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Interannual larval growth and condition variability of bluefin (*Thunnus thynnus*) consequent with climate-induced environmental changes off the Balearic Sea

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Abstract : Daily growth and nutritional condition variability of bluefin (*Thunnus thynnus*) larvae sampled in their Balearic Sea spawning grounds during the 2003-2005 spawning seasons is examined (Fig. 1). All the annual surveys were carried out during June/July (García *et al*., 2013). Environmental conditions during the 2003-2005 bluefin spawning seasons varied greatly as a result of the 2003 heat wave which caused substantial changes in the NW Mediterranean ecosystem (Schär *et al*, 2004; Schiaparelli, *et al*., 2007). As a result of the warming anomaly, an average increase of 2.7°C in surface waters (T10), low microzooplankton dry weight biomass (MDW, a proxy of larval food availability) and highest protein/microzooplankton dry weight ratios (PROT/MDW, a food quality proxy) was observed. In contrast, the 2004 bluefin spawning habitat was subject to the highest MDW and coldest T10 that suggest greater fertilization processes occurring in the area. The 2005 showed an intermediate environmental situation with significantly higher T10 than 2004 and lower MDW in comparison to 2004. Nonetheless, this difference was reflected in their difference between their respective PROT/MDW ratios (Fig. 2). The 2003 bluefin tuna (BFT) larval cohort showed fastest growth, recognizable from the enhanced otolith and somatic mass increment in comparison with the 2004-2005 larval cohorts (García *et al*., 2013), while the latter larval cohorts did not differ statistically (Fig. 3). The 2003 bluefin larval cohort showed significantly greater weight with standard length than the 2004-2005 larval cohorts. Consequently, the 2003 larvae had a significantly higher a mount of DNA, RNA and proteins with standard length (Fig. 4) (Cortés *et al*., 2007). Nonetheless, RNA/DNA ratios of the 2003 larvae were significantly lower than the 2004 larval cohort due to a significant temperature effect on these ratios. Overall, the mean RNA/DNA ratios of all the BFT larvae collected showed a significant linear decrease with surface temperature (Fig. 5).

The daily growth analysis showed that somatic and otolith growth rates were significantly related with T10 and MDW, as well as the PROT/MDW ratios. Otolith growth rates (OGR) showed significant interactions with T10*PROT/MDW and T10*MDW. Higher OGR is observed when T10 is high (H), MDW is low (L) and PROT/MDW is high (H), coinciding with the 2003 environmental scenario, which observed an anomalous warming of surface temperature, low planktonic biomass and possibly of greater larval feeding quality (Fig. 6). Somatic growth, expressed as larval DW growth increase (DWGR), showed three-factor significant interactions with T10*MDW*PROT/MDW (Fig. 7).

Key words : bluefin larvae, daily growth, climate variation, surface temperature, microzooplankton, Balearic Sea

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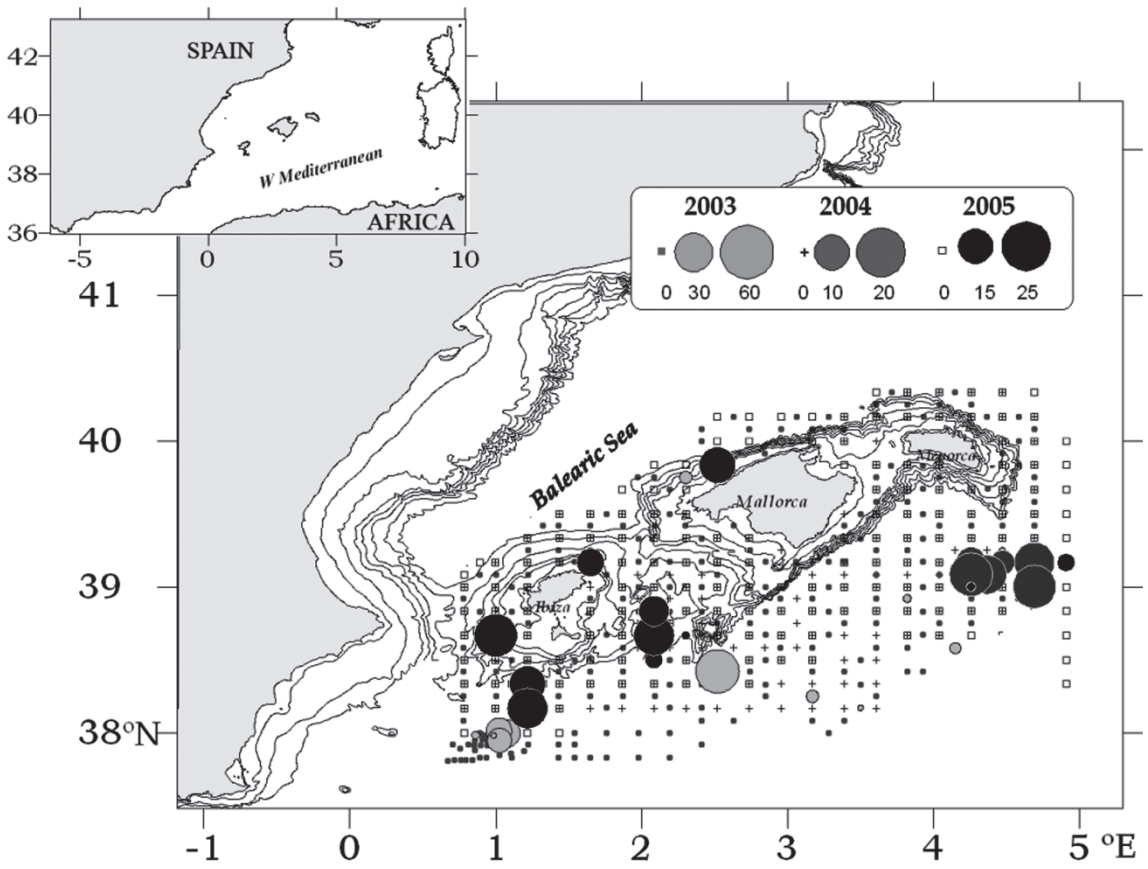

Fig. 1. BFT larvae sampled for the growth study represented by proportional circles for each survey with the TUNIBAL sampling grid in the background.

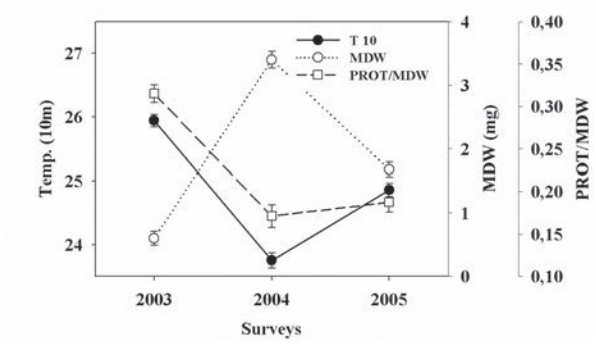

Fig. 2. ANOVA result test for temperature at 10 m depth ($F_{2, 385}$ = 381.04 p<0.01), MDW($F_{2, 385}$ = 522.23 p<0.01), and the PROT/MDW ratio ($F_{2, 385}$ = 183.04 p<0.01), undertaken in positive BFT hauls.

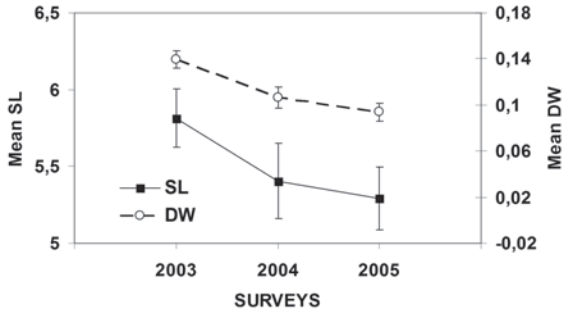

Fig. 3. Results of ANCOVA of SL vs DI (daily increments) and DW vs DI using DI as covariate. Significant difference is observed between 2003 and 2004-2005 in SL vs DI and DW vs DI relationships (p<0.01). The paired 2004-2005 did not show significant difference (p>0.05)(from Garcia et al., 2013).

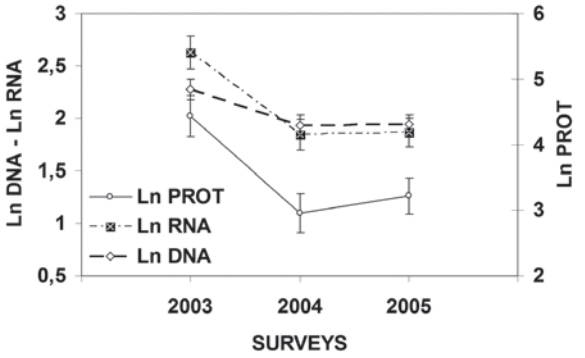

Fig. 4. Results of ANCOVA of LnDNA, LnRNA and LnPROT vs LnSL using LnSL as covariate. Significant difference is observed between 2003 and 2004-2005 in LnDNA, LnRNA and LnPROT vs LnSL relationships ($p<0.01$). The paired 2004-2005 did not show significant difference ($p>0.05$).

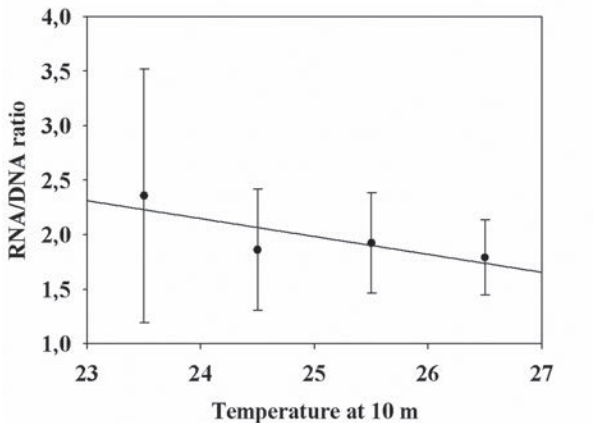

Fig. 5. Averaged RNA/DNA ratios by one Celsius temperature degree.

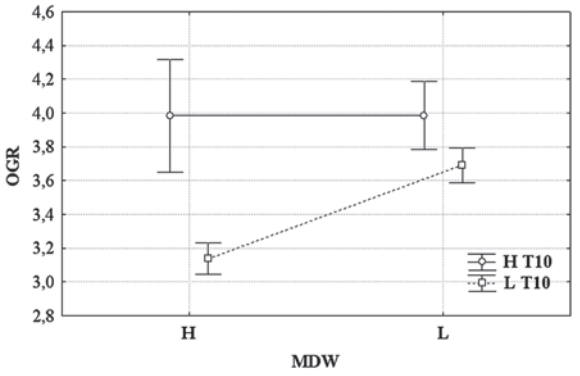

Fig. 6. Multi-factorial ANOVA of otolith growth rate (OGR) and the interaction of T10 and PROT/MDW.

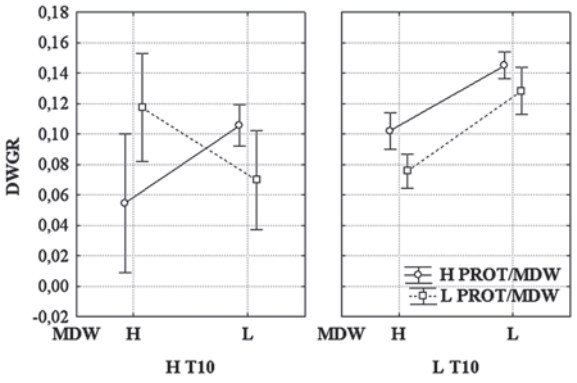

Fig. 7. Multi-factorial ANOVA of somatic growth rate (DWGR) and the interaction of T10, MDW and PROT/MDW.

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