Title

Breeding ecology of the Andalusian Buttonquail *Turnix sylvaticus sylvaticus*

Titre

Ecologie de reproduction du Turnix d'Andalousie *Turnix sylvaticus sylvaticus*

Authors

Carlos Gutiérrez-Expósito[1]*, Ruth García-Gorria[2], Abdeljebbar Qninba[3], Miguel Clavero[1], Eloy Revilla[1]

1. Departamento de Biología de la Conservación, Estación Biológica de Doñana CSIC. Calle Americo Vespucio 26, 41092, Isla de la Cartuja, Sevilla (Spain).
2. Ibn Khaldoun 1, El Jadida (Morocco).
3. Laboratoire de Géo-Biodiversité et Patrimoine Naturel (GEOBIO), Institut Scientifique, Mohammed V University in Rabat, Avenue Ibn Battouta, BP 703, 10090, Agdal, Rabat (Maroc).

ORCID and email list

Carlos Gutiérrez-Expósito (0000-0002-2907-7998) carlines@ebd.csic.es
Tel. 0034 954466700 ext. 1464
Ruth Garcia-Gorria ruthbagane@hotmail.com
Abdeljebbar Qninba (0000-0002-7572-7867) qninba@israbat.ac.ma
Miguel Clavero (0000-0002-5186-0153) miguel.clavero@ebd.csic.es
Eloy Revilla (0000-0001-5534-5581) revilla@ebd.csic.es

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Abstract

Understanding the breeding cycle of wildlife is essential to afford conservation strategies. This is especially important for barely studied species and urgent for those at serious risk of extinction. The Andalusian Buttonquail is an endangered endemic of the Western Mediterranean, confined to a cultivated strip in the Moroccan Atlantic coast. We performed 2302 sampling events to determine the presence-absence and breeding of the species. Breeding season lasted for 8 months, from February to October. Present in 17 different crops, breeding occurred in all but cucumber and artichoke. However, a strong preference for breeding crops was found for alfalfa, pumpkin and maize fields. Nests were 82 mm x 71.4 mm grass-lined structures built on a ground scrape. Eggs had 26.14 mm mean maximum length, 20.24 mean diameter and weighed 5.9 g. All complete clutches had 4 eggs and the hatching rate was 3.42. All but one of the monitored nests successfully reared at least one chick. Clutch size and hatching rate matched other Buttonquail populations and species, so causes of the decline must be found in other stages of the reproductive cycle. In this sense, additional studies are needed to reveal chick and juvenile survival.

Résumé

Comprendre le cycle de reproduction de la faune sauvage est essentiel pour pouvoir élaborer des stratégies de conservation. Ceci est particulièrement important dans le cas des espèces très peu étudiées et primordial pour celles au bord de l’extinction. Le Turnix d’Andalousie est une espèce endémique de la région ouest-méditerranéenne, très menacée et cantonnée dans une bande de terrains cultivés le long de la côte atlantique marocaine. Nous avons réalisé 2302 relevés pour déterminer la présence-absence ainsi que la reproduction de l’espèce. La saison de reproduction a duré 8 mois, de février à octobre. Présente dans 17 cultures différentes, le Turnix a nidifié au sein de tous ces cultures sauf au niveau de deux types, le concombre et l’artichaut. Cependant, une forte préférence a été observée pour la nidification dans les

champs de luzerne, de courge et de maïs. Les nids, bordés d’herbes, mesuraient 82 mm x 71,4 mm et étaient construits dans des cuvettes creusées dans le sol. Les œufs mesuraient en moyenne 26,14 mm de longueur maximale, 20,24 de diamètre et pesaient 5,9 g. Toutes les pontes complètes étaient de 4 œufs et le taux d’éclosion était de 3,42. Tous les nids contrôlés, sauf un, ont fourni au moins un poussin. La grandeur de ponte et le taux d’éclosion correspondant à ceux d’autres populations de Turnix, les causes de déclin de l’espèce devraient se trouver dans d’autres étapes de son cycle de vie. En ce sens, des études supplémentaires sont nécessaires pour préciser la survie des poussins et des juvéniles.

Introduction

The design of most wildlife conservation policies and management projects are based on demographic and habitat selection studies (Sanderson et al. 2002, Franco and Sutherland 2014). However, very often this approach is not enough for understanding the observed demographic changes and detecting which factors are affecting breeding success (Norment 2010). In this sense, knowledge of aspects of the breeding biology of a given population (i.e. sex-ratio, clutch rate, clutch size, nest success, productivity and chick survival) are essential to a proper link between the conservation needs and efforts (Newton 2004).

Buttonquails (Turnicidae) are small ground-nesting birds with a wide distribution in the Old World and are among the few bird species in which breeding roles are reversed. Females sing to attract males and have the initiative during the mating period and nest building, leave all incubation and chick rearing responsibilities exclusively to males (Debus 1996, Madge and McGowan 2002).

Due to the unobtrusive behaviour of all buttonquail species, studies on their natural history, biology and ecology are mainly obtained from observations on captive birds. Most of this knowledge is derived from historic papers (i.e. Hauth 1890, Langheinz 1891, Seth-Smith, 1907) or old studies on captive rearing (i.e. Phipps 1976, Trollope 1967, Lendon 1956). A few modern studies exist on caged birds (i.e. Lees and Smith 1998, Barnicoat 2008, Muck and Goymann 2011). Within this limited bibliographic knowledge, field based studies on the breeding biology of buttonquails are reduced to a handful of notes, including a couple of historic notes on the Red-backed Buttonquail *Turnix maculosus* (North 1891) and Buff-breasted Buttonquail *Turnix olivii* (White 1922). More recently Balatsky et al. (2014) and Nechaev (2005) focused on the Yellow-legged Buttonquail *Turnix tanki* in Primorie (Russia). The Black-rumped buttonquail *Turnix nanus* (Christian 2006) and the Hottentot buttonquail *Turnix hottentottus* (Ryan and Hockey 1995, Lee et al. 2019) have been studied in South Africa and with several studies from Queensland (Australia) on the near threatened Black-breasted

Buttonquail *Turnix melanogaster* (Smyth and Young 1996, Lees and Smith 1999, Macconell and Hobson 1995, Smith et al 1998).

The Common Buttonquail *Turnix sylvaticus* is the most widespread buttonquail species. Up to nine subspecies are described for this species, whose distribution extends from the Western Palearctic and sub-Saharan Africa, through the Middle East and south Asia to Java and the Philippines (Gutiérrez-Expósito et al. 2011). In spite of the extent of its range, it is almost as unknown as all other species in the family. Its breeding biology has been mainly described in captivity (i.e. Niethammer 1961, Bell and Bruning 1974, Flieg 1973) and has been barely studied in the field (i.e. Wintle 1975, Engelbrecht 2014) It is often referred to as the Kurrichane Buttonquail (*T. s. lepuranus*), its most abundant and widespread subspecies (Gutiérrez-Expósito et al 2011). The nominate subspecies, the Andalusian Buttonquail, (*T. s. sylvaticus*) is a highly endangered taxon endemic to the Western Palearctic, which has not been scientifically studied until recent times (Pertoldi et al. 2006, Gutiérrez-Expósito et al. 2019). Here, we present the first data on the breeding phenology, nesting habitat selection, nest structure, clutch size, egg dimensions and breeding success of the Andalusian Buttonquail. This information needs to be readily available in order to develop actions for the conservation of this critically endangered taxon.

Methods

The study area covers all the known distribution range of the Andalusian Buttonquail (Gutiérrez-Expósito et al. 2019), which consists of a cultivated strip of 4650 ha that runs along the Atlantic Moroccan coast between Sidi Abed (El Jadida province) (33.046 N, 8.688 W) and Cap Bedouzza (Safi province) (32.571 N, 9.243 W). The area is very intensively cultivated with a very fast crop rotation through the seasons, with up to four different crops growing in a single field through the annual cycle. Surveys in this area used the cultivated field as a sampling unit and aimed at detecting the occupancy and breeding events of buttonquails. We considered a sampling event every time a given field was surveyed in search of buttonquails. A single sampling event was made to each field in each season. Surveys consisted of scanning the walkable area within cultivated fields by at least one observer in search of indirect signs of presence, mainly faeces, but also, occasionally, tracks, feathers and direct detection by sight or hearing (Gutiérrez-Expósito et al. 2019). Between June 2009 and September 2017, we performed 2302 sampling events. Events were distributed throughout the year but with higher frequency around mid-June when maximum breeding activity was expected, following reports by local farmers (Table 1). For every sampling event, the presence or absence of buttonquails and the presence or absence of breeding activity was noted. We considered that buttonquails were present in a field when any kind of sign of presence was found, otherwise noting an absence. Our sampling systems has been proven to be very effective, so negligible false negatives are considered to occur in our data (Gutiérrez-Expósito et al. 2019). Breeding activity was considered to occur when we detected singing females, males with broods or nests (Figure 1).

We analysed the presence of breeding activity as a function of the phenology and traits associated with the positive surveyed fields. All sampling events were classified by season, month and into two-month classes: mid-winter (December-January), late-winter (February-March), spring (April-May), early-summer (June-July), late-summer (August-September) and autumn (October-November). As habitat predictors we calculated the area (m^2) of the fields and its perimeter with QGIS 2.18 (QGIS Development Team 2018), the crop mean height (cm) as well as its phenological stage as 0 bare land, 1 recently planted crops, 2 growing plants, 3 flowering, 4 harvest and 5 abandonment. Breeding habitat use statistical analyses were done over the 157 positive field sampling events made in early Summer (June-July) when most of the sampling effort has been done, in which field area, perimeter and mean coverage and vegetation height have been measured. Log transformation was used for area, perimeter and height. The effect of predictors was analysed by means of generalized linear mixed models (binomial distribution with a logit link) with the *lme4* package of the *R* computing environment (R Core Team 2017, Bates et al. 2015), using the field id as random factor. Crop occupancy preferences and breeding crop selection were described with Ivlev's electivity index, as modified by Jacobs (1974). The index measures avoidance or positive selection, ranking from 1 (total selection) to -1 (total avoidance) and was calculated for crop types with at least 50 sampling events. We calculated electivity for presence in all sampling events while for breeding we used the subset of sampling events with presence.

Nests were found opportunistically along with visits to the area between 2009 and 2019. The description of nests was based on its length, with and depth measurements (mm) and presence/absence of upper grass cover (Figure 1). Clutch size was noted and, when possible, eggs were weighted (0.1 g precision scale) and measured for maximum length and diameter (1 mm precision). Subsequent visits were performed to determine the fate of the nests and the number of successfully hatched eggs. A nest was considered as a success if at least one chick hatched.

Results

In total 20.3 % (N = 468) of the 2302 sampling events where positive for the presence of buttonquails. Breeding was confirmed in 104 of these positive sampling events (22.2 %). Almost half of the sampling events between the beginning of October and the end of January (N = 154) were positive for the presence of buttonquails (N = 67) but with no evidence of breeding during this period. Consequently, we classified those months as the non-breeding period and the remaining 2148 sampling events as occurring during the breeding period. Andalusian Buttonquail's breeding period was very long, lasting for eight months, from early February until the end of September (Figure 2). The proportion of sampling events with reproduction started to increase from the end of winter (February-March) with the highest proportion in spring (April-May), declining during mid-summer (June-July), and reaching its lower values at the end of the summer (August-September) (Figure 2). No differences in coverage and vegetation height were found between presence and breeding sampling events, however, they tended to select fields with higher area and perimeter as breeding sites (Table 2). In summary, buttonquails have a strong phenological pattern for breeding and tend to select bigger fields for breeding.

Buttonquails were found to be present in 17 different crops and breeding was recorded in all but cucumber and artichoke (Table 3). Pumpkin, alfalfa, maize and pepper were positively selected to be occupied, although the latter was not actively selected for breeding. Carrot was the most avoided crop for breeding (it is mainly a winter crop, occurring out of the breeding season, Figure 3).

During this 11-year period, we found 21 buttonquail nests. Almost half of the nests were in alfalfa fields (N = 10), while the rest were in fields growing pumpkin (N = 5), maize (N = 4), aubergine (N = 1) and zucchini (N = 1). Nests were small circular-shaped grass-lined structures, on average 82.5 ± 14.5 mm long (N = 11) and 72.1 ± 10.4 mm wide (N = 9). The mean depth of the incubation cup was 25 ± 12.2 mm (N = 6). Two of the nests had a grass upper cover forming a sort of protective ceiling (Figure 1).

All complete clutches (N = 12) had 4 eggs. Mean egg maximum length and diameter were 26.14 ± 1.19 mm (N = 26) and 20.24 ± 1.11 mm (N = 30), respectively (see Table 4 for details) and mean egg weight was 5.9 ± 0.28 g (N = 8). Hatching success of nests whose final fate could be determined was 91.7 % (N = 11), with 6 nests hatching all four eggs, three nests lost one egg, while in one nest two eggs did not hatch, and one being predated. Mean hatching rate was 3.5 eggs per clutch (N = 10; SD 0.71), and 87.5 % of monitored eggs (N = 40) hatched successfully.

Discussion

The breeding season of the Andalusian buttonquail proved to be surprisingly long, with breeding occurring at least between early February and the end of September. Moreover, beyond our data, a booming female was found in October 1st by a Dutch observer in 2009

(Gutiérrez-Expósito et al. 2011). Following the absence of breeding clues in our data between October and January, we can establish the breeding period for this species to last around eight months, being the longest breeding season for a temperate bird species (Lack 1950, Hagemeijer and Blair 1997). This time period is one month longer than that described at the Brookfield Zoo (Chicago), where three females where actively laying during seven months, between the end of February and September (Flieg 1973). In a similar captive breeding experiment in Namibia, one female was breeding continuously for ten months, producing seven clutches (Hoesch 1960). So, as a normal rule, apart from the annual variations due to weather conditions changes, mostly temperature, that can induce small variations in avian breeding periods among years (Visser et a. 2009), we can establish the breeding period for this population to last between the beginning of February and the beginning of October.

During the Brookfield Zoo breeding test, more than 300 eggs were obtained from just three Kurrichane Buttonquail females in a continuous way during the seven-months breeding period (Flieg 1973). A female of one breeding pair studied by Hoesch (1959, 1960) laid up to 28 eggs in 7 clutches during a period of 10 months. The time between clutches lasted 50 days when the female was retired and left the male to brood the chicks. When the female was retired and paired with a new male this period was only 11 days. Moreover, buttonquails are highly precocial birds, being sexually mature as early as four or five months after hatching (Hoesch 1960, Flieg 1973), and therefore, they are able to breed later in their year of birth during their natal breeding period. A moulting breeding female trapped and ringed in the study area in June 2009, still showed juvenile unmoulted secondaries and external primaries, inferring it had hatched early in the same breeding season (Figure 4, Gutiérrez-Expósito et al. 2017). Maintenance of such a laying rate in the sequential polyandry breeding system of buttonquails (Debus 1996) in the wild and breeding of early juveniles later in the season can explain the high increase of the proportion of breeding events found by us as the breeding season advances. For this population, Gutiérrez-Expósito et al. (2019) found a five-fold increase in buttonquail numbers between late winter and summer.

Gutiérrez-Expósito et al. (2019) found that presence of the Andalusian Buttonquail was highly determined by the phenological stage of the crop (and consequently by the height and coverage, with which the phenology is highly correlated). However, we found no significant differences in any of the studied variables (crop stage, crop height and field perimeter) between positive sampling events to the presence of buttonquails and those where breeding was confirmed. So, we can conclude that buttonquails are able to breed in fields with similar traits of those where they are usually present. However, we have found an important preference in crops selected to settle and to breed. Without more data it is difficult to know why they prefer some crops, although we can speculate that they may be favouring crops with fewer chemical treatments and therefore with more insects (alfalfa), those with a higher fraction of bare ground (pumpkin) or with irrigation systems, such as dripping, that do not flood the field (maize), or, simply, those that match crop phenology with the breeding needs. More detailed studies are needed to find out which variables can explain the occupancy and breeding in different crop types during the breeding period.

As described in the literature, the nests we found were poorly lined cup-shaped structures placed at a small scrape at the base of a plant or a grass tussock, occasionally with some longer stems forming a kind of canopy (Cramp and Simmons 1980, Debus 1996, Madge and McGowan 2002). We could confirm this by finding two nests out of 12 with a well-developed cover. Captive birds in Namibia also created a similar canopy when long grass stems where available (Hoesch 1960). Video footage of incubating nests in our study area (pers. obs.) and for the *lepuranus* subspecies in South Africa (Engelbrecht 2014) showed how the male continues adding material to the nest while incubating, so roofed and bigger nests are expected to occur at the end of the incubation period. For this reason, external dimensions of nests can vary as incubation advances, while the internal diameter should remain constant. No reference to nest size has been found by us in the literature, so currently, our nest measurements are the only ones available for this species.

Etchécopar and Hue (1967) described a 4 egg clutch size as being usual for this subspecies, although they found a mean clutch size of 3.6 (N = 5). Similar values are given for the Kurrichane Buttonquail: 3.6 in East Africa (N = 5) and 3.4 in Malawi (N = 21) (Urban et al. 1986). A recent nest monitoring study in South Africa found lower values, mean 3.0 for a sample of just three nests (Engelbrecht 2014). All values are slightly lower than the 4 mean clutch size found by us.

There were no significant differences in egg size between our data and those given for the same subspecies in the Western Palearctic (Etchécopar and Hüe 1967, Cramp and Simmons 1980). Egg size in the sub-saharan subspecies *T.s. lepuranus* is smaller, but they tend to be greater in South Africa (Urban et al. 1986, Dean 2005, Engelbrecht 2014) than in tropical Africa (Urban et al. 1986). Even smaller eggs are found in the also smaller Indian subcontinent subspecies *T. s. dussumier* (Table 3; Ali and Ripley 1980).

We found a very high egg hatching rate, with almost all eggs hatching successfully. Hatching rate has been shown to decline in populations of some bird species after severe bottlenecks (Briskie and Mackintosh 2004). However, this does not seem to be the case of the Andalusian Buttonquail after a strong historical decline (Gutiérrez-Expósito et al. 2011) and a recent reduction of this population to a few hundred individuals (Gutiérrez-Expósito et al. 2019). More surprisingly, almost all monitored nests had a successful ending, with only one being lost by predation. A three egg Kurrichane Buttonquail nest clutch monitored in South Africa also successfully hatched all eggs (Engelbrecht 2014).

Predation is one of the main causes of nest loss in ground nesting birds, even in precocial species whose offspring rapidly leave the nest (Rands 1988, Davison and Bollinger 2000). Nests of buttonquails can be consumed by a great variety of predators, as has been reported for this and other species (Mathieson and Smith 2009, Gordon et al. 2017). In our study area, predation pressure on the Andalusian Buttonquail is expected to be high, not only due to the presence of potential nest predators such as Marsh Harriers *Circus aeruginosus*, Genets *Genetta genetta*, Mongooses *Herpestes* spp. or Hedgehogs *Atelerix algirus* (Delibes at al. 1984, Rosalino and Santos-Reis 2009, Praus and Weidinger 2010), but also because of the high number of free-ranging cats and dogs (Woinarski et al. 2017). The incubation period in buttonquails is one of the shortest among birds, between 12 and 15 days (Hoesch 1960, Madge and McGowan 2002), or even as short as 10 days as described for the smaller Indian subspecies *T. s. dussimier* (Ali and Ripley 1980). This short incubation period and the reluctance of these birds to be flushed, which hinders the locating of the nest by potential predators, are probably behind the high nest success observed in this buttonquail population. Additionally, agricultural operations, such as harvesting or ploughing, have a relevant role in nest destruction in farmland birds (Ponce et al. 2018), but none of the nests monitored by us was lost in this way. The still traditional farming system in the area, with no machinery involved, makes changes in the crops to be slower than in areas with intensive agricultural practices. As an example, one nest seen by us in an alfalfa field was discovered by the farmer during manual harvesting, who left it untouched, allowing the male to return to finish the incubation process until hatching.

In summary, it seems that all the breeding cycle aspects studied, as fecundity and nest success, are performing well in this population. So, more effort is needed to understand other non-studied aspects as chick survival or recruitment rates which could be key factors in the conservation of this endangered taxon.

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Table 1. Year to year and bimonthly seasonal distribution of all sampling events (left number) and positive sampling events (mid number) and positive sampling events with breeding probed (right number).

Year/Season	dec-jan	feb-mar	apr-may	jun-jul	aug-sep	oct-nov	Year total
2009	0-0-0	0-0-0	0-0-0	1-1-1	0-0-0	0-0-0	1-1-1
2010	0-0-0	0-0-0	0-0-0	248-71-28	22-14-4	18-6-0	288-91-32
2011	11-4-0	11-3-1	9-2-0	296-65-16	17-11-1	6-6-0	350-91-18
2012	6-0-0	23-9-2	7-4-3	13-7-0	8-3-1	7-2-0	64-25-6
2013	12-5-0	29-4-0	63-14-3	48-22-4	0-0-0	21-9-0	173-54-7
2014	14-7-0	27-10-4	0-0-0	275-36-7	0-0-0	24-11-0	340-64-11
2015	14-3-0	11-4-2	6-4-2	17-12-3	23-16-1	4-4-0	75-43-8
2016	3-3-0	16-5-0	11-3-1	34-9-5	22-10-0	14-7-0	100-37-6
2017	0-0-0	218-9-2	252-10-4	238-23-7	203-20-2	0-0-0	911-62-15
Season total	60-22	335-44-11	348-37-13	1170-246-71	295-74-9	94-45-0	2302-343-104

Table 2. AICc values of breeding habitat use generalized linear mixed models output.

Model	AICc		Estimate	Std. Error	z value	P
Null	195.72	intercept	-0.8503	0.1743	-4.880	< 0.001
Coverage	196.39	intercept	-0.2028	0.5703	-0.356	0.722
		coverage	-0.0081	0.0069	-1.177	0.239
Height	195.08	intercept	-2.2564	1.0743	-2.352	< 0.05
		log-height	0.9563	0.5981	1.599	0.110
Area	191.25	intercept	-2.4174	0.9976	-3.621	< 0.001
		log-area	1.0954	0.4398	2.491	< 0.05
Perimeter	192.96	intercept	-4.9885	1.9274	-2.588	< 0.01
		log-perimeter	0.7971	0.7971	2.170	< 0.05

Table 3. Number of sampling events per crop type and results of presence/absence of buttonquails and breeding.

Crop	Scientific name	Sampling events	Presence	Breeding
broad beans	*Vicia faba*	1	0	0
clover	*Trifolium repens*	1	0	0
fennel	*Foeniculum vulgare*	1	0	0
radish	*Raphanus sativus*	1	0	0
watermelon	*Citrullus lanatus*	2	0	0
cucumber	*Cucumis sativus*	35	1	0
aubergine	*Solanum melongena*	24	2	1
cabbage	*Brassica oleracea vr. capitata*	65	4	1
gourd	*Lagenaria siceraria*	19	4	1
artichoke	*Cynara scolymus*	12	8	0
turnip	*Brassica rapa ssp. rapa*	53	8	1
potato	*Solanum tuberosum*	34	9	1
cauliflower	*Brassica oleracea var. botrytis*	45	12	1
zucchini	*Cucurbita pepo*	65	11	2
carrot	*Daucus carota*	123	15	1
wheat	*Triticum sp.*	293	24	8
pepper	*Capsicum annunm*	109	25	3
tomato	*Solanum lycopersicum*	218	26	8
fallow	-	257	30	8
pumpkin	*Cucurbita maxima*	149	46	11
maize	*Zea mays*	201	53	13
alfalfa	*Medicago sativa*	594	190	44
TOTAL		2302	468	104

Table 4. Egg measurements for different subspecies of *Turnix sylvaticus*.

Area	susbspecies	N	Egg height			Diameter			References
			min	mean	max	min	mean	max	
India	*dussumier*	60	-	21.3	-	-	17.3	-	Ali & Ripley 1980
East Africa	*lepuranus*	14	21.2	21.7	23.0	15.7	17.6	19.0	Urban et al 1986
South Africa	*lepuranus*	9	21.2	22.3	23.3	17.0	18.0	18.8	Engelbrecht 2014
South Africa	*lepuranus*	60	20.3	23.4	26.2	16.9	18.6	20.0	Urban et al 1986
South Africa	*lepuranus*	-	20.8	23.8	26.2	17	18.4	20	Dean 2005
West Palearctic	*sylvaticus*	60	24.0	26.0	30.0	19.0	21.0	22.0	Cramp & Simmons 1980
North Africa	*sylvaticus*	18	24.0	-	27.0	18.0	-	21.0	Etchécopar & Hüe 1967
Morocco	*sylvaticus*	26	24.5	26.1	29.2	18.0	20.2	21.8	this study

Figures legends

Figure 1. Upper: up covered nest in pumpkin field (Sidi Abed, June 2009). Lower: uncovered nest in alfalfa field (Sidi Moussa, June 2010), both with complete 4 egg clutch (Carlos Gutiérrez-Expósito).

Figure 2. Bimonthly proportion of sampled fields with presence (grey bars) and the proportion of positive sampled fields where breeding was confirmed (black dots).

Figure 3. Crop electivity Ivlev's index for presence and breeding.

Figure 4. Right wing of juvenile breeding female in active complete moult showing juvenile patterned old secondaries and external primaries (Sidi Abed, Morocco) in June 2009 (C. Gutiérrez-Expósito).

Figure 1

Figure 2

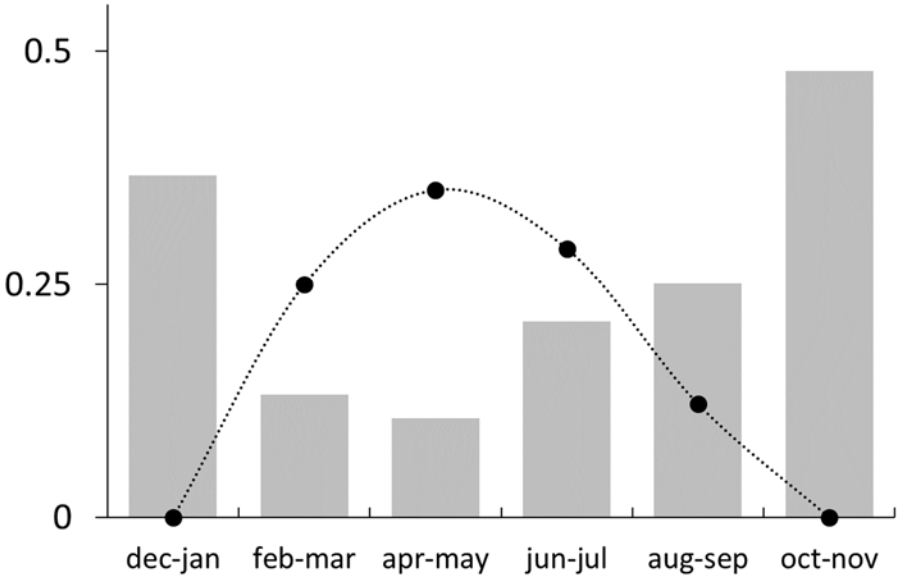

Figure 3.

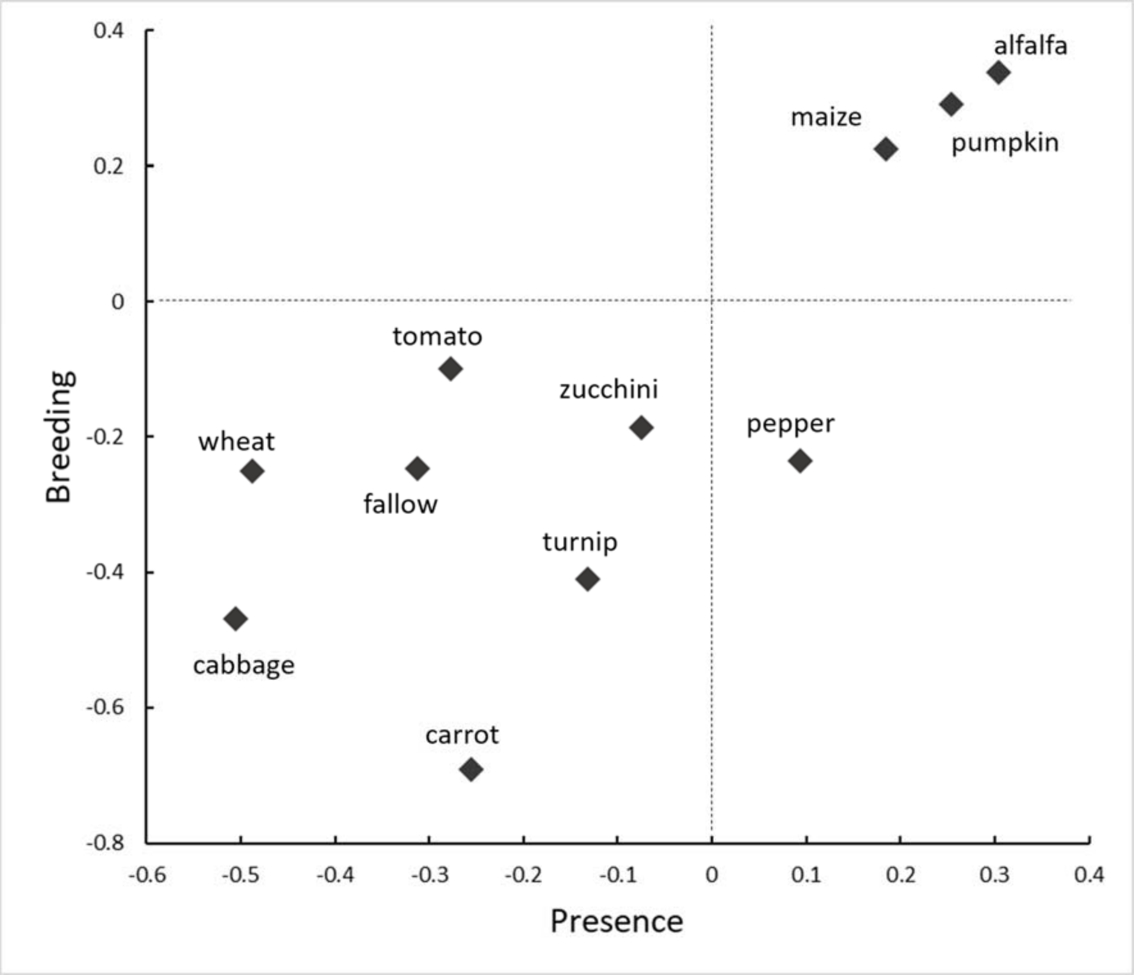
alfalfa
maize
pumpkin
tomato
zucchini
pepper
wheat
fallow
turnip
cabbage
carrot
Breeding
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
Presence

Figure 4.