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Research Article

A five-year cycle of coypu abundance in a remnant wetland: a case of sink population collapse?

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Abstract

In this work, we report a five-year study (2008–2013) of a coypu sub-population in a Mediterranean remnant wetland. Using a standardized transect, irregular inter-annual and seasonal patterns in mean abundance were observed over the five year period. A first phase of demographic explosion in autumn-winter 2008 was followed from 2009 to 2011 by a yearly-based hump-shaped pattern, with a progressive increase from winter to summer and a decline in abundance from late summer to winter. In 2013, a population crash was observed, with individuals being detected only occasionally. In 2010–2011, pattern in mean abundance was significantly correlated to pattern in minimum daily temperatures. Finally, in February 2012 a single event of snow with low temperatures probably contribute to the local population collapse. The correspondence between a strong isolated meteorological event (snow and sleet) and the disappearance of clear seasonal hump-shaped patterns followed by a population collapse suggests that this single climatic phenomenon played a role in strongly reducing coypu numbers. Our data may corroborate the hypothesis that extrinsic environmental stochasticity and intrinsic physiological sensitivity to cold weather may be important factors affecting coypu population dynamics. We hypothesize that this peripheral population may be a sink of a larger meta-population at regional scale. Our data may also have implications for wildlife management. In fact, at least for peripheral sub-populations, control/eradication plans should also take into consideration uncertainty deriving from stochastic events, which, disrupting local demography, may affect control success. In this regard, knowledge of spatial structure of coypu sub-populations may be important to devise appropriate strategies of population control.

Introduction

Coypu (*Myocastor coypus* Molina, 1782), an invasive semi-aquatic rodent introduced to North America as well as in several European countries as a domestic furbearer, is now widely diffused also in Italy (Bertolino and Genovesi, 2007). This species occurs mainly in plain landscapes with the presence of wet habitats. Since generally these habitat types have a patchy distribution in Mediterranean landscapes, coypu is usually spatially distributed with a meta-population structure (*sensu* Hanski, 1998). In this sense, an effective migration among coypu subpopulations with colonization dynamics and local extinctions, have already been documented (e.g. Callahan et al., 2005) and modelled (Reeves and Usher, 1989; Schippers at al., 1996).

In meta-population systems, the most important factors explaining the animal density in a single habitat patch are resource availability, extrinsic environmental factors (e.g., local climate), and extinction-colonization patterns among subpopulations. All these factors are capable of inducing change in demographic parameters (Hanski, 1998). Despite in the Mediterranean region coypu became invasive since its first introduction during the first half of 20th century (Reggiani et al., 1995; Cocchi and Riga, 2008), data on coypu seasonal and annual density and dynamics of subpopulations in this area are rare, covering a small time span (1-3 years: e.g. Doncaster and Micol, 1989; Guichón and Cassini, 2005), and are not carried out following a meta-population approach.

Along the Tyrrhenian coast of central Italy, coypu distribution is patchy at regional scale with large populations in wide land reclaimed plains (e.g. Tiber valley) and peripheral populations (*sensu* Rapoport, 1982; Hanski, 1982) inhabiting smaller river basins (for the area surrounding Rome, see Amori et al., 2009).

In a protected remnant wetland of Tyrrhenian Central Italy, the Local Administration (Province of Rome) has developed a pilot study (*sensu* Sutherland, 2004) since 2008 focused on the coypu population status and trend aimed to develop a control program in this area of conservation concern (Marini et al., 2011). The project is still ongoing and the continuous data collection on coypu density allows analysing multi-year patterns, also in relation to a set of meteorological variables. This data sampling allowed us to estimate coypu density over a relatively long time span.

In this work we reported the pattern of population abundance of a coypu sub-population on a 5-year time span that shown an apparent cycle of demographic explosion, stabilization and collapse. We tested the effects of a set of weather parameters on coypu abundance and discussed our results in relation to a spatial population approach (e.g. Bjørnstad et al., 1999).

Materials and methods

The study area is located inside the "Palude di Torre Flavia" Natural Monument (hereafter named, TFNM), in Central Italy (41°58′ N; 12°3′ E).This is a protected wetland on the Tyrrhenian coast (size-area: 40 ha), designated as a Special Protection Area, according to the EU Directive 79/409 (Code IT6030020). TFNM is the remnant of a larger wetland which, in the second half of the 20th century, was drained and converted into an agricultural and urbanized landscape. It shows semi-natural patchiness with ponds and channels (28 channel traits for approximately 2055 m/10 ha), reed beds (*Phragmites australis* with

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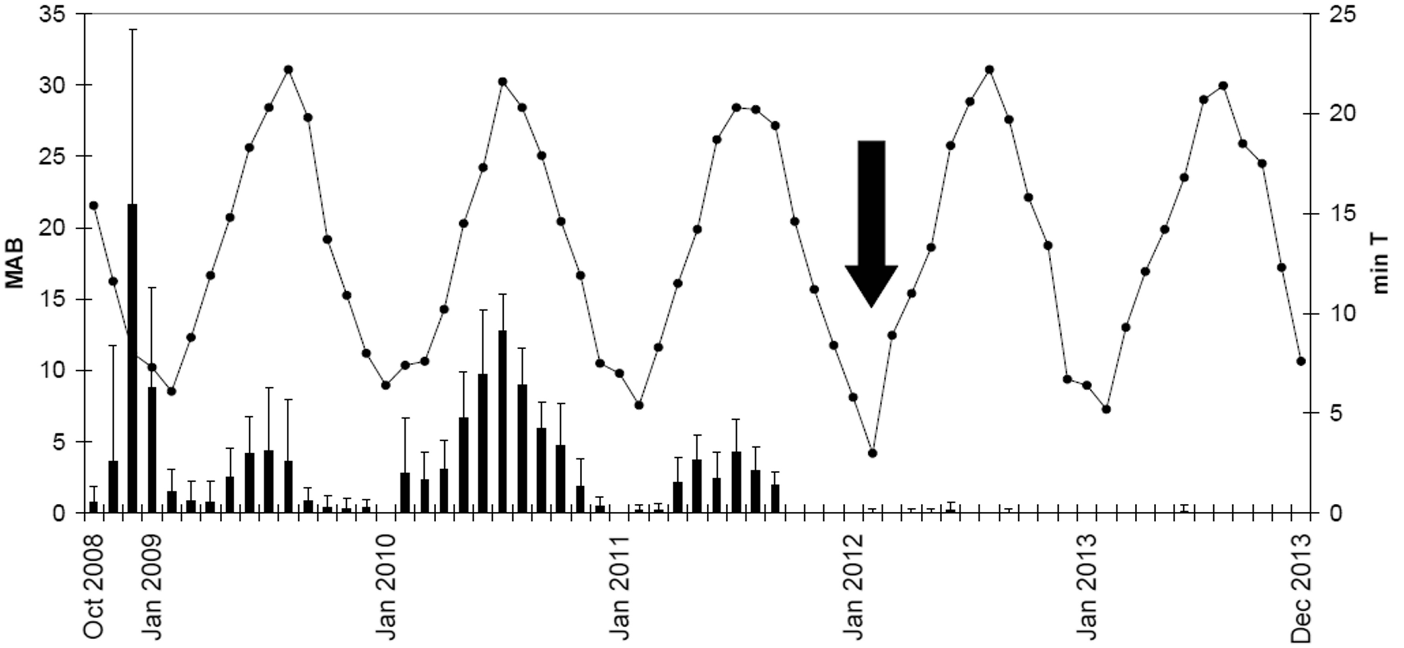

Figure 1 – Five-year pattern (October 2008-December 2013) in MAB (monthly mean coypu abundance and their standard deviation, s.d.: histograms) and in minimum temperatures (min T; continuous line). Black arrow corresponds to the single meteorological event.

rare occurrences of *Calystegia sepium* and *Sambucus nigra*), flooded meadows, dune and backdune areas, patches of *Carex hirta*, *Juncus acutus*, *Bolboschoenus maritimus* and Cyperaceae (*Juncetalia maritime*, 1410 EU Directive habitat type), Mediterranean salt meadows (*Sarcocornetea fruticosi* 1420 EU Directive habitat type), environment back dunes (embryonic shifting dunes, 2110 EU Directive habitat type) and annual vegetation of drift lines (1210 EU Directive habitat type). TFNM is intensely managed for fish farming in a network of channels (approximately 2000 m long, see above) developing mainly in a *Phragmites* reed bed core area. These channels have been artificially built in the first half of the 20th century for fish farming activity. The water supply comes largely from rainfall (meso-mediterranean xeric region characterized by hot summer with an aridity period and cold winter; Blasi, 1994), while flow from surrounding areas is scarce.

Water level is variable according to location and time of year, with an evident water stress induced by fishery farm activity in late spring–late summer (Causarano and Battisti, 2009; Battisti et al., 2008).

Coypu presence has been documented in this area since 2004 (Battisti, 2006) and some studies have been carried out on seasonal abundance (Marini et al., 2011), diet (Marini et al., 2013) and coypu impact on biodiversity (Amori and Battisti, 2008; Battisti et al., 2008; Angelici et al., 2012).

To estimate coypu relative abundance, individual coypu were counted directly along a standardized perimeter transect. This transect is representative of the whole study area, extending for about 2000 m from the southern (Ladispoli) to the northern side (Campo di mare –- Cerveteri), and encompassing all habitat types. From October 2008 to December 2013, a large number of replicated sessions along the transect were carried out (1140 sampling sessions; 18.1 sessions/month; range: 5–24). In each session, we sampled the total number of individual sighted by means of a 10×50 binocular inside a 100 m wide main belt, along a single side of the transect.

The maximum number of individual coypu observed along the transect were then grouped in monthly periods and an average monthly index of local abundance (MAB: mean abundance) was calculate, obtaining a multi-annual pattern of abundance.

From the meteorological station very close to the study site (Cerveteri, Ladispoli), we obtained the local values of minimum, medium and higher daily temperatures, humidity and rainy (in mm, Ufficio Idrografico e Mareografico della Regione Lazio; http://www.idrografico.roma.it/default.aspx). Since the minimum temperature (min T) was highly correlated to mean and maximum temperatures (both r_s=1, p=0), we used only min T, averaging their values monthly, and correlating them to monthly MAB.

The patterns of MAB (mean monthly coypu abundance) was modelled using Generalized Linear Models (McCullagh and Nelder, 1989). We built one model selecting as dependent variables the logarithm of MAB recorded in the years 2009–2013 (normal distribution and identity function; we excluded year 2008 – consisting in observation ranging from October to December – from the analysis in order to allow a whole inter-season comparison) as dependent variable. The season (nominal variable) and the year (ordinal variable) were included in the model as factors (categorical predictors), and min T, air humidity, and rainfall as covariates (continuous predictors); the model design included the main effects for each variable, and the 2-way interaction between the factors (fractional factorial design, McCullagh and Nelder, 1989). We also used univariate tests for comparing MAB values among months by performing the non parametric Kruskal-Wallis test (Dytham, 2010).

We set alpha level to 0.05, using the SPSS 13.0 software for Windows (SPSS, 2003). We followed the requisites requested for reliable data reported in Battisti et al. (2014).

Results

Overall, we obtained 2272 records of coypu during 1140 sampling sessions.

On a larger time scale (2008–2013) we observed a first phase of demographic explosion (higher MAB: autumn-winter 2008), followed by two years of stabilization (2009–2011) and a consequent collapse (2012–2013; see Fig. 1). In detail, from February 2009, we observed a yearly based hump-shaped pattern, with a progressive increase in MAB from winter to summer, and a decline from late summer to winter with significant changes among months (2009: χ^2=55.9; 2010: χ^2=156.2; 2011: χ^2=132.9, p<0.01, Kruskal Wallis test).

The MAB significantly varied among seasons and along the years with a clear effect of the interaction term YEAR*SEASON on the considered variable (Tab. 1 and Fig. 2). MAB showed a minimum in winter with a gradual increase through spring until reaching a peak in summer (Fig. 2a). During the five years of observations, coypu MAB showed an abrupt decrease after 2010 (Fig. 2b). The interaction term showed that coypu abundance started to collapse at the end of 2012 (winter) when no coypu was observed in the study site. The minimum temperature (average monthly values) strongly influenced MAB with a positive relationship (Tab. 1). Air humidity and rainfall did not show any effect on coypu abundance. As for the seasonal distribution of the monthly MAB within a given year, a hump-shaped pattern is evident in 2009 (excluding January), 2010 and 2011. From 2010 to 2011, MAB patterns showed a progressive decline in their modal values until 2012 and 2013, when we documented a collapse by observing few individuals occasionally.

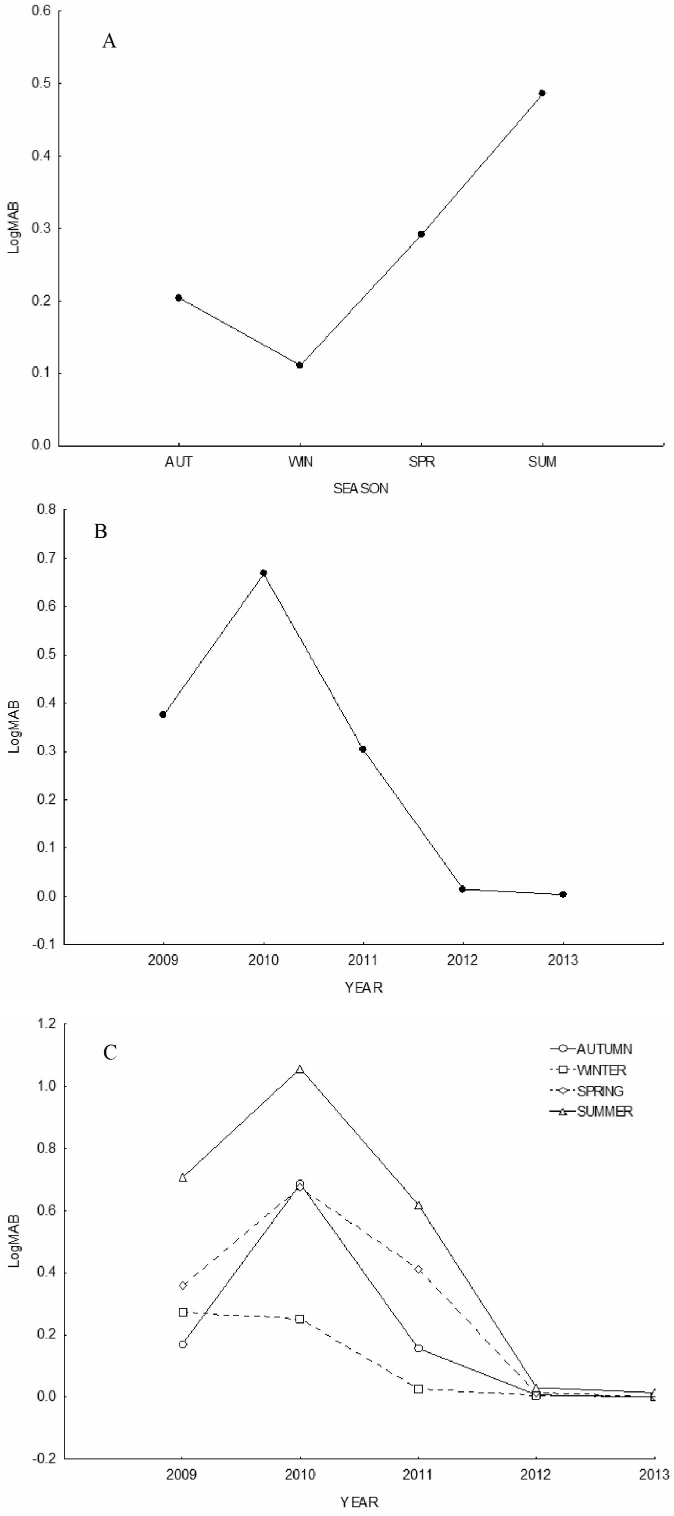

Figure 2 – Significant effects of SEASON (A), YEAR (B), and the interaction term SEASON*YEAR (C) on MAB (log transformed). For Wald statistics and statistical significance of each effect refer to the Generalized Linear Model results shown in Tab. 1.

Discussion

During the five-year period, irregular inter- and intra-annual MAB patterns of coypu subpopulation were observed. Following a phase of occasional presence documented in local literature (first individuals observed in 2004; Battisti, 2006), from autumn 2008, a colonization phase, characterized by a sudden increase in abundance, was observed. Then, starting from spring 2009 until 2011, three periodic hump-shaped yearly patterns of coypu abundance were registered, likely corresponding to the phase of stabilization. This phase was characterized by strong inter-and intra-annual oscillations (higher MAB values in 2010, lower in 2011 and higher values in summer when compared to winter). Finally, in 2012 and 2013, only a few coypu were occasionally observed, no longer distributed in a clear seasonal pattern.

We found an overall and significant correlation between MAB and min T. The lowest min T (<5 °C) was recorded in February 2012. In this month, presence of unbroken ice sheets on water surface, which prevent coypus from getting into the water, and the lack of thick vegetative cover above ground, contributed to exacerbate the impact of cold events on the species.

Our findings on this issue are consistent with the relationship between temperature and coypu abundance reported in literature (Doncaster and Micol, 1990). Other factors, such as humidity and rain, apparently did not affect MAB.

Moreover, the correspondence between a strong isolated meteorological event (wetland waters froze during a snowing event in February 2012: local min T about 0 °C; personal observation) and the disappearance of a clear hump-shaped patterns due to a consequent collapse suggests that this stochastic event could, at least partially, have played a role in the observed demographic variation. Probably this factor acted on a population yet declining for other undetected causes. However, while in the years before 2012 (2008–2010), the population showed a yearly decline in winter followed by a recovery from spring to summer, after the winter 2012 no population recovery was observed.

Density-independent environmental stochasticity (e.g. weather factors) may be an important factor affecting population dynamics in mammals (e.g. Post and Stenseth, 1998; Sibly et al., 2005; Saether, 1997), changing their dispersal and population growth (Usher, 1986), especially in small populations (Caughley, 1994). As for coypu, it has been suggested that its density is strictly related to the absence of severe winters as well as to resource availability (Reggiani et al., 1995; Carter and Leonard, 2002). Therefore, physiological sensitivity to cold weather could act as a strong selective factor, since in cold winter climate, when temperatures are below freezing for several days, coypu density decreases by increasing reproductive failure, abortion, and juvenile mortality (Doncaster and Micol, 1989, 1990; for Mediterranean region: Velatta and Ragni, 1991; Reggiani et al., 1995; Bertolino et al., 2005).

This response to climatic conditions (and to other stochastic events) may not be universal. For example, when a population is organized as meta-population, the effects of a cold winter may be limited or absent, at least in central sub-populations where the effects of local meteorological events may be counterbalanced by a higher birth rate and dispersal from other sub-populations (Doncaster and Micol, 1990; Bertolino et

Table 1 – Synopsis of the Generalized Linear Model (fractional factorial design) results, showing which parameter (including the between effects) significantly influence the MAB in the study species at the study area. MIN T: mean minimum monthly air temperature. Significant effects are in bold.

Variables	Degrees of freedom	Wald statistic	*p*
Intercept	1	0.923	0.337
MIN T	**1**	**7.956**	**0.005**
HUMIDITY	1	0.712	0.399
RAINFALL	1	0.866	0.352
SEASON	**3**	**22.303**	**0.00006**
YEAR	**4**	**183.067**	**0**
SEASON*YEAR	**12**	**80.869**	0

al., 2005; Panzacchi et al., 2007; Cocchi and Riga, 2008). Since we observed an evident demographic collapse after the cold event in winter 2012 not followed by a prompt population recovery, we hypothesize that our peripheral population may be a sink (Pulliam, 1988; Gosselin, 1996; Dias, 1996) of a larger meta-population diffused on regional scale (i.e., corresponding to the large Tiber river valley). This sink may be only occasionally interested by the occurrence of immigrant individuals that use this habitat patch more as a temporary trophic area (due the great cover of *Juncetalia maritimi* rush-beds and others palatable plants; Marini et al., 2013), than as a reproductive site (Aliev, 1973).

The interpretation of our data based on a multi-annual cycle of a coypu subpopulation inhabiting a remnant wetland allowed us to postulate an *a posteriori* hypothesis that should be tested in further research (inductive approach; Romesburg, 1981; Guthery, 2007), that is: single winter meteorological events (i.e. severe temperature, snow cover, frozen water surface) may contribute to induce collapses of peripheral sub-populations on a large temporal scale.

Although the long-term analysis conducted on a Mediterranean coypu population represents a key factor of our study, our data were based on observational data and the only demographic parameter used was a population trend index. Although this index may be useful to detect demographic patterns at coarse-grain temporal scale, we think that its predictive power to detect more fine-grained patterns, e.g. seasonally referred, may be very limited since the monthly variation could reflect more the activity of the animals (or their detectability across vegetation) then real variation in population density at monthly scale. Therefore, since in this case data on population dynamics may be biased (Gibbs, 2000; Meier and Fagan, 2000), and other more fine-grained parameters at single and regional population level (for example, juvenile individual density, reproductive failure, mortality rates, and adult survival) are needed to support our hypothesis.

Implications for management

At least for peripheral sub-populations, management plans should also take into consideration the uncertainty deriving from stochastic events. Indeed, such events, given their disruptive effects on local demography, may facilitate control and eradication actions Therefore, assessing the status of a coypu sub-population following a dynamic meta-population approach and checking the role of stochastic events is determinant to define the type and regime of actions in an eradication program and to determine the priority of sub-populations on which control should be concentrated.

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