing individuals in nature (Campana, 2001). Until recently few tagging experiments of hake had been conducted due to the poor survival of individuals captured by conventional methods (Belloc, 1935; Robles et al., 1975; Lucio et al., 2000). In 2002 a new trawl gear specially designed for the capture of live individuals was successfully tested by de Pontual et al. (2003). The survival rate after capture and tagging was 68% and the rate of recapture after three years was 3.1%. The results of that experiment indicated that the rate of somatic growth of Northern stock hake was two times higher than predicted by current growth models derived from internationally agreed otolith ageing criteria (de Pontual et al. 2006).

Internationally agreed criteria for hake otolith interpretation and age estimation, summarized by Piñeiro and Saínza (2003), have never been validated and have been questioned by the first results of Northern stock hake tag-recapture experiments (de Pontual et al., 2003, 2006) as well as by ICES (ICES, 2005). Here we present estimates of somatic growth rates obtained from the first successful tag-recapture experiment of Southern stock hake and compare them with growth rates obtained by conventional ageing criteria, as well as with those derived from tag-recapture experiments of Northern stock hake (Belloc, 1935; Lucio et al., 2000; de Pontual et al., 2003; 2006).

2. Material and Methods

Tagging was carried out in September-October 2004 off the NW Iberian Peninsula at depths from 40-130 m Locations of capture, release and recapture are shown in Figure 1. The fishing gear, a trawl (GOC-73) modified with a specially designed cod-end, and the handling method were as described in de Pontual *et al.* (2003). All hake were measured (total length, TL) and individuals < 40 cm TL were tagged with FF-94 Floy ® anchor tags while individuals ≥ 40 cm TL were tagged with the larger FD-94 Floy® anchor tag. All hake were also tagged internally by injection with Terramicine® (OTC) at a dosage of 60 mg*kg^{-1}, using the length-weight relationship $W_t = 0.00733L^{2.981}$ (Piñeiro and Saínza, 2003). Tagged hake were released in two locations selected to keep the animals temporarily safe from commercial fishing operations (Figure 1). The release was done through a smooth PVC pipe while seabirds were scared away to minimize predation. Recaptures came from commercial tangle-net and bottom trawl hake fisheries operating in the region. Whenever possible, recaptured individuals were measured and sexed, while the otoliths were removed for growth analysis based on the Terramicine® mark laid down at the time of tagging.

Somatic growth from release to recapture was computed for each recaptured individual. Mean growth rates were estimated for all the recaptures combined and separately for two recaptures with times at liberty > 340 days. Survival rates after capture and after tagging were calculated and their relationship with fishing depth was investigated by logistic regression analysis. Mortality due to seabird predation was estimated by eye.

3. Results

A total of 1131 hake were caught in 45 fishing sets (Figure 1.). The proportion of hake alive in the catch was 58%, of which 80% survived the tagging process. In total 527 hake (46.6% of the catch) were returned tagged to the sea. We estimated that about 10% of the released fish were affected by seabird predation.

The size structure of hake in the catch ranged from 7 to 61 cm TL and had two distinct groups with modal sizes of 15 and 30 cm TL (Figure 2). The proportion of hake dead in the first group was greater than in the second, suggesting a negative relationship with size (Figure 2). Mortality rates during capture and tagging were positively correlated with depth of capture, which explained 72% and 98% of their variation respectively (r^2=0.72, p= 0.07; r^2=0.99, p< 0.01). However, the correlation between fishing depth and hake size, the smaller hake being more abundant at greater depth, precluded contrast across the two effects.

One year after tagging, six tagged hake had been returned to the laboratory and one tag was recovered without the fish, resulting in a recapture rate of 1.3 % (Table 1). The time between release and recapture ranged from 29 to 466 days and the distance moved from release to recapture ranged from 1 to 14.7 nautical miles (Table 1, Figure 1).

The mean growth rate (±SD) of recaptured fish was 0.032±0.016 cm TL*day^{-1} (n= 6, sexes combined), while that of the individuals recaptured within three months of release was 0.021±0.003 cm TL*day^{-1} (n= 4, sexes combined). The mean growth rate of the two specimens that had spent over 340 days at sea was 0.052 ±0.003 cm TL*day-1 (Table 2).

4. Discussion

The first tagging trial of Southern stock hake was carried out off the NW Iberian Peninsula by Robles et al. in 1975. This experiment confronted high mortality and yielded no recaptures. Almost 30 years later, results of the second tag-recapture experiment in the region confirm the suitability of the method developed and successfully tested in the northern Bay of Biscay by de Pontual et al. (2003). In our experiment the survival rate after capture (58%) was lower than in Pontual et al. (2003) (68%), but survival rates can be improved in future surveys by targeting hake in shallow waters, thus reducing barometric stress, and by using a device to limit the size of the catch in the cod-end. The relatively low recapture rate of 1.3%, in comparison with that obtained by de Pontual et al. (2006) of 3.1%, may be partially attributed to the limited geographic scope of our publicity campaign to fishermen and to the lack of an economic reward for the return of tagged individuals.

In spite of the many efforts devoted to age estimation of *M. merluccius* over the years (see Piñeiro and Saínza, 2003 for a review), interpretation of otolith ring patterns remains controversial and uncertainty about the reliability of age estimates has not declined. Direct measures of growth derived from mark-recapture experiments provide invaluable data for the resolution of this problem. Until now, these data were only available for Northern stock hake. Here for the first time we provide direct measures of the growth rate of Southern stock hake. Our results support the fast growth model proposed by de Pontual et al. (2006) for Northern stock hake by which *M. merluccius* reach about 25, 45 and 60 cm TL at the end of the first, second and third year of life, instead of 20, 29 and 37 cm TL as estimated from otoliths using the internationally agreed age interpretation method (Piñeiro and Saínza, 2003). The striking consistency between our results and somatic growth rates from tag recoveries of Northern stock hake (Figure 3) is of prime interest because concurs with genetic studies which do not find significative differences between both stocks (Cimmaruta et al., 2005). Although earlier tagging studies had very low tag return rates (Belloc, 1935; Lucio et al., 2000), their findings also indicate a much faster growth rate of this species (Table 2).

The mean daily growth of individuals recaptured within three months (fall season) was less than half that of the hake recaptured after nearly one year at sea. This discrepancy may be due to seasonal variations in growth (Norbis et al. , 1999; Morales-Nin and Moranta, 2004), although short-term growth slow-down as a result of capture and tagging stress cannot be discounted.

Interestingly, the fast growth of this species had been repeatedly hypothesized, first by Bagenal (1954) on the basis of otolith readings and size frequency data and later by Piñeiro and Pereiro (1993) and Alemany and Oliver (1995) on the basis of size modal progression analysis, by Riis-Vestergaard et al. (2000) based on consumption rates and bioenergetic requirements, and by Kacher and Amara (2005) based on daily growth. A further indication of the failure of current otolith age estimation procedures is the lack of coherent evolution of cohorts in age structured models used by ICES (ICES, 2005).

In sum, our results coincide with all available tag-recapture data to indicate that the growth rate of European hake in the size range studied is about double that derived by the conventionally accepted and routinely applied otolith age interpretation method. We expect that these results will contribute to the discussion on European hake population dynamics as recent work by Bertignac and de Pontual (2007) has shown how bias in age estimations affect assessments of Northern stock hake. Our results thus emphasize the need to carry out large-scale tagging experiments covering the main geographic range of the species in order to develop new, validated ageing criteria for routine age estimation.

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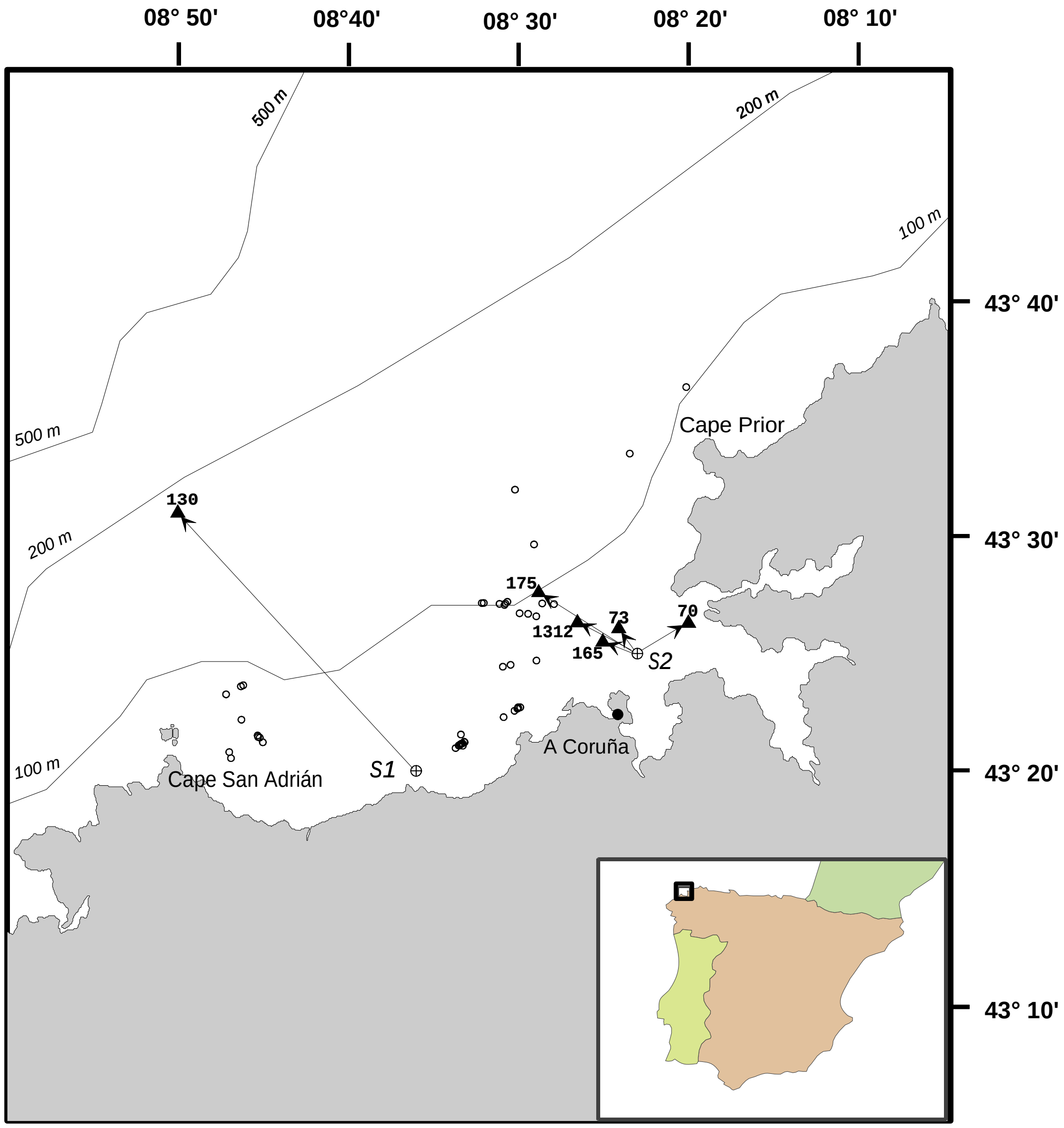

Fig. 1. Study area indicating capture (circles), release (cross circles S1, S2) and recapture (triangles) locations with fish codes.

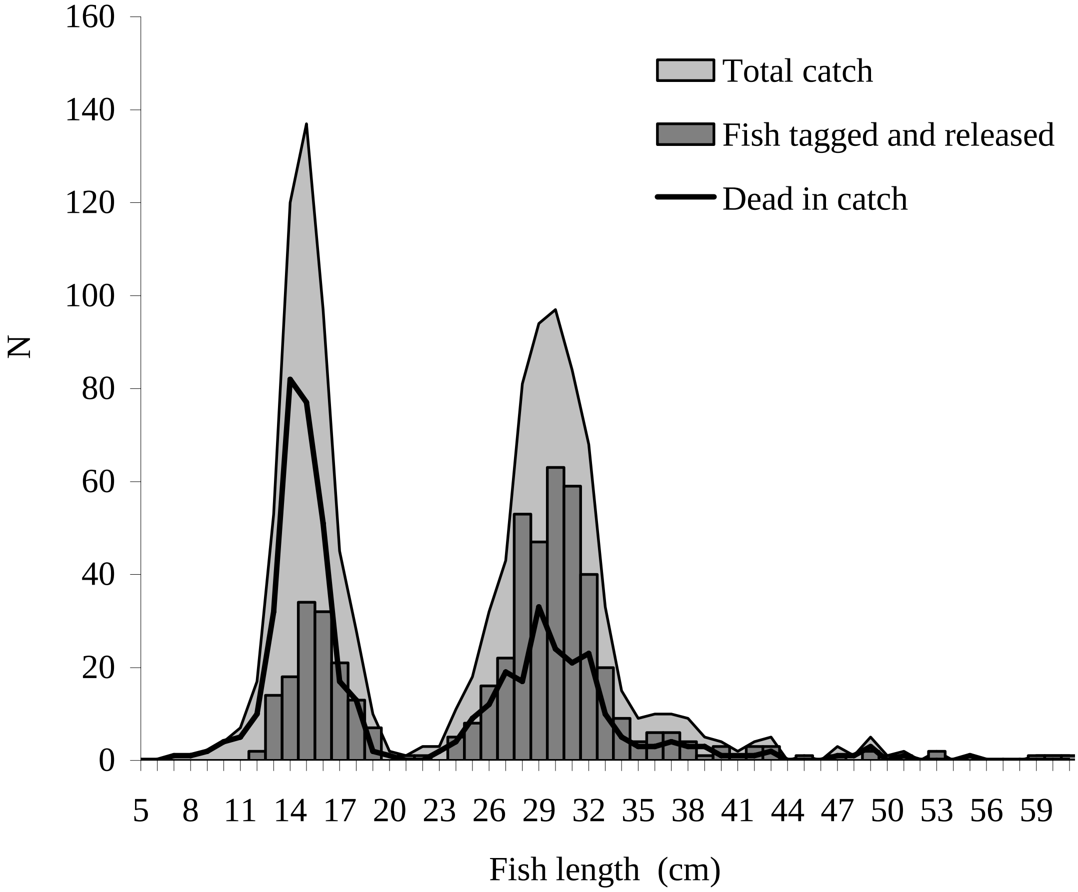

Fig. 2. Size frequency distributions (N) of the total catch, dead after captured fish and tagged-released fish.

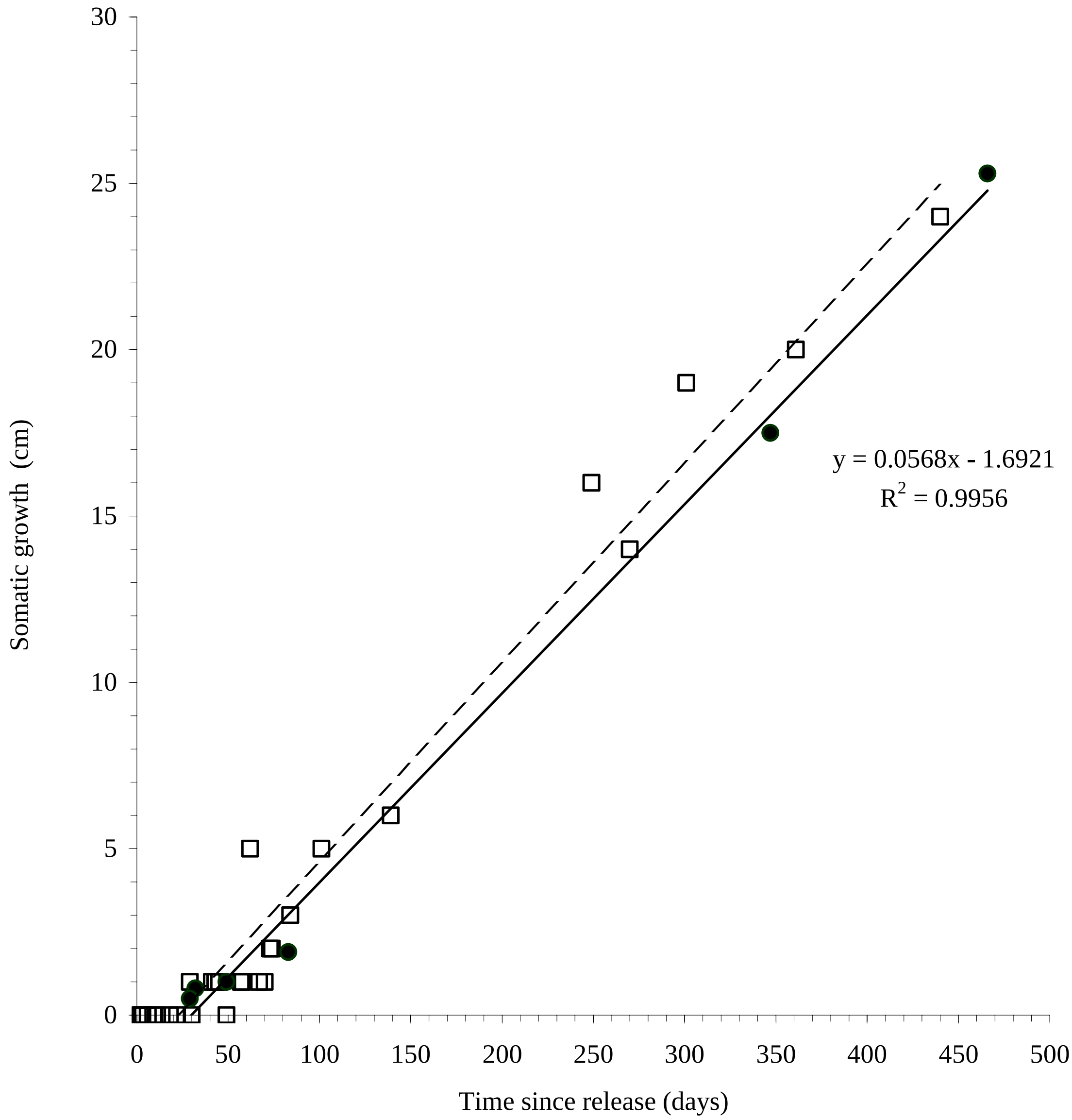

Fig. 3. Somatic growth increment (TL, cm) as a function of time since release. Black dots and solid line: this study; squares and dashed line: data of Northern stock hake (de Pontual et al. 2006) restricted to comparable time period (up to 500 days since release).

Table 1

Tag-recapture information of hake tagged during the experiment. M: male; F: female;

U; unknown (gutted)

Tagging data				Recapture data					
Fish Code	Date	Depth (m)	TL (cm)	Date	Time since release (days)	Distance (nautical miles)	TL (cm)	Sex	TL increment (cm)
165	04/10/04	61	30.7	03/11/2004	29	1.04	31.2	U	0.5
1312	02/10/04	63	30.7	04/11/2004	32	4.48	31.5	F	0.8
70	03/10/04	61	31.1	22/11/2004	49	2.45	32.1	F	1
149	04/10/04	61	36.2	29/11/2004	55	-	No fish	-	No fish
73	03/10/04	61	32.2	26/12/2004	83	1.09	34.1	F	1.9
130	04/10/04	61	29	21/09/2005	347	14.7	46.5	U	17.5
175	04/10/04	61	30.7	20/01/2006	466	2.45	56	U	25.3

Table 2

Summary of results of available tag-recapture studies of European hake. *: only tag (no fish) recaptured. **: information of fish that were >100 days at sea. (*NS* = Northern Stock; *SS* = Southern Stock)

Tagging experiment			Recapture results							
Author	Location	Nº individuals released	Number of tagged fish	Number of tags (*)	TL at release (cm)	Time since release (days)	Distance nautical miles (nm)	TL at recapture (cm)	Growth rate (cm. day^{-1} mean ± sd)	Recapture rate (%)
Belloc, 1935	NS: SW Ireland	78	1	-	28.9	255	130	40.6	0.046	1.3
Lucio *et al.*, 2000	NS: South Bay of Biscay	152	1	2	56	24	20	60	0.166	1.9
De Pontual *et al.*, 2006	NS: Bay of Biscay	1307	36	5	21-40 mode= 29	1-1066	0-112	24-67	0.038 ± 0.004	3.1
"	"	-	10 (**)	-	21-33	101-1066	11-112	34-67	0.052±0.009	-
This study	SS: NW Iberian Peninsula	527	6	1	(29-36) mode= 29	29-466	1-15	31-56	0.032±0.016	1.3
"	"	-	2(**)	-	29-30	347-466	2-15	46.5-56	0.052±0.003	-

x