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# Somatic condition of *Aphanius iberus* (Valenciennes, 1846) in Marchamalo wetland (Mar Menor; SE Spain): Effects of management

Ana Ruiz-Navarro, Francisco J. Oliva-Paterna & Mar Torralva
Departamento de Zoología. Universidad de Murcia. 30100 Murcia. España.

Correspondence:
A. Ruiz-Navarro
E-mail: anaruiz@um.es
Telf: +34 968 364961
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## Abstract

*Aphanius iberus* is an endangered cyprinodontid of which scarce populations are distributed along the Mediterranean coast of the Iberian Peninsula. In the southeast of the peninsula, salt exploitation wetlands are a priority habitat for conservation of the species. The objective of this study was to check possible effects of extractive management in a salt exploitation (Marchamalo wetland, Mar Menor) on condition of the species during a two-year period (May 2000 – June 2002). 2612 individuals were captured in 28 monthly samplings and processed *in situ* (sex, total length: TL), and a sub-sampling of 997 individuals was processed in the laboratory to obtain eviscerated weight (EW). Temporal cycle of somatic condition was studied by standardized residuals from TL-EW relationships. Hipersalinity episodes due to extractive management were detected and they appeared to be correlated with diminished somatic condition. In short, extractive management with no biological criteria produces deleterious effects on the condition of the species.

**Key words:** Cyprinodontid, Life-history, Growth, Condition, Endangered species.

## Resumen

*Condición somática de* Aphanius iberus *(Valenciennes, 1846) en las salinas de Marchamalo (Mar Menor; SE España): Efectos de la gestión extractiva.*

*Aphanius iberus* es un ciprinodóntido en peligro de extinción cuyas escasas poblaciones se distribuyen por la costa mediterránea de la Península Ibérica. En el sureste peninsular los humedales con salinas en explotación conforman un hábitat prioritario para su conservación. El objetivo de este trabajo fue constatar posibles efectos de la gestión extractiva en unas salinas (Salinas de Marchamalo, Mar Menor) sobre la condición de la especie durante un periodo de dos años (mayo 2000 – junio 2002). 2612 individuos fueron capturados en 28 muestreos con periodicidad mensual y procesados in situ (sexo, longitud total: TL), y una submuestra de 997 individuos se procesó en el laboratorio para obtener su peso eviscerado (EW). Se estudió la dinámica temporal de la condición somática mediante los residuos estandarizados obtenidos a partir de las relaciones TL-EW. Se han detectado episodios de hipersalinidad debidos a la gestión extractiva que se correlacionan con picos de disminución en la condición somática poblacional. En resumen, una gestión extractiva sin criterios biológicos provoca efectos perjudiciales sobre la condición de la especie.

**Palabras clave:** Ciprinodóntido, Estrategia de vida, Crecimiento, Condición, Especie en peligro.

## Introduction

*Aphanius iberus* (Valenciennes, 1846) (Spanish toothcarp) is an endemic cyprinodontid of the Iberian Peninsula that is now restricted to a few populations along the eastern Spanish coastline (Oliva-Paterna *et al.* 2006). The species is catalogued as Endangered (EN) in several national and international lists (Doadrio 2002; IUCN 2007); loss and chemical or biological pollution of their habitats are the most important threat factors (Torralva & Oliva-Paterna 2002).

Data about age and growth, together with others, such as reproduction or habitat preferences, are basic to knowing fish biology, and, therefore, for management and conservation (García-Berthou *et al.* 1999). There are some recent published studies on *A. iberus* feeding ecology (Vargas & D e Sostoa 1999, Alcaraz & García-Berthou 2007), genetic variation (Perdices *et al.* 2001) and ecophysiological parameters (Oliva-Paterna *et al.* 2007). However, life-history pattern of this species has only been studied in two populations from its northern distribution area: Ebro delta (De Sostoa 1983, 1984, Vargas & De Sostoa 1997, Caiola 2006) and Empordà salt marshes (García-Berthou & Moreno-Amich 1992, 1993, Alcaraz 2006). Moreover, salt exploitation wetlands, directly human-managed ecosystems, are among the most important habitats for the conservation of *A. iberus* in the southeast of the Iberian Peninsula (Torralva & Oliva-Paterna 2002). Understanding its life-history pattern in these specific systems is essential for developing recovery plans (Oliva-Paterna 2006).

This study, which forms part of a wider one about the species in Murcia Region (Oliva-Paterna 2006), examines the effect of a managed habitat for salt exploitation on the somatic condition of the species.

## Materials and methods

### Study area

The population studied inhabits a small wetland (Marchamalo; UTM 30SYG06) managed for salt exploitation in the south part of the Mar Menor, a big coastal lagoon located in the SE of Spain (Pérez-Ruzafa et al. 2005) (Fig. 1). In this wetland *A. iberus* co-exists with Mugilids and shows higher relative density than any other populations in Murcia Region (Torralva *et al.* 1999).

Temperature and salinity were registered at the sampling site, at 10 cm depth, by a multiparameter WTW-400®. Water temperature showed an annual pattern of variation, with maximum in summer (July-September) and minimum in winter (December-February). No significant difference was observed between the years: Summer 2000 = 29.74 ± 1.80ºC; Summer 2001 = 30.48 ± 1.15ºC; t-Student = -1.46; $p$ = 0.16. Winter 2000-01 = 12.08 ± 0.76ºC; Winter 2001-02 = 12.10 ± 0.96ºC; t-Student = -0.39; $p$ = 0.97.

Average salinity was 47.27‰ and remained quite stable during the studied period. Its stability depends on several factors, including evaporation, rainfall and, mainly, the quantity of sea water entering the pools. In July-August 2000, March 2001 and March 2002, silting of this entrance channel and scarce rainfall produced atypical increases in salinity: 71.00‰ in August 2000, 83.67‰ in April 2001 and 58.67‰ in March 2002.

### Sampling Methods and Statistical Analyses

In 28 monthly samplings from May 2000 to June 2002, a total of 2612 individuals were captured in pools containing the greatest species abundance and the same range of salinity and temperature (Fig. 1). Each sampling consisted in a combined process of sieving (quadrangular hand nets 40 x 40 cm; 1 mm mesh size) for 15-20 minutes in each pool and releasing 15-20 minnow-traps (30 mm diameter; 1 mm mesh size) uniformly distributed in each pool for roughly 24 hours.

After capture, sex (male, female or immature) and total length (TL, ±1 mm) were recorded *in situ* for each individual, and a maximum of 40 individuals per sampling (total n = 997) were anesthetized with clove oil (García-Gómez *et al.* 2002) and preserved in neutralized formaldehyde solution (10%). Fresh eviscerated weight (EW, ± 0.01 g) of mature individuals was registered by a precision balance (Mettler AJ 100®) to study somatic condition.

The relationships (log transformed data) between TL and EW (dependent variable) were estimated separately for males and females. To avoid the use of negative values, the variables were multiplied by $10^2$, a procedure suitable when variables range from 0 to 1 (García-Berthou & Moreno-Amich, 1993). The somatic condition cycle was indexed by standardized residual values (Kr) from these regressions (Sutton *et al.*, 2000) removing body length effects. An analysis of covariance (ANCOVA) was used to determine differences in TL-EW relationships for males and females.

Bivariate relationships between environmental variables (water temperature and salinity) and residual values using Spearman's correlation indices were also analysed. Statistical analyses were performed with the SPSS software package and a significance level of $p \leq 0.05$ was accepted.

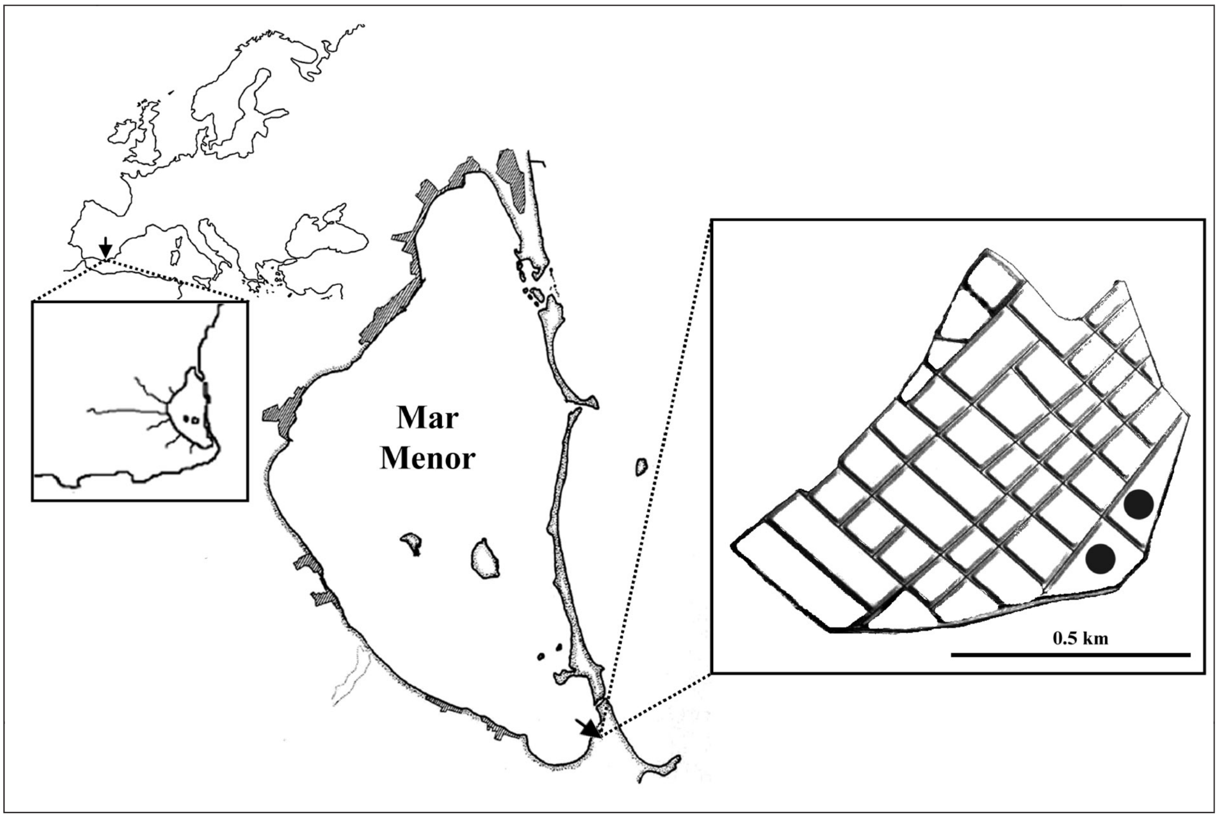


Figure 1. Location of Marchamalo wetland in the south of Mar Menor coastal lagoon and sampling pools (black points).
Figura 1. Localización de las salinas de Marchamalo en el sur de la laguna costera del Mar Menor y localidades de muestreo (puntos negros).

## Results

There were no significant differences between TL-EW relationships of male and female (ANCOVA; $F_{1,993}$ = 0.52, $p$ = 0.471, slope), therefore TL-EW relationship was presented for the whole of mature individuals ($b$ = 3.259, $R^2$ = 0.962) to obtain the standardized residual values (i.e. Somatic Condition Index), which were independent of TL (Pearson's correlation; r = 0.032, $p$ = 0.994).

Residual values were used to analyze the seasonal variation of the somatic condition for both males and females (Table 1, Fig. 2). A similar somatic condition cycle was evident in both sexes (Spearman's correlation of mean values; Rs = 0.724, $p$ < 0.001), although the differentiation of repetitive phases was difficult. Females reached higher average condition than males (Males: Kr = -0.18 ± 0.05; Females: Kr = -0.04 ± 0.06; t-Student = -2.283, $p$ = 0.023).

Minimum Kr values appeared at the end of autumn and winter, increasing during the spring and reaching maxima values in summer. There was observed a sharp and significant drop of this index in samples of beginning of summer 2000 (Table 1 $\mu_5$, $\mu_6$) and in the 17 April 2001 sample (Table 1 $\mu_{16}$).

Somatic condition was similar for the first (May 2000 – May 2001) and the second year of study (May 2001 – May 2002) (Males cycle-1: Kr = -0.17 ± 0.07; Males cycle-2: Kr = -0.20 ± 0.73; t-Student = -0.361, $p$ = 0.718) (Females cycle-1: Kr = -0.07 ± 0.06; Females cycle-2: Kr = 0.02 ± 0.05; t-Student = -0.930, $p$ = 0.353).

A significant correlation was detected between water temperature and somatic condition (Spearman's correlation; Males: Rs = 0.451, $p$ = 0.016; Females: Rs = 0.429, $p$ = 0.023). Temporal variations in water salinity were plotted as normalized values, which stated the significant increases and decreases (Fig. 2). High increases in salinity were directly related to salt extraction management of the wetland, and to the absence of new water inputs. A significant correlation was also observed between salinity and somatic condition in both sexes (Spearman's correlation; Males: Rs = -0.393, $p$ = 0.039; Females: Rs = -0.454, $p$ = 0.015).

## Discussion

To investigate temporal variation in somatic condition, analysis of the length-weight relationship

| **Seasons** | | | | |
|---|---|---|---|---|
| Males | **ANOVA** | **F** | **df** | ***p*** |
| | | 10.076 | 8, 482 | <0.001 |
| | **Tukey's HSD** | | | |
| | Spr00 < Smr00 > Aut00 = Wnt01 = Spr01 < Smr01 = Aut01 = Wnt02 = Spr02 | | | |
| Females | **ANOVA** | **F** | **df** | ***p*** |
| | | 16.148 | 8, 510 | <0.001 |
| | **Tukey's HSD** | | | |
| | Spr00 > Smr00 > Aut00 = Wnt01 = Spr01 < Smr01 = Aut01 = Wnt02 = Spr02 | | | |

| **Samplings** | | | | |
|---|---|---|---|---|
| Males | **ANOVA** | **F** | **df** | ***p*** |
| | | 10.754 | 27, 482 | <0.001 |
| | **Tukey's HSD** | | | |
| | μ1<μ2=μ3=μ4=μ5=μ6<μ7=μ8=μ9>μ10=μ11=μ12=μ13=μ14=μ15=μ16<μ17= μ18=μ19=μ20=μ21=μ22=μ23=μ24>μ25=μ26=μ27=μ28 | | | |
| Females | **ANOVA** | **F** | **df** | ***p*** |
| | | 13.613 | 27, 510 | <0.001 |
| | **Tukey's HSD** | | | |
| | μ1<μ2=μ3=μ4>μ5=μ6<μ7=μ8>μ9=μ10=μ11=μ12=μ13=μ14=μ15>μ16<μ17= μ18=μ19=μ20=μ21=μ22=μ23=μ24=μ25=μ26=μ27=μ28 | | | |

Table 1. Comparison of residual values of TL-EW relationship of *Aphanius iberus* by ANOVA and Tukey's HSD tests ($p \leq 0.05$): F-statistics, degrees of freedom (df) and *p* values. Spr00 = residual mean of Spring 2000, etc. $\mu_1$ = residual mean of the first sampling date, etc.
Tabla 1. Comparación de los residuos de la relación TL-EW de *Aphanius iberus* mediante ANOVA y test de Tukey ($p \leq 0.05$): estadísticos F, grados de libertad (df) y valores de la *p*. Spr00 = media de los residuos correspondiente a la primavera de 2000, etc. $\mu_1$ = media de los residuos correspondiente al primer muestreo, etc.

provided a good alternative method to the ratio-related indices (Sutton *et al.* 2000). Relative weight indices have been criticized on statistical grounds, and residual index has been proposed to separate the effects of condition from the effects of body size (Jakob *et al.* 1996). In fact, the use of residuals from length-weight regression has been used as a successful method with valid results in other fish species (Tomasini *et al*. 1999, Oliva-Paterna *et al*. 2002, Andreu-Soler *et al*. 2003, Verdiell *et al*. 2006, among others).

Somatic condition cycle appeared independent of sex, although condition values of females were higher than for males. An effect of the reproductive cycle on the somatic condition was detected because there was a significant correlation between values of somatic condition and gonadal development (unpublished data).

However, not only reproductive factors influence condition in fish. The annual cycle of the somatic condition reflected seasonality and the index reached its lowest values at the end of autumn and in winter, while maxima appeared in spring and summer. This relationship between somatic condition of *A. iberus* and environmental factors has also been described in other studied populations (García-Berthou & Moreno-Amich 1993, Vargas & De Sostoa 1997, Vila-Gispert & Moreno-Amich 2001), where the maxima summer values of condition have been seen to coincide with higher water temperature, productivity and large number of prey in the environment (Vargas & De Sostoa 1997, Vila-Gispert & Moreno-Amich 2001). In fact, water temperature is one of the environmental factors most correlated to growth traits (Weatherley & Gill 1987, Schreck & Moyle 1990).

Continuous monitoring of our studied population showed how drastic changes in water salinity can cause a sharp decrease in fish condition, specially in females (Fig. 2). Although fish from habitats characterized by a wide range of salinity fluctuations (estuaries, salt marshes, etc.) show ecophysiological adaptations that enable them to tolerate and survive both extreme salinity levels and fluctuations (Nordlie & Haney 1998, Plaut 2000), drastic increases in salinity could cause deleterious effects on important

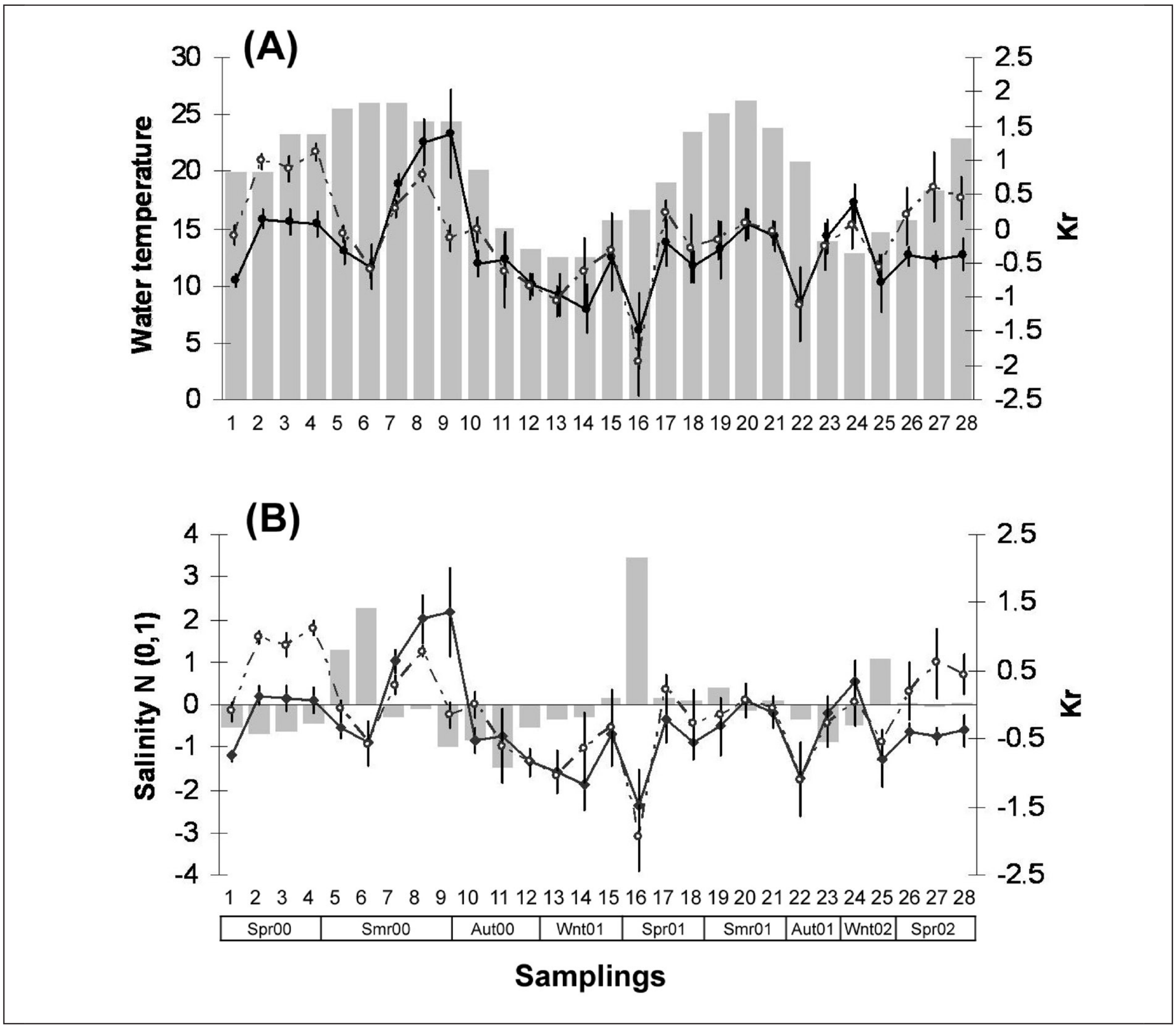


Figure 2. Temporal variation of the somatic condition (solid line, represented as residual values of TL-EW relationship) in males and females of *Aphanius iberus*. In (A) condition is plotted with water temperature; in (B) it is plotted with normalized values of salinity. 95% of confidence limit.

Figura 2. Evolución temporal de la condición somática (línea continua, representada como los valores residuales de la relación TL-EW) en machos y hembras de *Aphanius iberus*. En (A) la condición se dibuja junto a la temperatura del agua; en (B) se dibuja junto a los valores normalizados de la salinidad. Límites de confianza al 95%.

fractions of the populations (e.g. larval stages, young-of-year individuals) (Bohlen 1999) and a decrease in the metabolic rate in the surviving specimens (Boyce 1999, Swanson 1998). In cyprinodontids, the effect of salinity on metabolic rates has been demonstrated in several studies (Jordan *et al.* 1993, Plaut 2000) and Oliva-Paterna *et al.* (2007) have studied its effect on ammonia excretion of *A. iberus*.

Coinciding with the first salinity increase ($\mu_5$,$\mu_6$, Fig. 2), massive mortalities were observed in the studied population (unpublished data). In confined aquatic systems, collateral effects such as the accumulation of ammonia components, increased vulnerability to disease and pathological changes in gill structure, among others (Wilkie 1997), could maximize the falls detected in the temporal pattern of fish condition.

It is known that current threats to habitats and populations of *A. iberus* include the destruction of habitats, water pollution and the introduction of exotic species, mainly *Gambusia holbrooki* (Agassiz 1859), which appears to have displaced *A. iberus* (Rincón *et al.* 2002, Caiola & De Sostoa 2005). In this study, as a first approach, it has also been shown that life-history traits of *A. iberus* populations confined in salt exploitation wetlands, as one of the most important habitats for conservation of the species (Oliva-Paterna *et al.* 2006), is affected by management activities without biological criteria. In particular, the non-input of water could have negative effects on fish condition. These effects should be considered when such populations are subjected to recovery plans or any other management programme.

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