Factors affecting body condition in a great crested newt *Triturus cristatus* population.

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ABSTRACT - Body condition index (BCI) was calculated for 942 individual great crested newts *Triturus cristatus* captured from four ponds 2007 - 2011. Body condition did not vary significantly between ponds. BCI varied significantly between years and seasons but in different ways between the sexes. Males exhibited lowest body condition in March followed by a rise in the period March to May then a fall in June in three out of five years. There was no significant change in female BCI March to April within each year. There was no significant relationship between BCI scores and mean winter minimum air temperature in both sexes. Findings indicate that BCI varies considerably due to a range of factors and that long-term studies are required to determine whether changes in winter climatic conditions significantly affect great crested newt body condition.

INTRODUCTION

The use of Body Condition Index (BCI) scores to assess the physiological state of an individual has been widely applied in many studies of animal populations including amphibians (Cooke & Arnold, 2003; Kopecký et al., 2010), seabirds (Le Bohec et al., 2007; Lormée et al., 2003) and mammals (Schulte-Hostedde et al., 2001). Body Condition Index scores, which are usually based on mass/length regressions, may give an indication of the fat reserves of an animal and reflect its underlying health and susceptibility to disease (Janin et al., 2011). BCI scores may also indicate past foraging success, fighting ability and the capacity to cope with environmental pressures, which may impact on reproductive success (Jakob & Marshall, 1996). In the British Isles, research by Reading (2007) and Griffiths et al., (2010) indicates that populations of common toad *Bufo bufo* and great crested newt *Triturus cristatus* respectively have lower body condition after milder winters. This may be because individuals expend more body fat reserves in higher temperatures due to an increased metabolism (Reading 2007), resulting in increased susceptibility to disease, lower reproductive success and subsequent population decline. The great crested newt is of conservation concern, and may be the fastest declining amphibian within Europe (Griffiths, 2001). Within the British Isles this species is fully protected as part of Schedule 5 of the Wildlife and Countryside Act 1981 and Annexes II and IV of the European Habitat Directive 1992 (English Nature, 2001). Although many population studies have been conducted in this species (e.g. Baker, 1999; Williams, 2000; Jarvis, 2010) few have examined factors affecting body condition indices and how this may impact on population size and recruitment.

This study examined the body condition index scores of adult great crested newts from three breeding ponds over a five-year period from three ponds within Epping Forest, UK. Specific aims were to determine whether BCI scores varied between years, ponds and seasons as well as whether there was a relationship between winter temperatures and BCI scores of adults in the spring.

MATERIALS AND METHODS

Adult *T. cristatus* were captured in funnel traps as described in Griffiths (1985) and Griffiths & Inns (1988) from three ponds within Epping Forest, UK (51° 39’ 47” N, 0° 2’ 35” E) in the period 2007 to 2011. Two of the ponds (Frog and Lily) were 25 m apart whilst the third (Oak Plain) was separated across deciduous woodland by approximately 500 m. All great crested newts captured were taken to an outside work station located by the pond of capture. Snout-vent length (SVL) was measured to the nearest 0.5 mm using callipers. Body mass was recorded to the nearest 0.01 g using digital pocket scales. To record belly markings individuals were placed on a small plastic transparent plate with raised sides and a sponge gently placed over the top to provide a uniform background. A compact digital camera was used to take photographs of belly pattern markings from underneath since each individual has a unique belly pattern marking (Arntzen et al., 1999) which can result in subsequent identification of individuals. Once all measurements and data had been collected all newts were released into the pond of capture.

Data analysis

Body condition index (BCI) scores were calculated using residuals (y) from a Model II regression of mass against SVL after log transformation using the formula: BCI = (Log10 SVL) / (Log10 mass)y (Green, 2001). Male body condition indices were calculated March to June each year 2007 to 2011. Female body condition indices were restricted from March to the end of April each year 2007 to 2011 due to a drop in the incidence of capture later in the breeding season and a lack of data from May to June. Therefore no analysis was conducted for females in May and June of each year. Male and female great crested newts were grouped separately for BCI calculation due to differences in size (Verrell & Halliday, 1985). An unbalanced two-way analysis of variance (ANOVA) was performed using the general linear model (GLM) facility in Minitab to determine whether there was a difference in BCI with year, pond and season, which were treated as fixed factors. Calculations for BCI were made just once (at first capture) for each individual (as identified by belly recognition, Artnzen et al., 1999) to avoid pseudoreplication. Individuals identified as recaptures were not included in analysis. Weather data were collected from an on-site meteorological station. Mean winter (November to February) minimum air temperature was calculated since adults are typically in their terrestrial phase during this period (English Nature, 2001; Baker et al., 2011). Linear regression was used to determine whether there was a relationship between winter temperature and the BCI of males and females the following spring.

RESULTS

Differences in body condition between ponds

A total of 942 individual adults (540 male, 402 female) were captured in the period 2007 to 2011 from three ponds. Neither male nor female body condition varied significantly between ponds.

Differences in body condition between years

Adult male *T. cristatus* showed significant variation in Body Condition Index scores between years (Fig. 1) ($F_{4,540} = 6.61$, $P < 0.0001$). Post hoc ANOVA revealed a significant difference in BCI scores between the years 2007 to 2009 ($F_{2,488} = 73.78$, $P < 0.0001$) but not between 2009 and 2011 ($F_{2,181} = 2.00$, $P = 0.19$). Mean BCI scores were significantly lower in 2007 at 2.06, compared to a range of 2.78 to 3.74 in the period 2008 to 2009. BCI scores were highest in 2008 at 3.74.

Body Condition Index scores were significantly different across years in females (Fig. 2) ($F_{4,402} = 19.52$, $P < 0.0001$). Post hoc ANOVA revealed a highly significant difference in BCI scores between 2007 and 2008 ($F_{1,171} = 27.68$, $P < 0.0001$) as well as in the period 2008 to 2011 ($F_{3,355} = 10.31$, $P < 0.0001$). The pattern of BCI scores was different to that exhibited by males. The highest mean BCI score was in 2007 at 4.71, the opposite for that shown by males. Females in the period 2008 to 2011 had more consistent mean BCI scores ranging from 2.31 to 2.94. The lowest BCI score was in 2011 at just 2.31, after a cold and relatively dry winter. Body condition appeared to decline through the study period 2007 to 2011. It was not possible to determine whether this was a temporary trend.

Differences in body condition between seasons

Within each year, male body condition varied significantly between months (Fig. 1) ($F_{3,540} = 5.36$, $P = 0.01$). Mean BCI scores increased through the months March to May 2007 to 2009. This pattern was not as evident in the remaining years 2010 and 2011. BCI scores also fell in June 2008, 2009 and 2011 but not the remaining years. These results show that BCI is highly variable between months but overall appears to show an increasing trend through the breeding season, often with a fall in June. There was no significant variation in female BCI March to late April (Fig. 2).

Interaction effects of pond, year and season

Male BCI scores showed significant interaction between year and season ($F_{12,540} = 2.65$, $P = 0.002$) and year and pond ($F_{8,540} = 2.25$, $P = 0.02$), indicating that both seasonal and pond variation depend on year. There was no significant interaction between pond and season ($F_{6,540} = 2.00$, $P = 0.06$). Due to lack of data in some months, a combined interaction of pond, year and season could not be performed.

Female BCI scores showed a similar pattern to that shown by males with significant interactions between year and season ($F_{4,402} = 2.90$, $P = 0.02$) but not pond and season ($F_{2,402} = 1.40$, $P = 0.25$). This also suggests that seasonal variation depends on year. Due to lack of data, a combined interaction of pond and year, along with year, pond and season could not be performed.

Effects of winter temperature

There was no significant relationship between mean winter temperature each year and mean male or female body condition index scores the following spring. Therefore body condition in spring was not affected by winter temperature over the five year duration of the study.

DISCUSSION

Results from this five year study show that neither male nor female *T. cristatus* showed a significant difference in body condition between ponds. Previous studies on the common toad *B. bufo* have demonstrated that body condition indices vary between sites (Sztatecsay & Schabetsberger, 2006; Reading, 2010). However these studies were conducted at sites separated by a larger spatial scale than the ponds in this study. The ponds in the study area of this study were all within 500 m of each other such that microhabitat conditions such as light, temperature and vegetation cover, which may impact on feeding and therefore body condition, were very similar and not great enough to cause significant variations in BCI scores at breeding ponds.

Both males and females showed significant differences in Body Condition Index scores between years with significant interaction between both years and seasons. However, only males showed a significant variation in BCI between seasons. The pattern of BCI scores across years was considerably different for each sex. Males had the lowest BCI in 2007, before scores rose in 2008 and levelled off in the period 2009 to 2011. In contrast, females had the highest BCI scores in 2007, followed by a drop in BCI

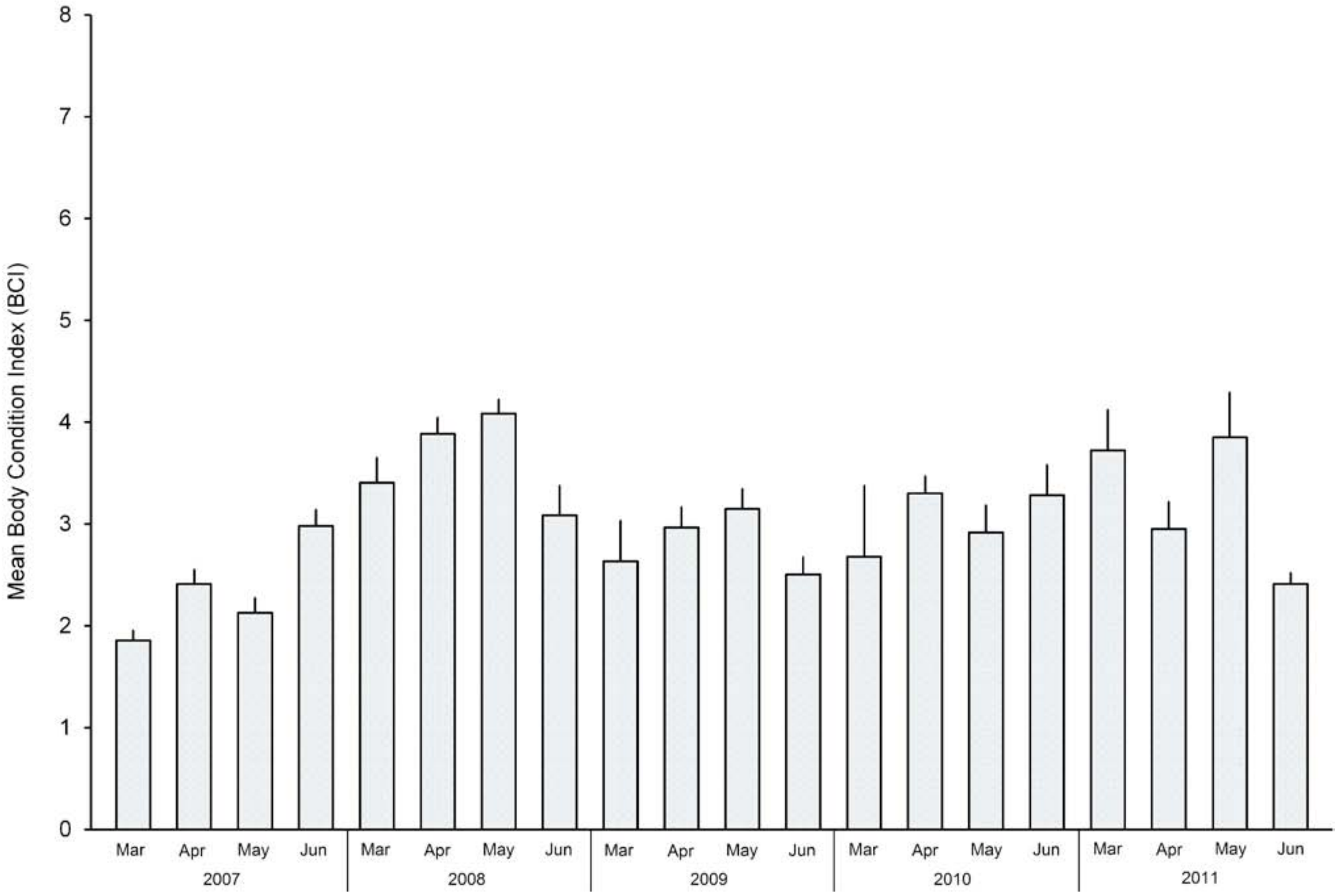

Figure 1. Mean Body Condition Index (BCI) of adult males March to June, 2007 - 2011. Error bars denote standard error.

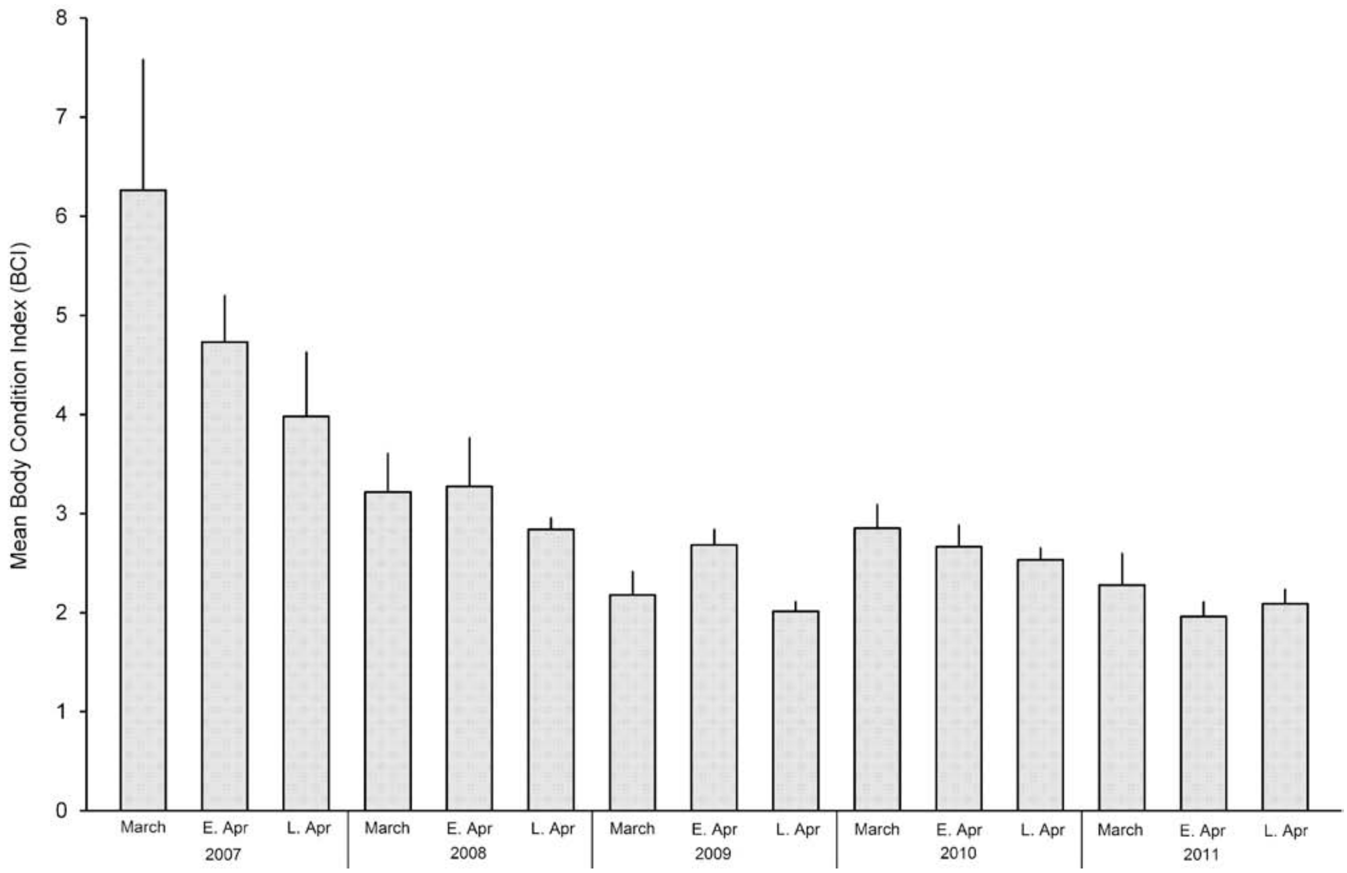

Figure 2. Mean Body Condition Index (BCI) of adult females March to April, 2007 - 2011. Error bars denote standard error. Mar = March; E. Apr = Early April; L. Apr = Late April.

scores through the rest of the study period. The reasons for the observed differences in BCI between the sexes may be because BCI scores are likely to indicate fecundity in females and fat reserves in males. Individuals from different sexes are likely to be differentially affected by variations in biotic and abiotic factors in different years at breeding and overwintering habitats. In addition males and females exhibit different microhabitat utilisation in aquatic and terrestrial habitats, which may affect acquisition of fat reserves or development of eggs in males and females respectively. Therefore the differences in patterns of BCI in males and females may be due to differences in the way the sexes allocated food resources and fat reserves.

Other studies on amphibians have shown that BCI scores vary over time (Arntzen et al., 1999; Wheeler et al., 2003; Băncilă et al., 2010) but few have documented differences in sexes between years. Griffiths & Mylotte (1987) state that male *T. cristatus* probably do not feed on the way to breeding ponds, however they do appear to take prey on arrival at the aquatic environment (Griffiths & Mylotte, 1988). Griffiths (1986) recorded differences in prey captured by different co-habiting newt species but not between male and female great crested newts. Further research specifically examining how biotic factors affect BCI scores is required before more definite conclusions can be drawn.

Male, but not female, *T. cristatus* exhibited a significant change in body condition between seasons. Males showed low body condition at the start of the season in the period 2007 to 2009, followed by a rise until May within each of these years. Body condition declined in June in three of the five study years. This trend appears contrary to that found by Arntzen et al. (1999) and Sinsch (2003) who both found that great crested newts had highest BCI scores at the start of the year and declined as the breeding season progressed. Similarly, Băncilă et al., (2010) noted that yellow-bellied toads had highest body condition index scores in spring and lowest in the autumn. However, Verrell (1986) observed a decrease in body fat content in smooth newts *Lissotriton vulgaris* over the winter period. The reason why males had low BCI scores at the start of the season in this study may reflect specific microhabitat conditions in terrestrial habitats or differences in timings in emerging from hibernation and first breeding. Once males enter water, an increase in hydration may alter body mass and condition. Therefore BCI scores may very seasonally due to differences in hydration levels of individuals. Males in this study exhibited a drop in BCI score in June in three years. Arntzen et al., (1999) state that this is due to high energy expenditure during the aquatic reproductive phase which lowers mass and therefore body condition.

There was no significant difference in female BCI across March to late April. A high BCI score at the start of the season would be expected in females due to individuals holding large numbers of eggs (Halliday & Tejedo, 1995). These will be lost through the breeding season, resulting in a drop of BCI score. However a drop in BCI across the breeding season was not observed in this population, perhaps due to analysis being restricted to the early and mid-parts of the breeding season (March to April). Further data across over a longer seasonal time period are required to determine whether BCI in females changes with season in this population.

The effects of winter temperature revealed non-significant trends in both males and females. Therefore further data are required to ascertain whether trends become significant over a longer time period. The results from this research highlight that long-term studies over more than five years are required before significant inferences can be drawn from climatic data and its influence on body condition and survival.

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