Biology and Conservation of the Andalusian Buttonquail

(*Turnix sylvaticus sylvaticus* Desf. 1789)

Carlos Gutiérrez Expósito

PhD 2020

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Biology and Conservation of the Andalusian Buttonquail (*Turnix sylvaticus sylvaticus* Desf.) 1789)

Biología y Conservación del Torillo Andaluz (*Turnix sylvaticus sylvaticus* Desf. 1789)

Memoria presentada por el Licenciado en Biología

Carlos Gutiérrez Expósito

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Firmado Carlos Gutiérrez Expósito

Dr. Miguel Clavero Pineda, Científico Titular de la Estación Biológica de Doñana (EBD-CSIC) y Dr. Eloy Revilla Sánchez, Investigador Científico de la Estación Biológica de Doñana (EBD-CSIC).

CERTIFICAN:

Que los trabajos de investigación desarrollados bajo nuestra dirección en la Memoria de la Tesis Doctoral "Biología y Conservación del Torillo Andaluz (*Turnix sylvaticus sylvaticus* Desf. 1789)" cumplen con los requisitos de calidad, originalidad y rigor, siendo por tanto aptos para ser presentados por el Licenciado en Biología Carlos Gutiérrez Expósito ante el Tribunal que en su día se designe, para aspirar al grado de Doctor por la Universidad Pablo de Olavide de Sevilla.

Y para que así conste, y en cumplimiento de las disposiciones legales vigentes, firman el presente documento en Sevilla, a 15 de octubre de 2019.

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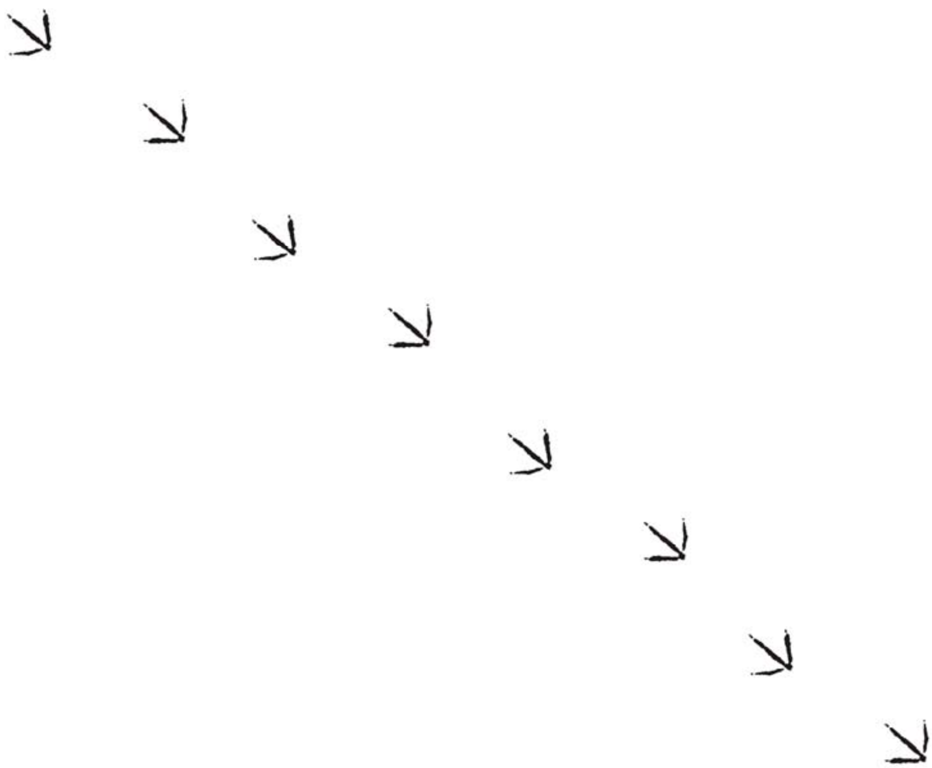
Universidad Pablo de Olavide

A mi familia

A Raquel



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To accomplish with the standards of the Severo Ochoa program for Centres of Excellence, this PhD project has an international advisory committee with researchers of recognized international prestige in the area:

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Abstract

Abstract

Rise of agriculture and livestock growing during the Mesolithic-Neolithic transition gave birth to a new biotope, the farmland, which in a few thousand years reached a planetary scale at the expense of natural ecosystems. This widespread land use change implied a demise of many avian species as its natural habitats were replaced by crops and grazing lands. However, it became into a new habitat for some steppe, grassland and savannah birds who were able to shift from its natural habitats to human-made environments. Some avian species of many bird families found there a land of opportunity, among them a few buttonquail (Turnicidae) species. However, the recent farmland intensification is leading to a general decline of these species. In this PhD we use the Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*) as a case study of a taxon, at least in part, able to cope with traditional farming, which until recently had a wide distribution in the western Mediterranean countries, and currently is in the verge of extinction. Starting from a global and historical scale approach, contextualizing the taxon at biogeographic and taxonomic levels, we will arrive at the "in situ" study of the only population that still survives. Firstly, we will try to establish the historical evolution of the extinction process in Europe and North Africa, to model and evaluate the historical distribution area based on environmental variables and to establish the phylogeographic relationships of the historical populations of this subspecies and their relationship with the rest of the species of the family. Secondly, the study of the population present in Morocco is carried out in order to determine the size of the population at different times, to evaluate the population trend and to describe habitat selection and reproductive biology.

Chapter I. Who's first? A rarity index to prioritize monitoring and conservation efforts of the poorly known buttonquails (Turnicidae).

Wildlife conservation status assessments are usually made at species level. However, the risk of extinction of subspecies or local populations often go unnoticed due to the lack of a proper assessment. Buttonquails are very secretive birds whose conservation assessment has proven to be very difficult due to the lack of good field data. Here we used the Turnicidae family to create a rarity index, which can also be applied at subspecific level, based exclusively on data provided by eBird, a citizen science birding platform. At species level, our rarity index matches with the IUCN red list categories assigned to every buttonquail species, classifying at higher level the most endangered or unknown species: New Caledonian Buttonquail (*Turnix novaecaledoniae*), Luzon Buttonquail (*Turnix worcesteri*) and Buff-breasted Buttonquail (*Turnix olivii*). By applying this index at subspecific level, we found that at least 12 buttonquail subspecies have a rarity index similar or higher than these three buttonquail species, all of them being island endemisms of Common Buttonquail (*Turnix sylvaticus*), Barred Buttonquail (*Turnix suscitator*) and Red-backed Buttonquail (*Turnix maculosus)* from the Philippines, Indonesia and Papua New Guinea. We propose the use of this index to detect bird species, subspecies or populations which could be in high risk of extinction and are lacking the necessary field studies.

Chapter II. Asymmetric heterochromia in birds: the dark crescent of buttonquails.

I describe for the first time the unique coloured pattern of the iris of buttonquails (Turnicidae). This unique pattern is due to the presence of a dark-brown crescent in the iris below the pupil, whose form and extent varies in response to light conditions. This dark crescent is present in the eyes of all individuals of *Turnix* species at every life stage, a consistency that has not been previously observed for the iridal marks found in other avian groups. This consistency suggests that the crescent-shaped spot in buttonquails' eyes is a character with some adaptive value, probably related to light regulation. This possibility deserves further study.

Chapter III. Vanishing wildlife in populated areas: the demise of the Andalusian Buttonquail.

Extinction risk is often associated with species intrinsic traits such as bigger size, higher trophic level, narrower habitat niche or smaller distribution areas. Despite this, fast extinctions can also occur in species apparently not matching with any of these traits. The Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*) is a critically endangered taxon, which barely survives in a single population in western Morocco. Here we describe how this taxon with a former wide distribution range, high reproductive rates, with a low trophic level in the food chain, small size and apparently coarse habitat requirements, is leading to extinction. By environmental niche modelling we outline its historical distribution and then at a regional scale (Andalusia) we explore the role of historical land use changes and human population trend in the rapid decline of the species. PCA analysis of environmental variables showed how its distribution was mainly determined by low continentality and aridity. Since the 19th century, the decline in the extent of occurrence has been above 99.99%. PCA analysis of land use changes showed that areas with a higher probability of historical presence have suffered more intense agriculture intensification and afforestation processes. These areas have been also those which have suffered a higher human population pressure and development. Any conservation efforts should focus on maintaining coexistence of the species with the human being.

Chapter IV. The farmland refuge of the last Andalusian buttonquail population.

The last populations of threatened taxa usually survive in low-impacted areas, whose protection and management is critical for its conservation. However, they can also be located in humanized and highly dynamic areas, whose management can be extremely challenging. The Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*) is the critically endangered nominal subspecies of the Common Buttonquail, a largely unknown species due to its secretive habits. Here, we show how the last Andalusian

Buttonquail population is restricted to a small, intensively used agricultural area (4,675 ha) in the Atlantic coast of Morocco, where the birds adapt their life cycle to a fast crop rotation. Buttonquails occupy crops in the flowering and fruiting stages, thus changing the preferred crop types along the year, although alfalfa fields were occupied in all seasons. We used estimated occupancy rates in different crops to obtain seasonal (2017) and year-to-year population estimates (2011, 2014 and 2017). Numbers showed wide seasonal fluctuations between the lowest in winter and the maximum in summer (112 to 719 individuals). Year-to-year summer estimates also showed wide variations and large uncertainties, ranging between a maximum 1,890 estimated in 2011 and a minimum in 2014 with 492 individuals. The last population estimate available was 596 in 2017. The area is suffering a rapid shift from traditional irrigation farming towards practices more akin to commercial industrial agriculture. The conservation of this critically endangered taxon is highly dependent on the maintenance of traditional farming practices and a rational on-site agricultural modernization.

Chapter V. Breeding ecology of the Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*).

Understanding the breeding cycle of wildlife is essential to afford conservation strategies. This is especially important for barely studied species and urgent for those in a serious risk of extinction. The Andalusian Buttonquail is an endangered endemism 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 was probed to occur in all but cucumber and artichoke. However, a strong selection for breeding crops was found to occur towards 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 weighted 5.9 g. All complete clutches had 4 eggs and the hatching rate was 3.42. All monitored nest successfully reared at least one chick. Clutch size and hatching rate matched the standards for 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.

Chapter VI. Gardens by the sea: the last Andalusian Buttonquail refuge.

The last known Andalusian Buttonquail population is restricted to an intensively cultivated small area in Morocco. In such circumstances, the conservation of this taxon must involve not only the conservation biology discipline, but also an agronomical and social sciences approach.

Andalusian Buttonquail. Acrylic painting over canvas. Clara Expósito Martínez

Resumen

Resumen

El auge de la agricultura y la ganadería durante la transición mesolítica-neolítica dio lugar a un nuevo biotopo: las tierras de cultivo, que en pocos miles de años alcanzó una escala planetaria a expensas de los biotopos naturales. Este cambio generalizado en el uso de la tierra implicó la desaparición de muchas especies de aves, ya que sus hábitats naturales fueron reemplazados por cultivos y pastizales. Sin embargo, para muchas aves esteparias, esta tierra cultivada se convirtió en un nuevo hábitat, pudiendo colonizar desde sus hábitats naturales este nuevo entorno creado por el hombre. Algunas especies de aves de muchas familias han encontrado aquí una tierra de oportunidades, entre ellas algunas especies de torillos (Turnicidae). Sin embargo, la reciente intensificación de las tierras de cultivo está provocando una disminución general de estas especies de aves. En esta tesis doctoral utilizamos el torillo andaluz como caso de estudio de un taxón, al menos en parte adaptado a la agricultura tradicional, que hasta hace poco tenía una amplia distribución en los países del Mediterráneo occidental, y que actualmente se encuentra en vías de extinción. Partiendo de un enfoque a escala global e histórica, contextualizando el taxón a nivel biogeográfico y taxonómico, llegaremos al estudio "in situ" de la única población que aún sobrevive en la actualidad. En primer lugar, se intentará establecer la evolución histórica del proceso de extinción en Europa y el norte de África, modelar y evaluar el área histórica de distribución en base a variables ambientales. En segundo lugar, se llevará a cabo el estudio de la población presente en Marruecos para determinar el tamaño de la población en diferentes momentos, evaluar la tendencia de la población y describir la selección de hábitat y la biología reproductiva.

<u>Capítulo I. ¿Quén va antes? Un índice de rareza para priorizar los esfuerzos de seguimiento y conservación para los poco estudiados torillos (Turnicidae).</u>

La evaluación del estado de conservación de la vida silvestre se suele hacer a nivel de especie, sin embargo, con frecuencia las subespecies o las poblaciones locales en riesgo de extinción pasan desapercibidas debido a la falta de una evaluación adecuada.

Los torillos son aves muy discretas cuya evaluación de conservación ha demostrado ser muy difícil debido a la falta de buenos datos de campo. Aquí utilizamos la familia Turnicidae para crear un índice de rareza, que también puede ser aplicado a nivel subespecífico, basado exclusivamente en datos proporcionados por una plataforma de observación de aves de ciencia ciudadana: eBird. A nivel específico, nuestro índice de estado de preocupación coincide con las categorías de la lista roja de la UICN asignadas a cada especie de torillo, clasificando a un nivel más alto a las especies más amenazadas o desconocidas como el torillo de Nueva Caledonia (*Turnix novaecaledoniae*), el torillo de Luzón (*Turnix worcesteri*) y el torillo de Robinson (*Turnix olivii*). Aplicando este índice a nivel subespecífico, encontramos que al menos 12 subespecies de torillos tienen un índice de rareza similar o superior a estas tres especies. Todas ellas son endemismos insulares de Filipinas, Indonesia y Papúa Nueva Guinea pertenecientes al torillo andaluz (*Turnix sylvaticus*), el torillo batallador (*Turnix suscitator*) y el torillo moteado (*Turnix maculosus*). Proponemos el uso de este índice para detectar especies, subespecies o poblaciones de aves que puedan estar en alto riesgo de extinción y carezcan de los estudios de campo necesarios.

<u>Capítulo II. Heterocromía asimétrica en aves: la media luna oscura en los torillos.</u>

Describo por primera vez el patrón de color único del iris de los torillos (Turnicidae). Este patrón se debe a la presencia de una media luna de color marrón oscuro en el iris, justo debajo de la pupila, cuya forma y extensión varía en respuesta a las condiciones de luz. Esta media luna oscura está presente en los ojos de todos los individuos del género *Turnix*, en todas las etapas de la vida, una consistencia que no se ha observado previamente en las marcas del iris encontradas en otros grupos de aves. Esta consistencia sugiere que la mancha en forma de media luna en los ojos de los torillos es un caracter sometido a selección natural, probablemente relacionada con la regulación de la luz. Esta posibilidad merece un estudio más profundo.

Capítulo III. Extinción de fauna silvestre en zonas pobladas: el declive del torillo andaluz.

El riesgo de extinción se asocia a menudo a rasgos intrínsecos de las especies, como un mayor tamaño, un mayor nivel trófico, un nicho de hábitat más estrecho o áreas de distribución más pequeñas. A pesar de esto, también pueden ocurrir extinciones rápidas en especies que aparentemente no coinciden con ninguno de estos rasgos. El torillo andaluz (*Turnix sylvaticus sylvaticus*) es un taxón en peligro crítico, que apenas sobrevive en una sola población del oeste de Marruecos. Aquí describimos cómo este taxón, con una amplia área de distribución histórica, situado en un nivel bajo de la cadena trófica, siendo de pequeño tamaño y aparentemente con pocos requisitos de hábitat, está sufriendo un proceso de extinción. A través de la creación de modelos de nicho, hemos reconstruido su área de distribución histórica para luego, a escala regional (Andalucía), explorar el papel que los cambios históricos en el uso del suelo y la tendencia de la población humana han tenido en el rápido declive de la especie. El análisis de las variables ambientales mediante análisis de componentes principales mostró cómo su distribución estaba determinada principalmente por bajos índices de continentalidad y aridez. A lo largo del siglo XXI, la disminución del área de distribución ha sido superior al 99,99%. El análisis de componentes principales de los cambios en el uso del suelo mostró cómo las áreas con mayor probabilidad de presencia histórica han sufrido procesos más intensos de intensificación agrícola y forestación. Estas zonas han sido también las que han sufrido un mayor aumento de la población humana. En resumen, el nicho ambiental del torillo andaluz se ajustaba a las mejores zonas para un desarrollo humano intenso. Cualquier esfuerzo de conservación debe centrarse en la necesaria co-ocurrencia de la especie con el ser humano.

Capítulo IV. El refugio agrícola de la última población de torillo andaluz.

Las últimas poblaciones de taxones amenazados suelen sobrevivir en áreas de bajo impacto, cuya protección y manejo son críticos para su conservación. Sin embargo, también pueden ubicarse en áreas humanizadas y altamente dinámicas, cuya gestión puede ser extremadamente desafiante. *Turnix sylvaticus sylvaticus*) es la subespecie nominal del torillo andaluz, se encuentra en peligro crítico de extinción y, debido a sus hábitos discretos es una especie muy desconocida. Aquí mostramos cómo la última población de torillo andaluz se encuentra restringida a una pequeña zona agrícola (4.675 ha) en la costa atlántica de Marruecos, donde las aves adaptan su ciclo de vida a una rápida rotación de cultivos. Los torillos principalmente ocupan los cultivos cuando están en floración y fructificación. Si bien los campos de alfalfa se encuentran ocupados en todas las estaciones del año, los torillos van cambiando sus preferencias a medida que la rotación de cultivos va teniendo lugar. Se utilizaron las tasas de ocupación estimadas en diferentes cultivos para obtener estimaciones de población estacionales (2017) y anuales (2011, 2014 y 2017). Los cifras mostraron amplias fluctuaciones estacionales siendo más bajos en invierno (112) y más altos en verano (719 individuos). Las estimaciones estivales para cada año también mostraron amplias variaciones, oscilando entre un máximo de 1.890 estimado para 2011 y un mínimo en 2014 con 492 individuos. La última estimación de población disponible para el verano de 2017 fue de 596 individuos. La zona está sufriendo un rápido cambio de la agricultura tradicional hacia prácticas más parecidas a la agricultura intensiva. La conservación de este taxón en peligro crítico depende en gran medida del mantenimiento de las prácticas agrícolas tradicionales y de una modernización agrícola racional.

Capítulo V. Ecología reproductora del torillo andaluz (*Turnix sylvaticus sylvaticus*).

Comprender el ciclo de reproducción de la vida silvestre es esencial para poder afrontar estrategias de conservación. Esto es especialmente interesante para especies todavía poco estudiadas como los torillos y muy urgente para aquellas en serio riesgo de extinción como es el torillo andaluz (*Turnix sylvaticus sylvaticus*). Este taxón es un endemismo en peligro de extinción de la cuenca del Mediterráneo occidental, confinado a una franja cultivada en la costa atlántica marroquí. Entre 2009 y 2017 se realizaron 2.302 muestreos en parcelas de cultivo para determinar la presencia-ausencia y reproducción de la especie. La temporada de reproducción duró 8 meses, entre principios de febrero y principios de octubre. Se encontró en hasta 17 tipos de cultivos diferentes, confírmandose la reproducción en todos ellos, excepto en cultivos de pepino y alcachofas. Sin embargo, existe una fuerte selección para le reproducción hacia cultivos de alfalfa, calabaza y maíz. Los nidos son estructuras de 82 mm x 71,4 mm revestidas de herbáceas y construidas sobre una pequeña zona escarbada del suelo. Los huevos tienen una longitud máxima media de 26,14 mm, un diámetro medio de 20,24 mm y un peso de 5,9 g. Todas las puestas completas tenían 4 huevos y la tasa de eclosión resultó ser de 3,5 huevos por nido. Todos los nidos minitorizados, excepto uno, criaron exitosamente al menos un pollo. El tamaño de puesta y la tasa de eclosión coinciden con los estándares para otras poblaciones y especies de torillos, por lo que las causas de la disminución deben encontrarse en etapas más avanzadas del ciclo reproductivo. En este sentido, se necesitan estudios adicionales para revelar la supervivencia de los pollos una vez abandonan el nido y de los juveniles una vez alcanzada la independencia.

Capítulo VI. Huertos junto al mar: el último refugio del torillo andaluz.

La última población conocida de torillo andaluz está restringida a una pequeña área cultivada en Marruecos. En tales circunstancias, la conservación de este taxón debe involucrar no sólo la disciplina de la biología de la conservación, sino también el enfoque de las ciencias agronómicas y sociales.

General introduction

General introduction

General framework

Since the beginning of sedentary human settlements, land transformation for agriculture and livestock has been a ceaseless process (Gignoux et al. 2011), whose magnitude has been increasing along history (Hazell and Wood 2008). Moreover, this panorama is suffering a dramatic shift in the last two centuries. In the current global change scenario, together with global warming, land use intensification is the main driver of environmental change, and consequently severely affecting the conservation of biodiversity (Vitousek 1994, Dawson et al. 2011). All along this long process, open biotopes such as steppe, savannah or grassland have been some of the most affected biomes by human impact (Sala et al. 2000). These areas held formerly strict grassland or steppe bird species, many of which had the potential to adapt to the new human-made environment (Dengler et al. 2014). In this context, bird species fate has been mediated by intrinsic specific biological traits that allow species to adapt to this new environmental conditions (McKinney 1997).

First steps of human land transformation during the Mesolithic-Neolithic transition (Pinhasi et al. 2005), could affect positively some of these species during millennia, to the point that currently some of them are highly dependent on non-intensified farmlands (Wolff 2001, Palacín et al. 2012). The current worldwide grassland and steppe land transformation into crops and the intensification of the existing ones is affecting adversely to steppe bird species and those adapted to traditional farming (Donald et al. 2006, Kehoe et al. 2015, Cardador et al. 2015). In this sense the loss of traditional farming practices by leaving fallow land between two crop cycles is behind the drastic decline of some farmland bird species (Traba and Morales 2019). Additionally, these usually flat and easily accessible areas have also been largely affected by modern industrial uses such as commercial afforestation (using fast-growing trees such as *Pinus* or *Eucalyptus*) (Allan et al., 1997) or wind farms (Laiolo and Tella 2006).

Many bird groups originally adapted to occupy natural grasslands and steppes were able to thrive in traditional farming landscapes. Classical examples are quails and partridges (Phasianidae), sandgrouses (Pteroclidae), bustards (Otididae), and some raptors as harriers (*Circus*, Accipritidae) and a few Passerines: i.e. larks (Alaudidae), pipits and wagtails (Motacillidae), new world sparrows (Passeridae) or buntings (Embericidae).

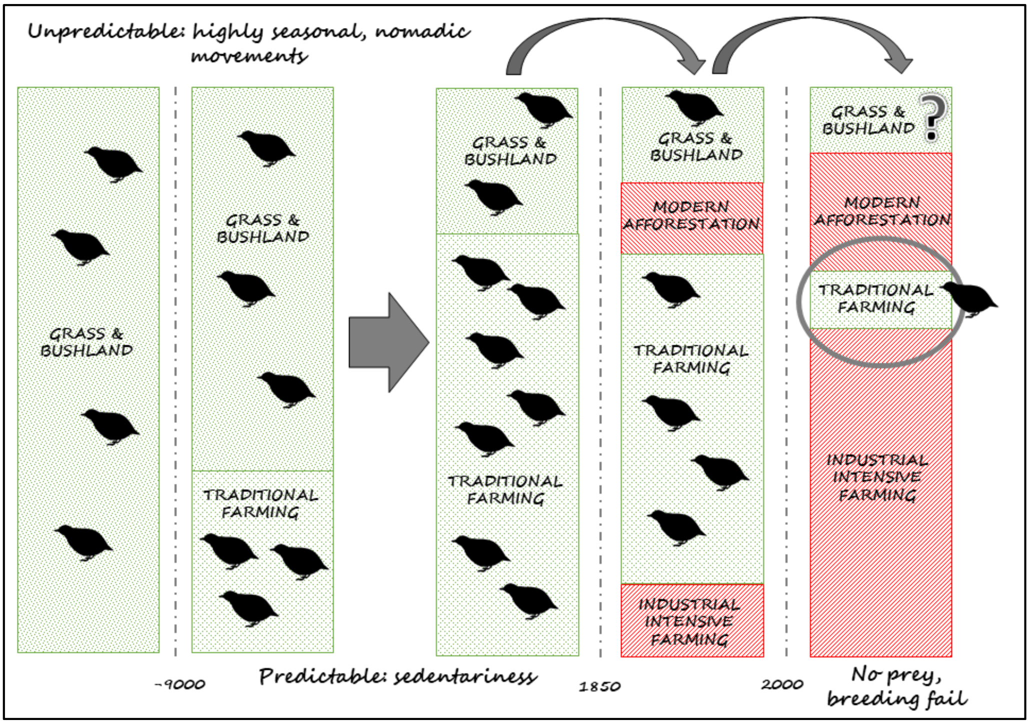


Figure 1. Schematic illustration of the PhD framework.

Suborder	Family	Genus	N species
Charadrii	Burhinidae	*Burhinus*	8
	Charadriidae	*Oreopholus*	1
		Eudromias	1
		Charadrius	3
		Vanellus	17
		Peltohyas	1
	Pedionomidae	*Pedionomus*	1
	Thinocoridae	*Attagis*	2
		Thinocorus	2
	Scolopacidae	*Bartramia*	1
Larii	Turnicidae	*Turnix*	17
		Ortyxelos	1
	Glareolidae	*Smutsornis*	1
		Rhinoptilus	3
		Cursorius	5
		Stiltia	1

Table 1. Number of Charadriiformes species adapted to live in steppe and grassland habitats, sorted by Suborder, Family and Genus.

The order Charadriiformes is a very diverse group with up to 19 bird families, usually related to rivers, wetlands and marine environments (i.e. waders, jacanas, sheathbills, auks, skimmers, gulls and terns). However, a good number of species are adapted to inhabit grassland and steppes (Table 1). Among them, the Turnicidae (buttonquails), together with the australian Plains-wanderer (*Pedionomus torquatus*), are those more adapted to a terrestrial way of life, as all species within the family inhabit grasslands or shrublands. Moreover, many of them can also be found in farmland, mainly by occupying disused cultivation and fallow land as well as certain types of crops.

The Turnicidae family.

Buttonquails are small ground birds, characterized by their discrete and secretive habits, which show certain similarities with true quails (*Coturnix*), although they are not phylogenetically related. Traditionally buttonquails were placed within bird phylogenies as an idependent family, the Turnicidae, in the order Gruiformes, associated with other ground bird families (Gruidae, Rallidae) (Dementiev & Gladkov 1970, Cramp & Simmons 1980, Johnsgard 1991, Urban et al. 1986, Debus 1996, Madge & McGowan 2002).

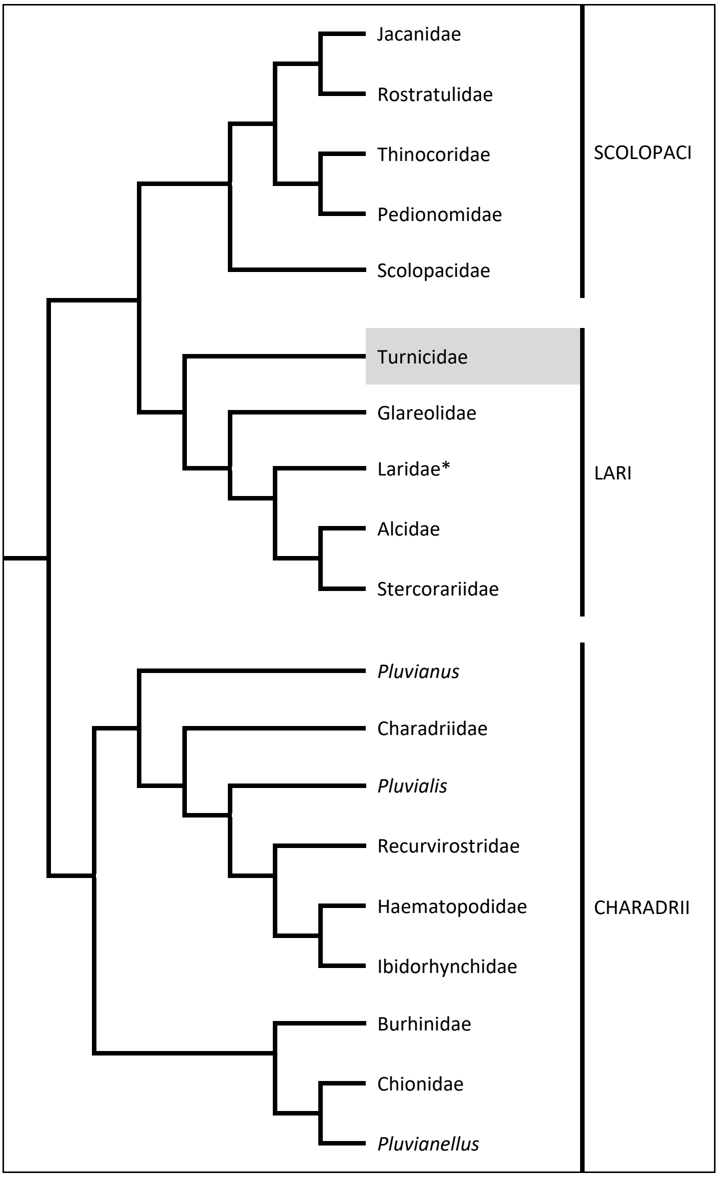


Figure 2. Bayesian mDNA tree relationships within the Order Charadriiformes (Baker et al. 2007). * Currently the family Laridae includes terns (former Sternidae) and skimmers (former Rynchopidae).

Although some morphological studies supported linking them closely with the Rallidae (Rotthowe and Starck 1998), other authors placed buttonquails in its own order (Sibley & Monroe 1990, Livezey & Suzi 2007). Genetic studies have in fact revealed that the Turnicidae is a lineage withinin the Order Charadriiformes (Figure 2).

Molecular analysis places them as a sister clade of the Lari (terns, gulls, skimmers, auks, skuas, pratincoles and coursers) (Paton et al. 2003, Fain & Houde 2007, Hackett et al. 2008, Paton & Baker 2006). The family ram its roots as early as the late Cretaceous, 80 Ma (million years ago) (Baker et al. 2007). Fossil remains from the Lower Oligocene (23.7 - 28.5 Ma) assigned to the genus *Turnipax*, have been described as the earliest stem lineage of the Turnicidae, also linking them with the Charadriiformes (Mayr and Knopf 2007). Structure and morphology of modern buttonquails have been quite constant since the Late Miocene (5.3 - 11.6 Ma), when fossils alredy assigned to *Turnix* have been found in Eurasia (Zelenkov et al. 2015). Fossils apparently assignable to a living buttonquail species (*T. hottentottus*) have been found in South Africa and have been dated in the Early Pliocene (3.6 - 5.3 Ma) (Olson 1994).

With the exception of the Quail-plover (*Ortyxelos meiffrenii*), whose distribution is restricted to the Sahel belt, all buttonquail species belong to the *Turnix* genus, which consists in 17 species of Afrotropical, Indomalayan and Australian distribution (Table 2). Up to six species are Australian endemics, of which four are widely distributed: Varied, Chestnut-backed, Little and Red-chested Buttonquails, while Black-breasted Buttonquail is restricted to east Australia and Buff-breasted Buttonquail to the Cape York peninsula (NE Australia). The Red-backed Buttonquail, also present in Australia, is found in SE Asia. In Asia, two exclusive species are widely distributed: Yellow-legged and Barred Buttonquails, together with the Common Buttonquail whose distribution also extends to Africa, and formerly to south Europe. Two more species are found in Africa, the widespread Black-rumped Buttonquail and its sister species, the Hottentot Buttonquail, endemic of the fynbos biome in South Africa. The other five species are island endemics:

Madagascar Buttonquail from Madagascar and Reunion Island; Spotted and Luzon Buttonquails found in Luzon (N Philippines), Sumba Buttonquail in Sumba island (E Indonesia) and New Caledonian Buttonquail from New Caledonia (French Pacific Overseas Territories).

English name	Scientific name	Distribution	N subspecies
Common Buttonquail	*Turnix sylvaticus*	W Palearctic, Africa, S Asia	9
Red-backed Buttonquail	*Turnix maculosus*	SE Asia, Australia	14
Yellow-legged Buttonquail	*Turnix tanki*	Asia	2
Black-rumped Buttonquail	*Turnix nanus*	Sub-Saharan Africa	monotypic
Hottentot Buttonquail	*Turnix hottentottus*	South Africa	monotypic
Spotted Buttonquail	*Turnix ocellatus*	Luzon Is. (Philippines)	2
Barred Buttonquail	*Turnix suscitator*	S Asia	18
Madagascar Buttonquail	*Turnix nigricollis*	Madagascar, Reunion	monotypic
Black-breasted Buttonquail	*Turnix melanogaster*	E Australia	monotypic
New Caledonian Buttonquail	*Turnix novaecaledoniae*	New Caledonia (France)	monotypic
Painted Buttonquail	*Turnix varius*	Australia, Tasmania	2
Buff-breasted Buttonquail	*Turnix olivii*	Cape York Pen. (Australia)	monotypic
Chestnut-backed Buttonquail	*Turnix castanotus*	N Australia	monotypic
Red-chested Buttonquail	*Turnix pyrrhothorax*	Australia	monotypic
Sumba Buttonquail	*Turnix everetti*	Sumba Is. (Indonesia)	monotypic
Luzon Buttonquail	*Turnix worcesteri*	Luzon Is. (Philippines)	monotypic
Little Buttonquail	*Turnix velox*	Australia	monotypic
Quail-plover	*Ortyxelos meiffrenii*	Tropical Africa	monotypic

Table 2. Buttonquail list of species with general distribution and number of subspecies.

Morphological and behavioural aspects of buttonquails

Buttonquails are small sized ground birds. Ranking between 10 and 23 cm of length and 20 and 130 g of weight. Their body structure largely reminds the true quails (Galliformes) with which very often they share habits and habitats. Generally, they live in grassy or low shrubby habitats, with the exception of the Black-breasted Buttonquail, which is restricted to drier rain forest or scrublands, deeply covered by leaf litter. The feet of buttonquails are adapted to a largely terrestrial way of life, by reduction in the number of toes to three, lacking the hind toe (Figure 3). Reproduction follows a sequential polyandry system, where females can pair sequentially with different males.

As other Charadriiforms in which the usual breeding roles are reversed (i.e. phalaropes, plains-wanderer, jacanas), females are bigger and more colourfull patterned than males. To attract males, female buttonquails emit a series of low frequency booming calls produced thanks to and enlargement of the trachea. Calls of every species differ in pitch or tempo, or both, but are in general very similar in the whole family. On the other hand, males are more cryptic and are totally in charge of the incubation and chick rearing tasks (del Hoyo 1996, Madge & McGowan 2002).

The Common and the Andalusian Buttonquail

Out of all seventeen recognized *Turnix* species, the Common Buttonquail is the one with the larger distribution area. It's closely related with the Red-backed Buttonquail, with which it may form a superspecies. These two species, together with the Barred Buttonquail, have the higher sub specific variation, and currently up to nine subspecies of Common Buttonquail are recognized (Debus 1996, Madge & McGowan 2002) (Table 3, Figure 4).

Figure 3. Three toed foot of a female Andalusian Buttonquail trapped for ringing and sampling. Sidi Abed, Morocco (2009).

The nominate race *sylvaticus*, is closely related to the sub-Saharan form *lepuranus*. Traditionally the species has been named as Andalusian Buttonquail or Hemipode, however, lately the English name used for this species has been changed to Small (Svensson et al. 2009) or more recently to Common Buttonquail (del Hoyo and Collar 2014). Nevertheless, it has been proposed to maintain the name Andalusian Buttonquail for the West Palearctic subespecies *Turnix sylvaticus sylvaticus* evocating the Spanish (Torillo Andaluz) and French (Turnix d'Andalousie) names, as well as is usually done with the Kurrichane Buttonquail (*Turnix sylvaticus lepuranus*) (Gutiérrez-Expósito et al. 2011).

Subespecies	Name	Distribution area
T.s.bartelsorum	Indonesian Common Buttonquail	Java and Bali (Indonesia)
T.s.suluensis	Sulu Common Buttonquail	Sulu Island (SW Philippines)
T.s.celestinoi	Visayas Common Buttonquail	Bohol and Mindanao (S Philippines)
T.s.nigrorum	Negros Common Buttonquail	Negros (SE Philippines)
T.s.whiteheadi	Luzon Common Buttonquail	Luzon (N Philippines)
T.s.davidi	Indochinese Common Buttonquail	Indochina, China, Taiwan and Hainan
T.s.dussumier	Indian Common Buttonquail	India and Myanmar
T.s.lepuranus	Kurrichane Buttonquail	Sub-Saharan Africa
T.s.sylvaticus	Andalusian Buttonquail	West Palearctic

Table 3. subspecies of Common Buttonquail adapted from Gutiérrez-Expósito et al. 2011.

Differences between Andalusian and Kurrichane Buttonquails consist basically in size and colour. Together with the bigger size, Andalusian shows a darker ground colour on the back feathers, being more reddish in Kurrichane, and more orange underparts and flanks (Figure 5). A genetic study, using the cytochrome b of the mitochondrial DNA revealed these two forms to be more closely related than was initially thought due to the observed size and colour differences and proposes to maintain the actual status of well differentiated subspecies of the same species (Pertoldi et al. 2006). Nevertheless, further studies using nuclear DNA and genome wide methods are needed to dilucidate the filogeographic status of these subspecies.

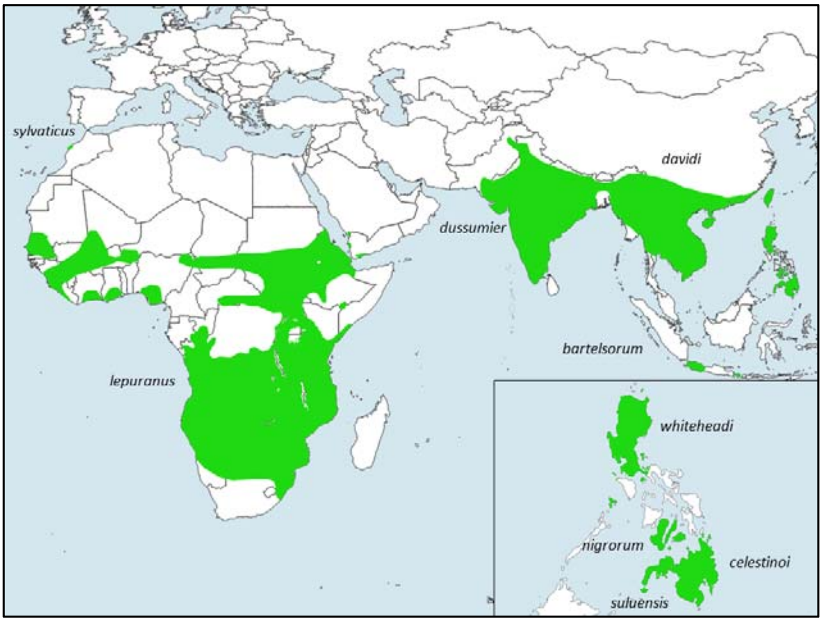
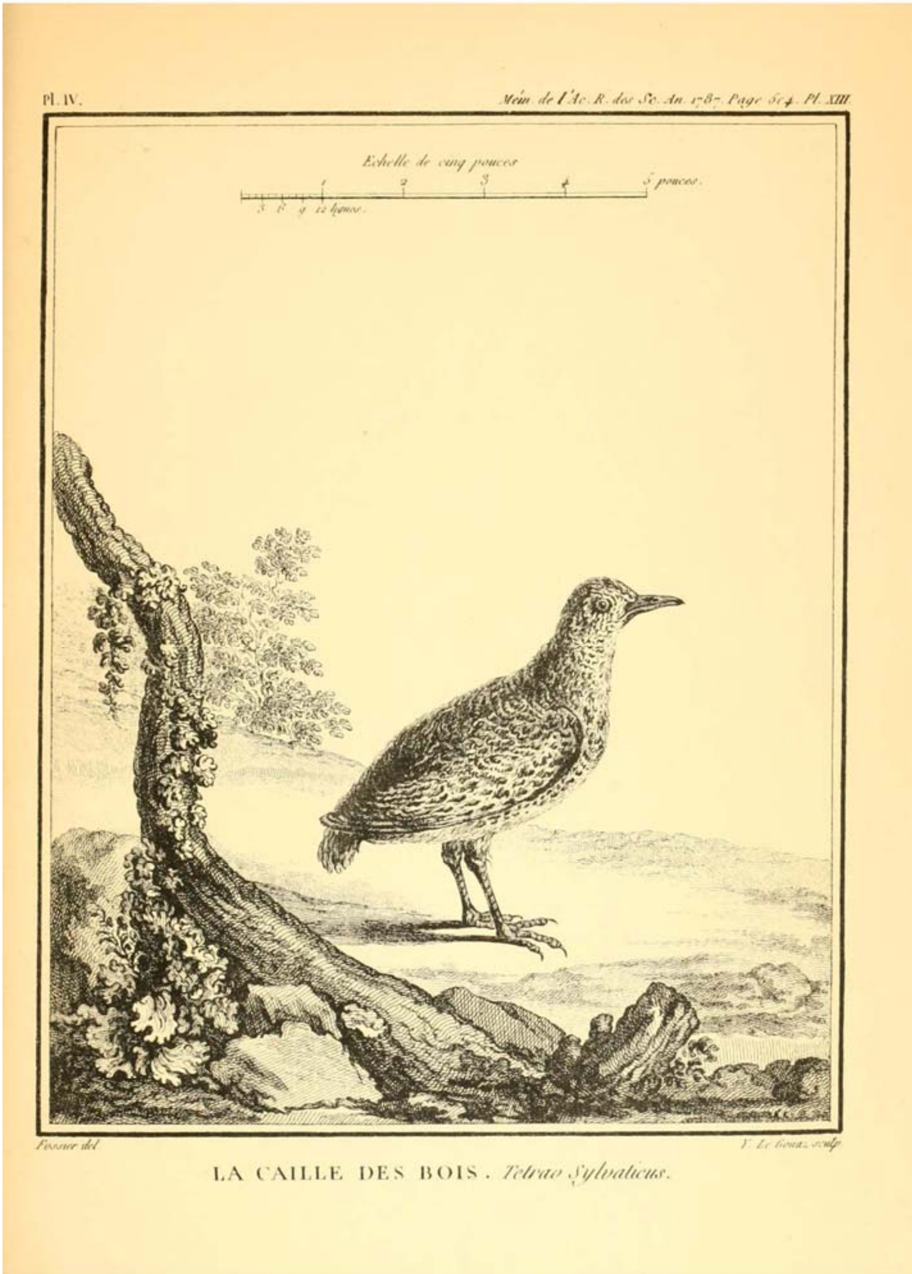


Figure 4. Common Buttonquail distribution map with subspecies. Modified from IUCN 2017.

Figure 5. Adult female skins of Andalusian (up) and Kurrichane (down) Buttonquails at Estación Biológica de Doñana-CSIC scientific collection.

By the end of the 19th century, the Andalusian Buttonquail was distributed in seven countries in the western Mediterranean. They were found in Sicily (Italy), Andalusia (Spain) and Portugal in the European side and in Lybia, Tunisia, Algeria and Morocco in North Africa (Gutiérrez-Expósito et al. 2011). By 1920 it was considered extirpated from Sicily due to overhunting (Violani and Massa 1993). Subsequently a silent vanishing process occurred in other countries (Catry 1999, Bundy 1976, Isenmann et al. 2005), and by the eighties it was considered only to persist in Morocco and Spain (Gutiérrez-Expósito et al. 2011). Last documented record in Spain were three birds shot in Doñana National Park area in 1981, and without recent records from Morocco, the taxon was thought to be almost extinct (Pertoldi et al. 2006). However, in 2000 some sights were confirmed in the Doukkala-Abda region in Morocco. Subsequent observations lead to the discovery of the last known population of Andalusian Buttonquail in coastal farmland between Sidi Abed (El Jadida) and Cap Beddouza (Safi) (Gutiérrez-Expósito et al. 2011).

This taxon is one of the most threatened vertebrates within the Western Palearctic biogeographic region (Madroño et al. 2004, Hagemeijer & Blair 1997), while is one of the most understudied (Pertoldi et al. 2006, Gutiérrez-Expósito et al. 2011). The absence of knowledge on this and other *Turnix* taxa is arguably related to their very secretive habits, not being until quite recently that specific effective detection and study methods have been developed (Gutiérrez-Expósito y Qninba 2010).



Desfontaines' drawing of the "Caille des bois" on his work "Memoire sur quelques nouvelles espèces des côtes de Barbarie", published in 1789 with the first formal description of the species as *Tetrao sylvaticus*.

Objectives

Objectives

General objective of the thesis is to set the basis of knowledge of this poorly-know taxon, by exploring the historical evolution of the Andalusian Buttonquail populations, evaluating the role that may have had historical changes in land uses in the near-extinction of the taxon and generate the basic knowledge and essential tools to face the conservation of the taxon and its future recovery in the western Mediterranean

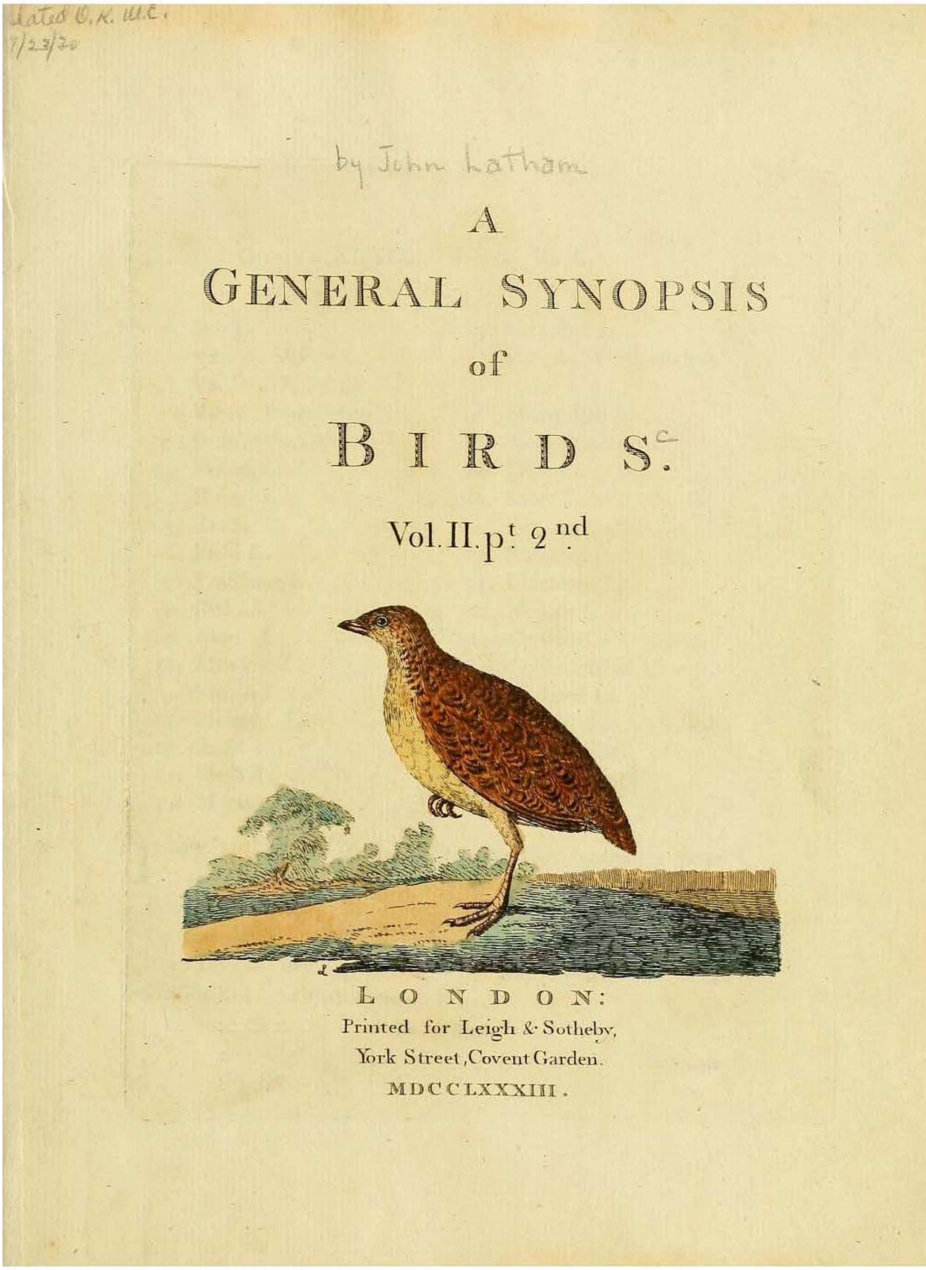
This general objective can be divided in the following specific aims:

- Aim 1. Review and update the state of knowledge of all buttonquail species.
- Aim 2. Review the conservation status of all buttonquail species.
- Aim 3. Estimate the historical distribution area of the Andalusian Buttonquail, based on historical occurrence records and their relationships with environmental variables.
- Aim 4. Analyse the relationships between land use changes and with the evolution of Andalusian Buttonquail populations.
- Aim 5. Estimate the size and the trend of the only known extant Andalusian Buttonquail population.
- Aim 6. Describe habitat use and selection by the Andalusian Buttonquail.
- Aim 7. Define the breeding biology parameters of the Andalusian Buttonquail.

To achiveve these goals, we planned a six-chapter working schedule, divided into two sections. In the first, we review the state of knowledge and conservation status of all members of the Turnicidae family and bring to light the structural coloration of the iris of buttonquails, an unexpected output of the research work of this PhD thesis. In the second section we use the Andalusian Buttonquail to study how a species primarly adapted to grasslands and schrublands is able to live in cultivated environments. First we try to establish the historical evolution of the process of extinction of the Andalusian Buttonquail in the western Mediterranean (Portugal, Spain, Italy, Morocco, Algeria, Tunisia and Lybia). To that aim, we use ecological niche models based on historical records of the species and their relationship to different environmental variables in the historical distribution area. Then we analysise the role of both human population and land uses in the local extinction of the taxon at a regional scale. Finally, we develop a field study of the only known Andalusian Buttonquail population, in order to determine its population size and trend and to describe its habitat selection and reproductive biology. A summary of the included chapters with their realted aims is given in Table 4.

CHAPTER	TITLE	AIM
I	Who's first? An index to priorize monitoring and conservation efforts for the poorly known buttonquails (Turnicidae)	1, 2
II	Asymmetric heterochromia in birds: the dark crescent of buttonquails	1
III	Vanishing wildlife in populated areas: the demise of the Andalusian Buttonquail	3, 4
IV	The farmland refuge of the last Andalusian Buttonquail population	5, 6
V	Breeding ecology of the Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*)	6, 7
VI	Gardens by the sea: the last Andalusian Buttonquail refuge	6

Table 4. Summary of chapters and aims



Cover painting by John Latham on its work "A General Synopsis of Birds, Vol. II" (1783), appearing as Andalusian Quail, being the first reference to its presence in Spain.

General Methods

General methods

Bibliographic review

An extensive search of literature concerning buttonquails has been done by a combination of web based searchs and traditional scanning of bibliographic sections of books and scientific publications. We reduced the search to publications that explicitly focused on one or more buttonquail species, excluding those concerning to species descriptions. To further narrow the search, regional faunas, inventories on specific areas, bird atlases, and studies describing bird communities were also ruled out. Searchs were done by using the scientific and common names (in English, French, Italian, German, Russian, Chinese and Spanish) of all buttonquail species in the major scientific search engines (Table 5).

Scientific references search engines	URL
Google Scholar	https://scholar.google.es/
Biological Abstracts	https://www.ebscohost.com/academic/biological-abstracts
Bio One	http://www.bioone.org/
Wos and the Zoological Record	https://webofknowledge.com/
Scopus	https://www.scopus.com/
Russian	http://elibrary.ru/defaultx.asp
China Knowledge Integrated Database	http://oversea.cnki.net/

Table 5. Scientific search engines scanned in search of buttonquail related publications.

Classical reference searchs started with the two major authoritative books on buttonquails: "Bustards, Hemipodes and Sandgrouse: Birds of Dry Places" (Johnsgard 1991) and "Pheasant, Partridges and Grouse" (Madge & McGowan 2002), together with all major handbooks and faunas: India & Pakistan (Ali & Ripley 1980), Western Palearctic (Cramp & Simmons 1980), Africa (Urban et al. 2002) former Soviet Union (Dementiev et al. 1970), Australia & New Zealand (Marchant & Higgins 1993) and the World (del Hoyo et al. 1996). All references found in those sources and the references cited by them were revised and fed to a bibliographic database. This process was systematically repeated for all references until no new references were found on either the new publications or the internet search engines.

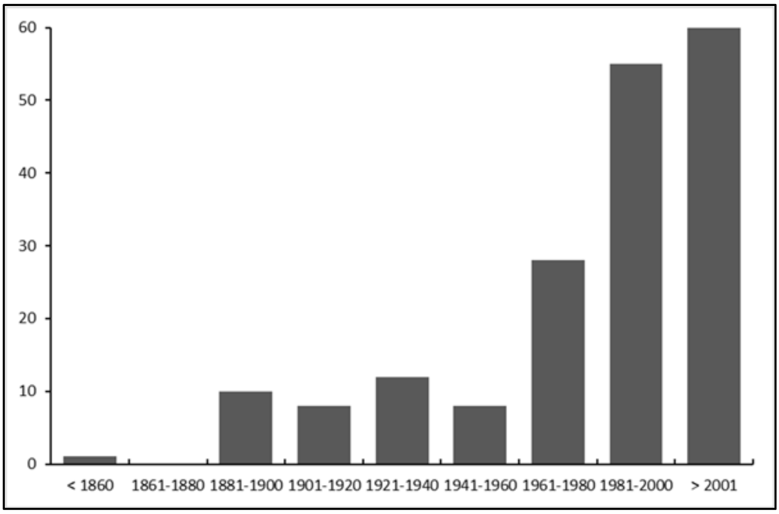


Figure 7. Number of publications sorted in periods of 20 years.

As a result, I found a total of 184 publications which specifically dealt with buttonquail species. One study has been found to be published twice, within an interval of 20 years (Balatsky et al. 1994 and Balastsky et al. 2014). Together with the two mentioned books, up to six works aim at the study of the whole family (Ogilvie-Grant 1889, Ridley 1983, Rotthowe and Starck 1998 and Gutiérrez-Expósito 2019), four more study extinct taxa in a paleontological context (Olson 1994, Mayr and Knopf 2007, Meijer et al. 2019, Zelenkov et al. 2016) while the remnant 172 focused on one or a very limited number of species. As in other bird groups, the number of publications has increased in the last 40 years. However, the number of references prior to 1960 is quite important (21.3 %) with up to 11 dated in the XIX century (Figure 7).

Species	Publications	Species	Publications
Common Buttonquail	73	New Caledonian Buttonquail	0
Red-backed Buttonquail	7	Painted Buttonquail	7
Yellow-legged Buttonquail	7	Buff-breasted Buttonquail	12
Black-rumped Buttonquail	3	Chestnut-backed Buttonquail	1
Hottentot Buttonquail	7	Red-chested Buttonquail	4
Spotted Buttonquail	0	Sumba Buttonquail	1
Barred Buttonquail	15	Luzon Buttonquail	1
Madagascar Buttonquail	7	Little Buttonquail	6
Black-breasted Buttonquail	24	Quail-plover	3

Table 6. Buttonquail species within the Turnicidae family, sorted by systematic order, noting number of publications referring to any species.

The number of publications per species is shown in Table 6. All references have been classified by its publication year, type of publication, review system, publisher type, base of the study, study subject, language and focal species (Table 7). A comprehensive list of these references is given in the References section (even if they have not been cited in any of the sections or chapters of the PhD) and have been marqued with an asterisc.

Classification	Types	N
Publication type	book	2
	papers and articles	147
	technical report	18
	proceedings	2
	PhD thesis	1
Review process	blind peer	78
	editor	71
	specific advisors	4
	not reviewed	31
Publisher type	editorial	35
	government agencies	17
	non-governmental organizations	59
	research institute	14
	scientific society	89
Base of study	museum specimens	3
	field	104
	captive	42
	review	35
Study subject	acoustics	1
	captive breeding	32
	ecology	27
	conservation	15
	monographies	2
	genetics	1
	identification	3
	methods	3
	migrations	3
	paleontology	4
	parasitology	2
	physiology	10
	predation	2
	status and distribution	72
	taxonomy	7
Idiom	Chinese	2
	English	127
	French	3
	German	16
	Italian	3
	Portuguese	1
	Russian	3
	Spanish	29

Table 7. Classification of buttonquails publications (N = 184) by type, review system, publisher type, base of the study, study subject and idiom.

General study area

The field study area is situated in the region of Doukkala-Abda in the Atlantic coast of Morocco. It consists in a narrow coastal sandy agricultural area which runs from NE to SW between Sidi Abed (33.047 N, 8.688 W) and Cap Bedouzza (32.571 N, 9.243 W) and some remnants of Mediterranean scrubland, characterised by palmetto (*Chamaerops humilis*), bridal broom (*Retama monosperma*) and Moroccan spiny broom (*Chamaecytisus mollis*), embedded within a calcareous plateau of highly degraded arid pastureland a few km inland of the town of Oualidia (Figures 8 and 9).

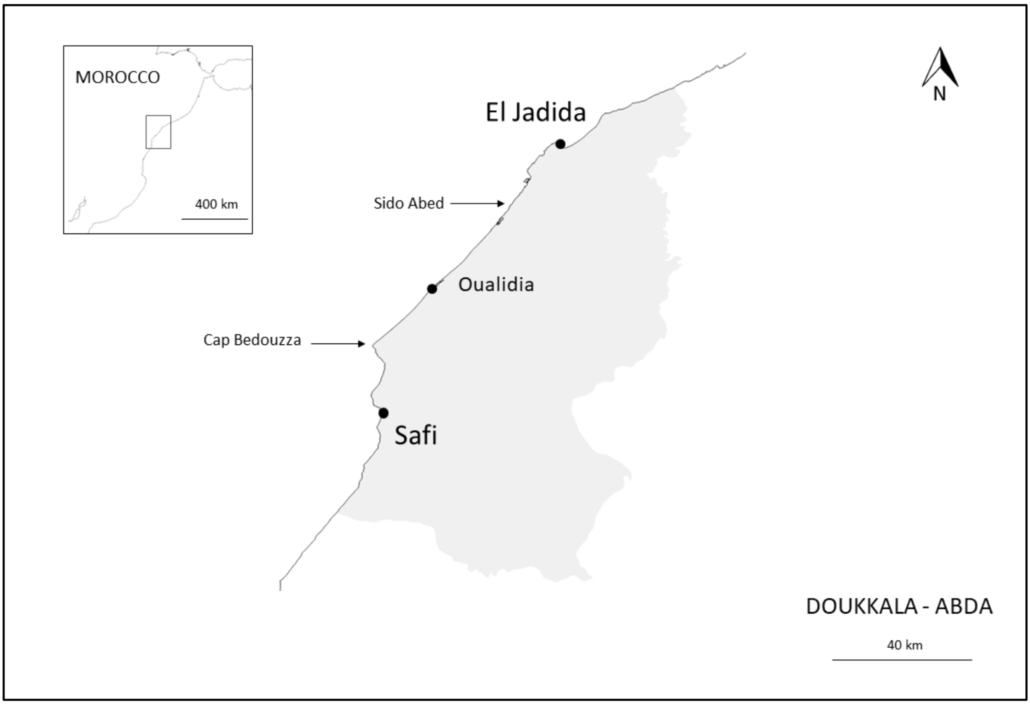


Figure 8. Map of situation of the study area in the Doukkala-Abda region (grey shaded area).


Appearance of the agricultural area at Ouled Ghanem (left) and Sidi Moussa (right)


Palmetto shrub | Spiny broom

Figure 9. Landscape examples of the field study area.

Materials, techniques and methodologies

To achieve the goals planned for this thesis, many traditional methodological procedures have been used. However, probably the main issue to solve has been the detection of the presence of buttonquails. The striklingy sculking nature of these creatures made the mere detection of their presence to be a true challenge for field biologists. Search field techniques have alredy been published as supplementary material of Chapter IV (Gutiérrez-Expósito et al. 2019), but due to is transversal importance for the whole PhD, are detailed here.

Buttonquails are very secretive birds that are most often very difficult to sight. This shy behavior has made these birds very difficult to study in the wild (Lee et al. 2019), so indirect approximations based on the identification of signs, more commonly used in the study of mammals than in ornithology, showed to be very helpful (i.e. Mills et al. 2002, Smart et al. 2003). The presence of buttonquails was detected using the signs of presence described by Gutiérrez-Expósito and Qninba (2010). In the 2010 survey, for each positive plot, we noted all buttonquail signs of presence (N = 69). The histogram obtained showed that excrements were the more reliable and easy track to find (Figure 10).

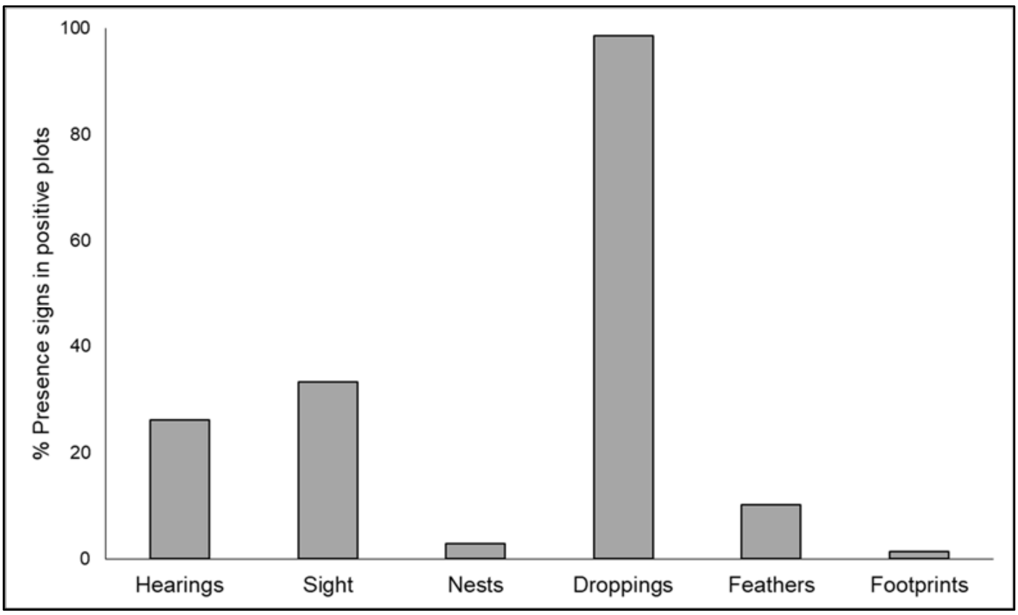


Figure 10. Percentage of different signs of presence in the positive plots.

For positive plots in 2011, 2014 and 2017, we also noted the time spent to find the first sign of presence and calculated the relative time (minutes/ha) needed (N = 46). The resulting curve of cumulative effort showed a fast saturation of the form (Figure 11):

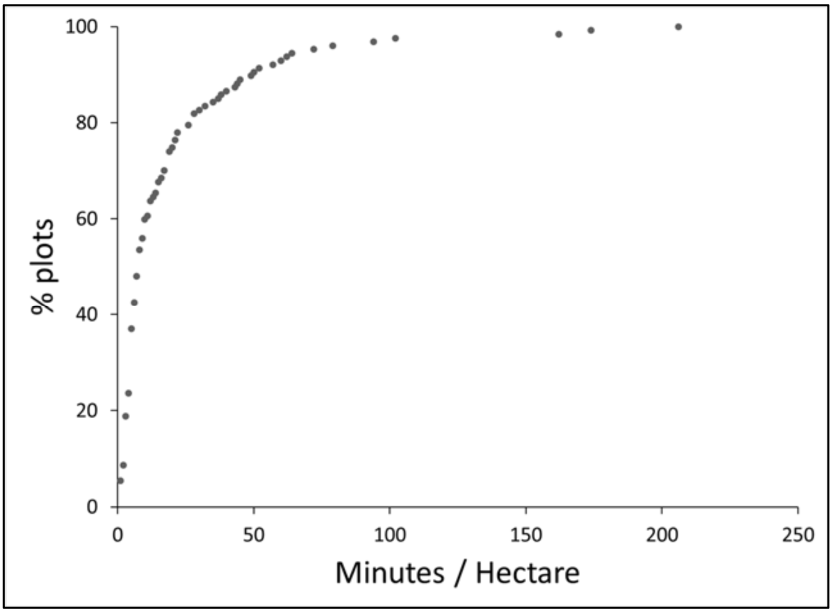


Figure 11. Effort (minutes/hectare) accumulative data to find the first dropping.

We used the resulting curve to calculate the probability of false negatives in non-positive plots for these three surveys. Just one negative parcel had a probability higher than 0.5 of being a false negative and only 6 % of the negative plots have a probability of 0.3 or higher of being false negatives, while up to 53,8 % of them were on the 100% of probability of being a real negative. Besides this, a number of techniques and methodologies has been used for the development of the PhD, which are summarized here.

Internet search

Apart from the academic search mentioned above, two specific internet searches have been done to feed the database. By using the images Google search engine, a systematic search of thousands of high resolution pictures of bright coloured eyes in birds has been done to study the presence of asymmetric heterchromia in the whole Class Aves (Chapter II). Finally, specific museum and biodiversity databases have been consulted (vertnet.org, gbif) to find all the localities of Andalusian Buttonquail specimens in museums to reconstruct the historical distribution area of the taxon (Chapter III).

eBird

eBird is the world's largest biodiversity-related citizen science project, contributed each year by eBirders around the world. Managed by the Cornell Lab of Ornithology, eBird is a collaborative enterprise with hundreds of partner organizations, thousands of regional experts, and hundreds of thousands of users. Basically eBird users record bird checklists for a given location at a given moment. Users are encouraged to do complete checklists by logging all birds seen during a sampling event and explicitly ticking it when uploading. These complete checklists allow the use of pseudoabsences for species distribution modelling. At the moment of writing this text, eBird have data on 10,508 bird species and have generated 39,074,475 complete checklists by 497,994 users around the globe.

As part of the Turnicidae review (Chapter I) up to 21,511 buttonquail observations have been obtained from eBird, together with 6,823,781 sampling events performed by eBirders within the distribution areas of all buttonquail species.

Geographic Information System

To work with this huge amount of buttonquail spatially explicit information, the use of Geographic Information Systems (GIS) has been essential. A GIS is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. This spatial data is stored in tabular form, an associated with attribute tables. Attribute data can be generally defined as additional information about each of the spatial features (metadata). Together with the analysis of spatial distribution of all Turnicidae species (Chapter I), the GIS has also a basic role as main tool to reconstruct the historical distribution area of the Andalusian Buttonquail and extract the environmental variables for spatially explicit niche modelling and PCA analyses (Chapter III). All work has been done by using the open license software QGIS (qgis.org).

Statistical analyses

Statistical procedures were used in almost all chapters based maily in linear regressions and principal component analysis. Prior to the analyses, the correlation among variables was evaluated by constructiing a correlation matrix with the "GoodmanKruskal" R package (Pearson 2016) and variables multi-collinearity was assessed with the "cor" R package (Fox and Weisberg 2011). Model selection was made using the Akaike Information Criteria for smaller samples (AICc) (Hurvich and Tsai 1989).

Principal component analysis (PCA) is a technique used for identification of a smaller number of uncorrelated variables (normally 2) known as principal components from a larger set of covariates. The technique is widely used to emphasize variation and to capture strong patterns in a data set and as a tool used in predictive models and exploratory data analysis. To study the decline of the Andalusian Buttonquail (Chapter III), niche modelling was used to reconstruct the historical distribution area of the taxon with a reduced series of environmental variables into two gradients. The same procedure was used to analyse the land use change proceses from historical times to present in Andalusia (Chapter III).

Generalized linear models (GLM) are a flexible generalization of ordinary linear regressions used in statistics that allows for response variables that have error distribution models other than a normal distribution. The GLM generalizes linear regression by allowing the linear model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value. In our niche modelling analysis for historical distribution and land use changes (Chapter III) and breeding habitat selection (Chapter V), we used the presence/absence of buttonquails, so we proceed with a binomial distribution with a logit link function, with the R package "stats" (R Core Team 2017). To deal with the different sampling sites in the habitat occupancy analysis (Chapter IV), we used Generalized Linear Mixed Models (GLMM), using the sampling site as random effect (Bates et al. 2015). GLMMs fitness level was measured by evaluating ROC curves with the "pROC" R package (Robin et al. 2011).

Finally, breeding habitat selection (Chapter V) was analysed by means of the Ivlev''s electivity index, as modified by Jacobs (1974).

Andalusian Buttonquail by Francesco Cupani, published in 1713 as Coturnix triunguis in his work Panphytum Siculum. This is the oldest known illustration of any buttonquail species

SECTION 1

Chapter I

Who's first? A rarity index to priorize monitoring and conservation efforts of the poorly-known buttonquails (Turnicidae)

Gutiérrez-Expósito, C., Clavero, M., Revilla, E. (in prep.)

Introduction

The assessment of conservation status is largely based on accurate scientific knowledge of the natural history of species, the ecosystems where they live and the trends in their distribution ranges and/or overall abundances (Dayton, 2003; Groves et al., 2002; Sutherland et al., 2004). Due to the high diversity of living forms, these assessments are usually made only at species level (IUCN 2019). Nevertheless, conservation status can also be evaluated at lower taxonomic levels, such as subspecies, and at multiple ecologically or geographically defined units, such as populations. While invertebrates, plants and fungi have an insufficient evaluation coverage, vertebrates have a much better assessment level, being birds the first group to achieve a complete extinction risk evaluation for all the known species (IUCN 2019). However, when dealing with secretive species, it is not always possible to achieve strong scientifically supported assessments, due to the absence of both scientific knowledge and good field data (Papeş and Gaubert, 2007; Raphael and Molina, 2013). Among terrestrial vertebrates, perhaps birds are the easiest group to detect by sight and thus to study. However, a few bird groups are particularly difficult to observe as is the case of some nocturnal, marsh or forest bird species (e.g. Owls *Strigidae*, Crakes and Rails *Rallidae*, Pittas *Pittidae* or Tapaculos *Rhinocryptidae*). Even so, most of them are quite easily detected by their vocalizations, which helps in their study. However, there are a few bird species on which no behavioral or biological trait gives a definitive clue to be detected. Among them, buttonquails *Turnicidae* are one of the most difficult birds to detect by both sight and voice. This family is composed by 18 bird species, all belonging to the genus *Turnix* except the rare Quail Plover (*Ortyxelos meiffrenii*). Including the monotypic species, up to 59 taxa are recognized at subspecific level (del Hoyo and Collar 2014). These small ground birds are rarely detected due to their secretive habits and the absence of powerful songs and calls (Debus, 1996; Madge & McGowan, 2002; Gutiérrez-Expósito et al., 2011), being most notably detected by their tracks and other signs of activity (Gutiérrez-Expósito et al., 2011; Lees and Smith, 1998). This unobtrusive behavior has made buttonquails one of the least studied bird families.

App-based citizen science platforms provide an opportunity to overcome the scarcity of scientific-based information on buttonquails and other poorly-known bird groups through the participation of a huge amount of bird observers reporting worldwide (Wiersma 2010, Wood et al. 2011). Among others, eBird is a worldwide used citizen science birding web based platform created by the Cornell Lab of Ornithology. Simultaneously a GPS supported mobile phone app has been developed to allow observers logging their observations in a straightforward way, including data on effort as time spent birding or distance walked (Sullivan et al. 2014). Bird data is based on the creation of birding checklists for a given location and date. Every checklist gives the option to record bird numbers or just presence under different protocols. Moreover, its necessary to note if all observed birds have been recorded (complete checklist) or not (partial checklist), allowing the use of pseudoabsences in ecological modelling. Currently, eBird is the largest birding platform with near half a million users distributed around the globe, who have contributed to this day nearly 40 millions of complete checklists.

In this paper we evaluate the conservation and knowledge status of the elusive buttonquails (Turnicidae) using the available published information and the field data provided by eBird (ebird.org), and by means of a description of their relative abundance and the amount and accuracy of available information.

Methods

We requested the Cornell Lab of Ornithology for all buttonquail species data (hereafter observations) available in the eBird platform, together with a global database of effort events (hereafter checklists). We accesed all datasets between 1913 and may 2019. The use of the application increses dramatically from 2016 onwards, so up to 50 % of the observations belong to the last four years (Figure 1.1).

Buttonquails are terrestrial birds, so we used all eBird available data except those logged under the pelagic protocol (Sullivan et al. 2009). With these data we created a spatially explicit GIS file for every buttonquail taxon. Even when common, buttonquails are seldom seen and any sight is very appreciated by birdwatchers, so we assumed that all buttonquails are equally difficult to observe and that they are always registered when an encounter with any of the species takes place. Consequently, we assumed that whenever buttonquails were not mentioned in a checklist the bird had not been spotted and thus we treated those checklists as buttonquail absences.

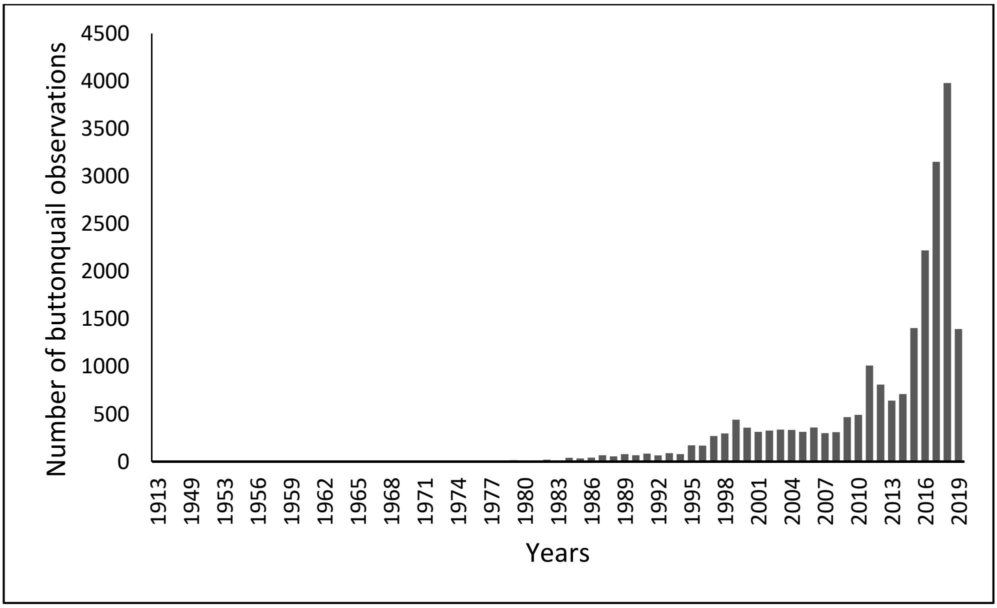


Figure 1.1. Annual distribution of buttonquail observations in the eBird database.

We used buttonquail distribution maps provided by BirdLife International and Handbook of the Birds of the World (2018) to define the working areas for every buttonquail species. We calculated the area, in km^2, by using the “area” algorithm of QGIS in the World Cylindrical Equal Area coordinates reference system. The same data was extracted for every recognized subspecies except for those of Barred Buttonquail (*Turnix suscitator*) in mainland Asia for which a clear barrier between races can not be defined. Consequently, Indian Subcontinent subspecies *taigoor* and *bengalensis* have been treated together and SE Asia races *blackistoni*, *pallescens*, *thai* and *plumbiceps* have also been treated jointly. For every taxon, we calculated a rarity index as a combination of two parameters: the scarcity of the taxon and the uncertainity of the available data, which respectively are based on two components (Table 1.1).

Index	Parameter	Component
Priority	Scarcity	relative abundance
		relative extent of occurrence
	Uncertainity	eBird coverage
		extent of occurrence accuracy

Table 1.1. Components conforming the parameters to build the priority index.

We defined the relative abundance as the proportion of positive checklists out of all checklists made within the taxon BirdLife distribution area. The relative extent of occurrence results from scaling, between 0 and 1, all distribution areas by min-max normalization. We calculated the eBird coverage as the eBird checklist density within the BirdLife distribution area, while the extent of occurrence accuracy is the proportion of the positive checklists which lay within the BirdLife distribution area. Considering a possible multiplicative effect of the components, each parameter is calculated as the geometric mean of its correspondent components. To avoid the skewness of results we used as parameters the absolute values resulting of a logarithmic transformation. To allow operations, all zero and zero/zero values have been approximated to 10^{-10}. Finally, we calculated the monitoring priority index as the Euclidean distance to the origin in a bidimensional space defined by the uncertainity and scarcity parameters.

To validate our priority index, we gave values to the IUCN Red List categories as Least Concern = 1, Near Threatened = 2, Vulnerable = 3, Endangered = 4 and Critically Endangered = 5 (IUCN 2019). Correlation has been calculated with these values and the obtained priority index value for every species.

Results

eBird data

We obtained a total of 21,511 buttonquail eBird observations from 8,948 different localities worldwide (Table 1.2), comprising all buttonquail species except the Luzon Buttonquail (*Turnix worcesteri*) (Figure 1.2) and the New Caledonian Buttonquail (*Turnix novaecaledoniae*) (Figure 1.3). More than half of the observations corresponds to a single species, the Barred Buttonquail (N = 11,314) (Figure 1.4), while other frequently recorded species are the Painted (*Turnix varius*) (N = 2,929 - 13.7 %) (Figure 1.5), Common (*Turnix sylvaticus*) (N = 1,964 - 9.2 %) (Figure 1.6) and Little (*Turnix velox*) (N = 1,783 - 8.3 %) (Figure 1.7) buttonquails. All other species comprise less than 5 % of the overall buttonquail observations (Table 1.1). The proportion of observations of a species that fell within its distribution area as reported by BirdLife International ranged between 100% in Spotted Buttonquail (*Turnix ocellatus*) (N = 171) (Figure 1.8) and Sumba Buttonquail (*Turnix everetti*) (N = 36) (Figure 1.9) and 0% in the Buff-breasted Buttonquail (*Turnix olivii*) (N = 12) (Figure 1.10). The sampling effort made by birdwatchers within the distribution areas of the different buttonquail species was very variable ranging from 2 checklists/100 km^2 for the Black-rumped Buttonquail (*Turnix nanus*) (Figure 1.11) to 60 checklists/100 km^2 and 86 checklists/100 km^2 for the Black-breasted Buttonquail (*Turnix melanogaster*) (Figure 1.12) and the Buff-breasted Buttonquail respectively (Table 1.2). Distribution maps and eBird sightings of all buttonquails species are shown in figures 1.2 to 1.19.

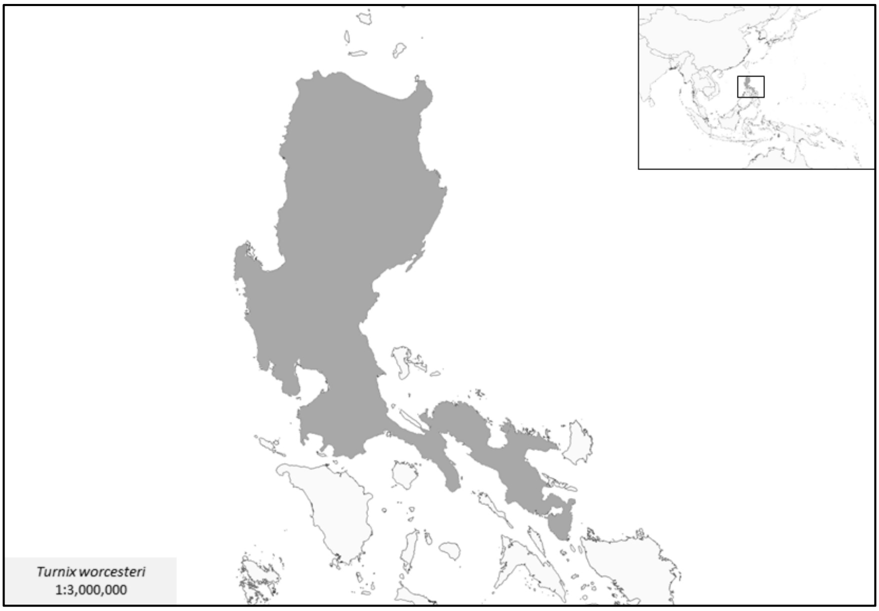


Figure 1.2. Luzon Buttonquail (*Turnix worcesteri*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area). No eBird data exists.

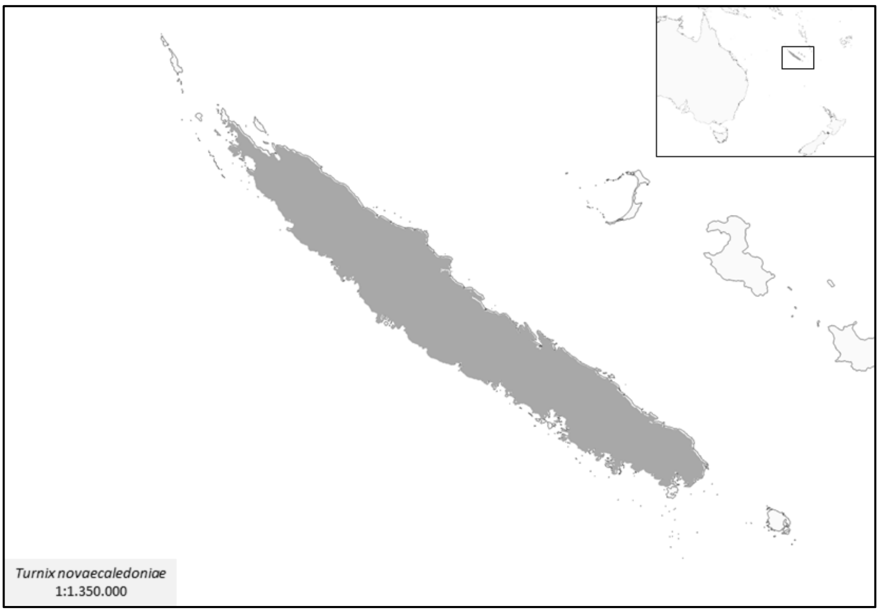


Figure 1.3. New Caledonia Buttonquail (*Turnix novaecaledoniae*) former distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area). No eBird dat exists.

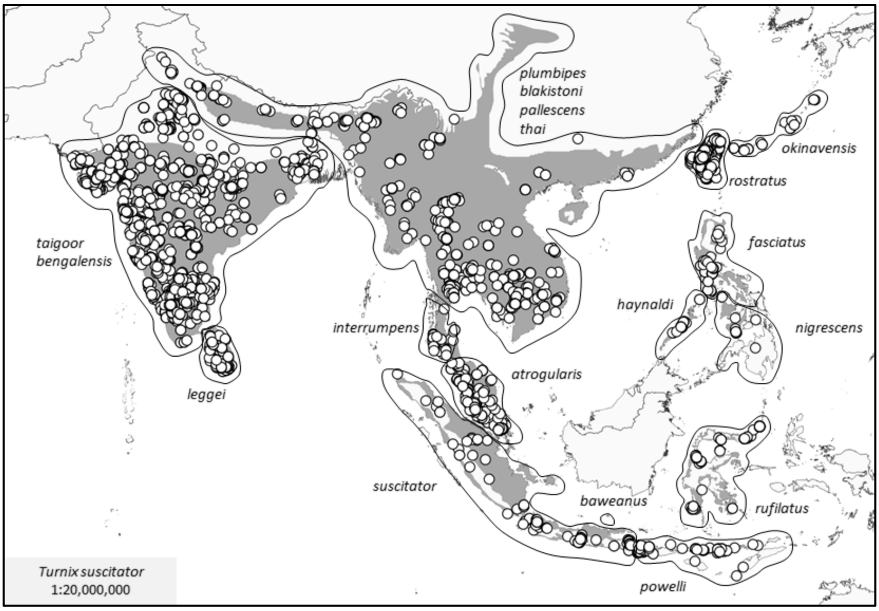


Figure 1.4. Barred Buttonquail (*Turnix suscitator*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

Figure 1.5. Painted Buttonquail (*Turnix varius*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

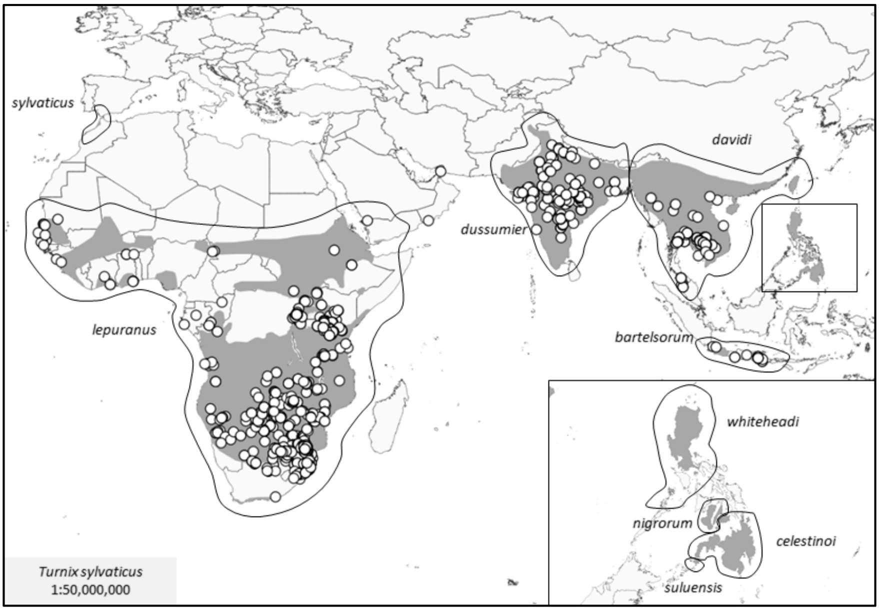


Figure 1.6. Common Buttonquail (*Turnix sylvaticus*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

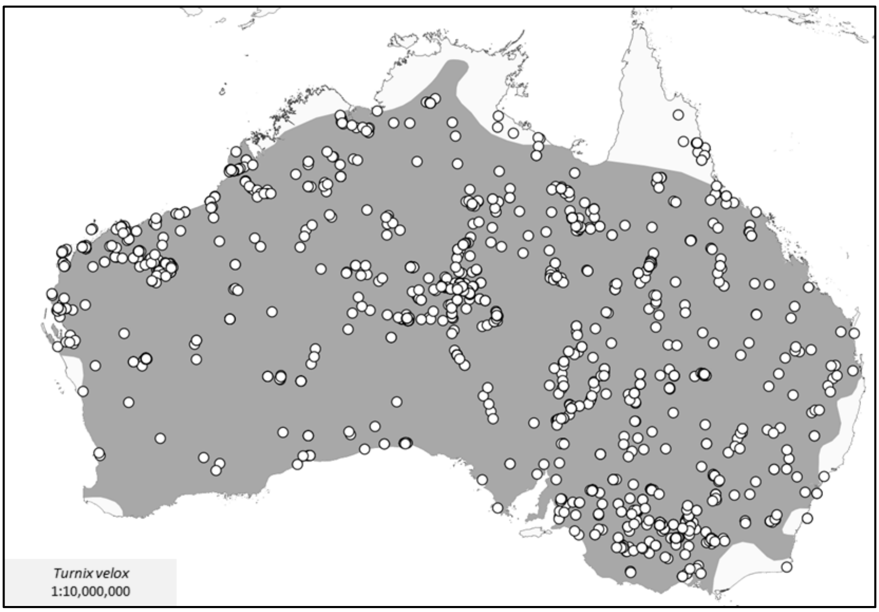


Figure 1.7. Little Buttonquail (*Turnix velox*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

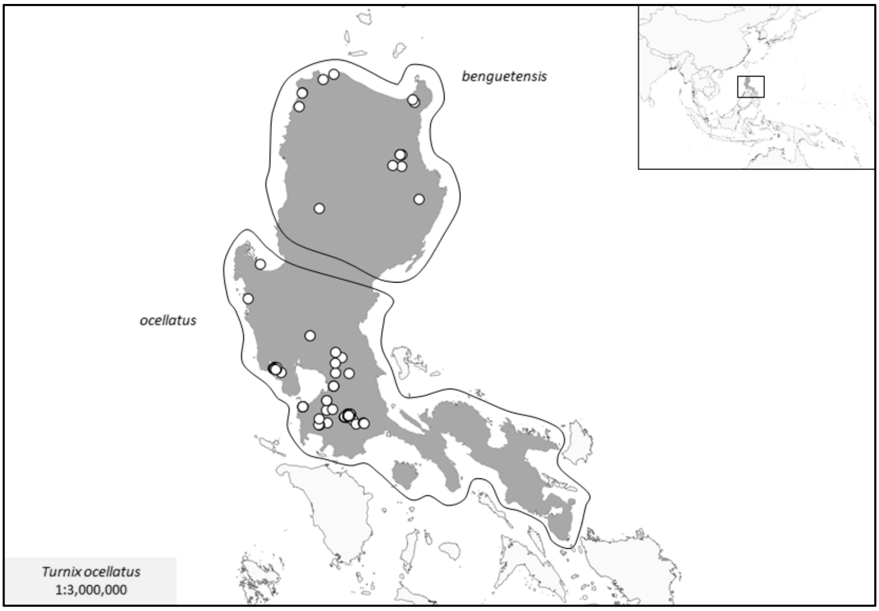


Figure 1.8. Spotted Buttonquail (*Turnix ocellatus*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

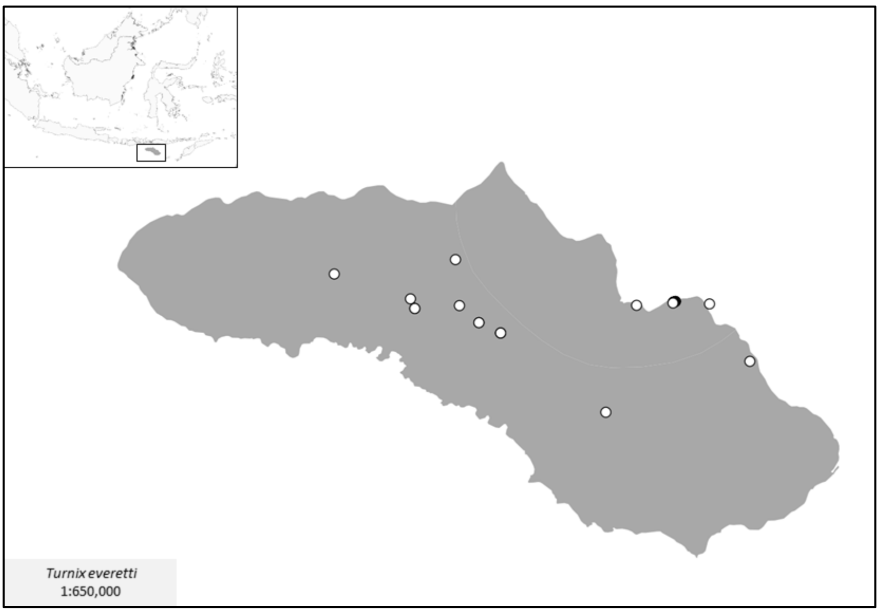


Figure 1.9. Sumba Buttonquail (*Turnix everetti*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

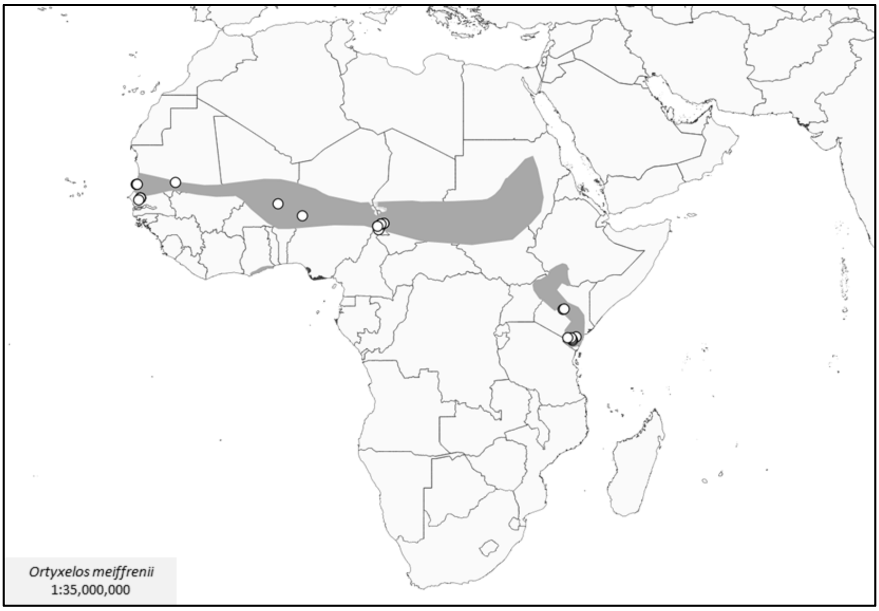


Figure 1.10. Black-rumped Buttonquail (*Turnix nanus*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

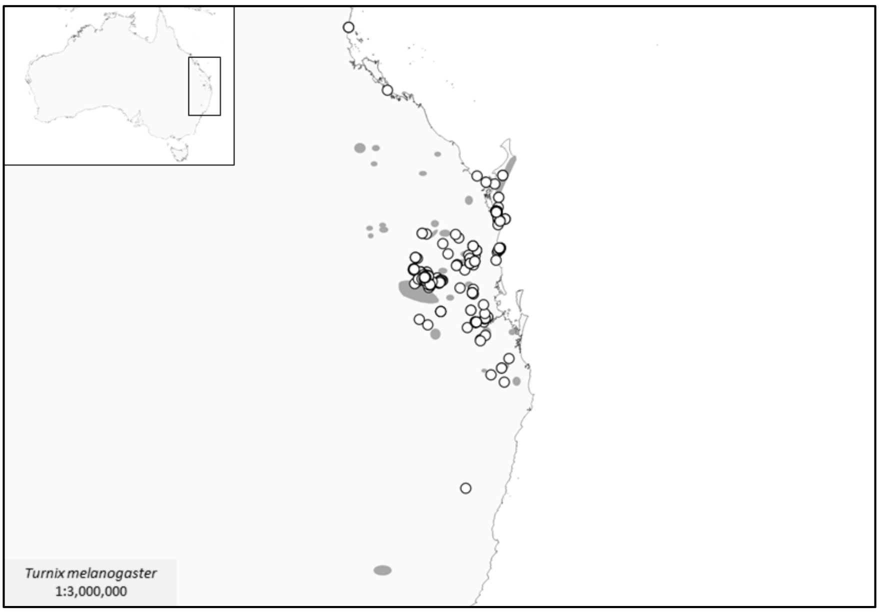


Figure 1.11. Black-breasted Buttonquail (*Turnix melanogaster*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

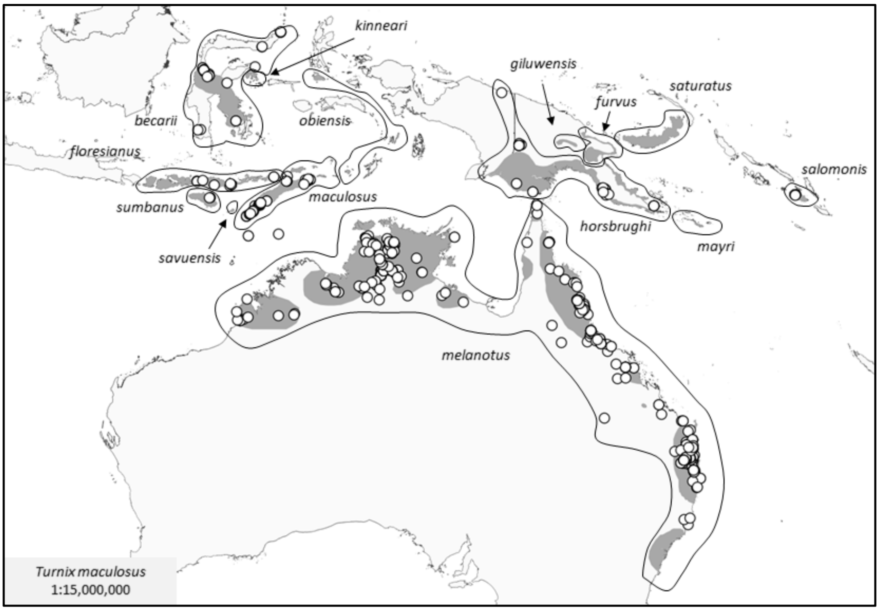


Figure 1.12. Red-backed Buttonquail (*Turnix maculosus*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

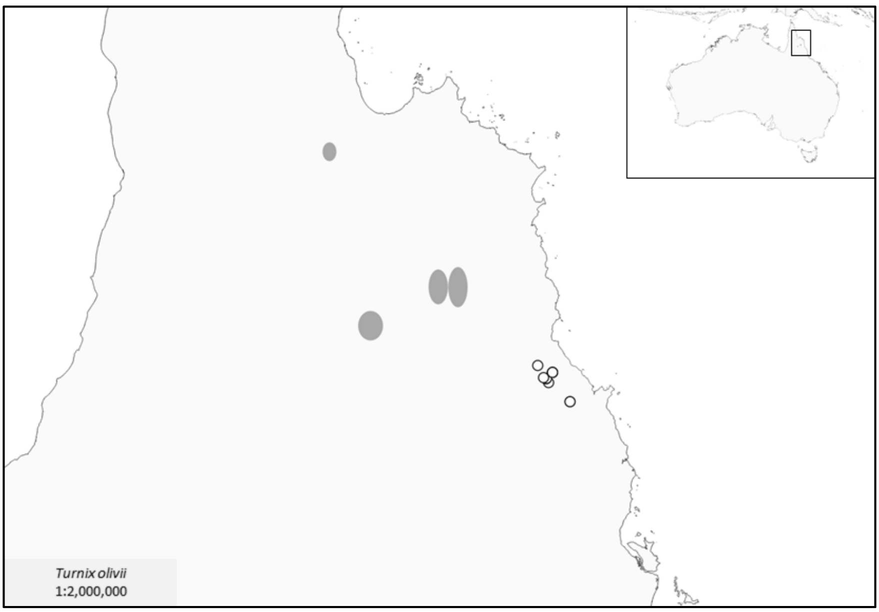


Figure 1.13. Buff-breasted Buttonquail (*Turnix olivii*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

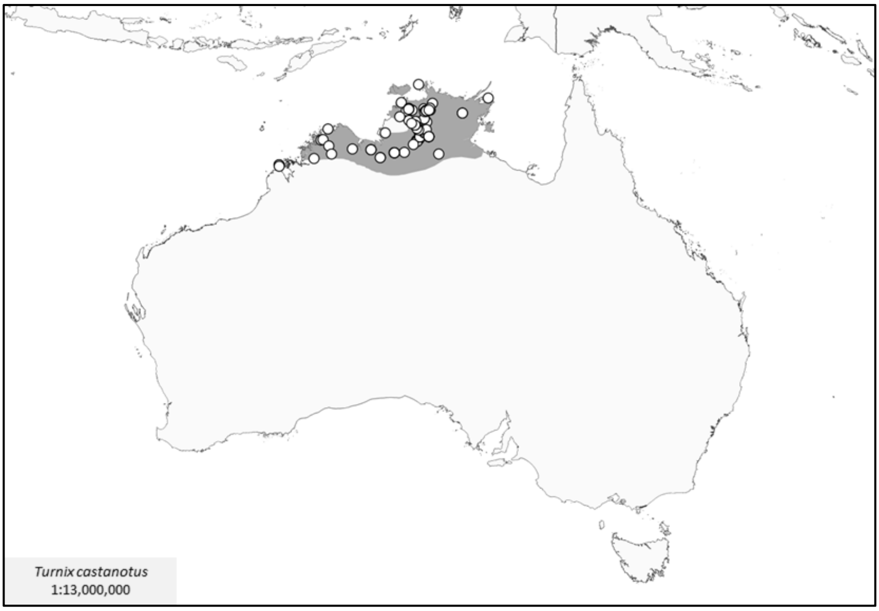


Figure 1.14. Chestnut-backed Buttonquail (*Turnix castanotus*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

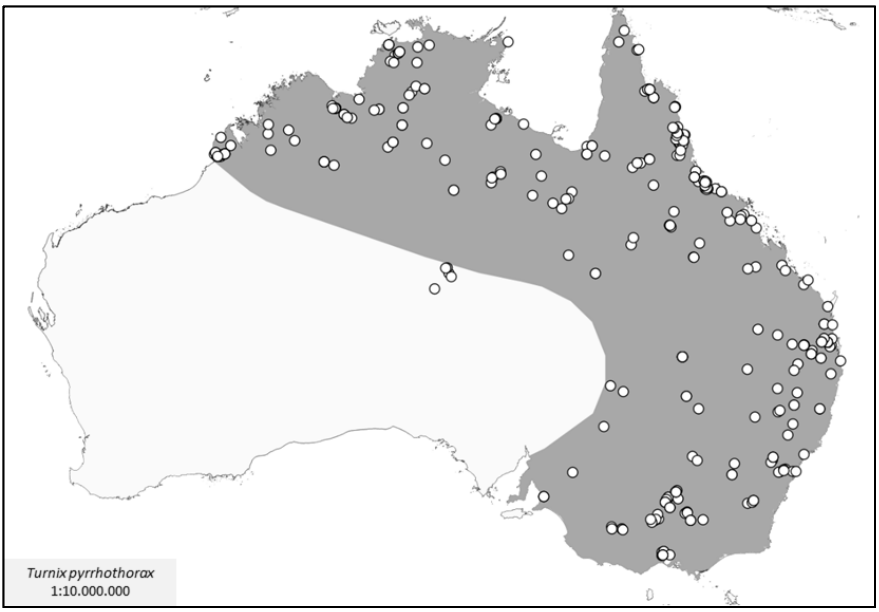


Figure 1.15. Red-chested Buttonquail (*Turnix phyrrothorax*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

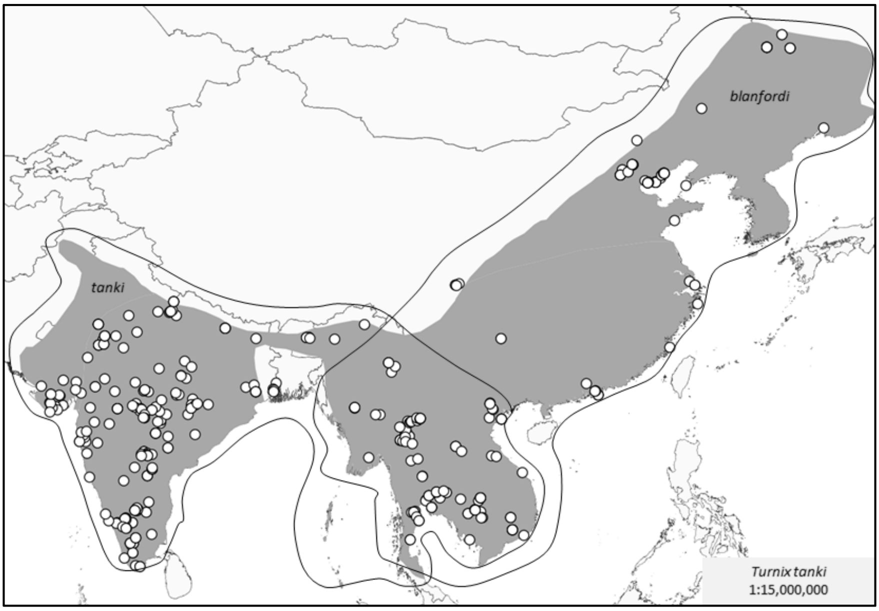


Figure 1.16. Yellow-legged Buttonquail (*Turnix tanki*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

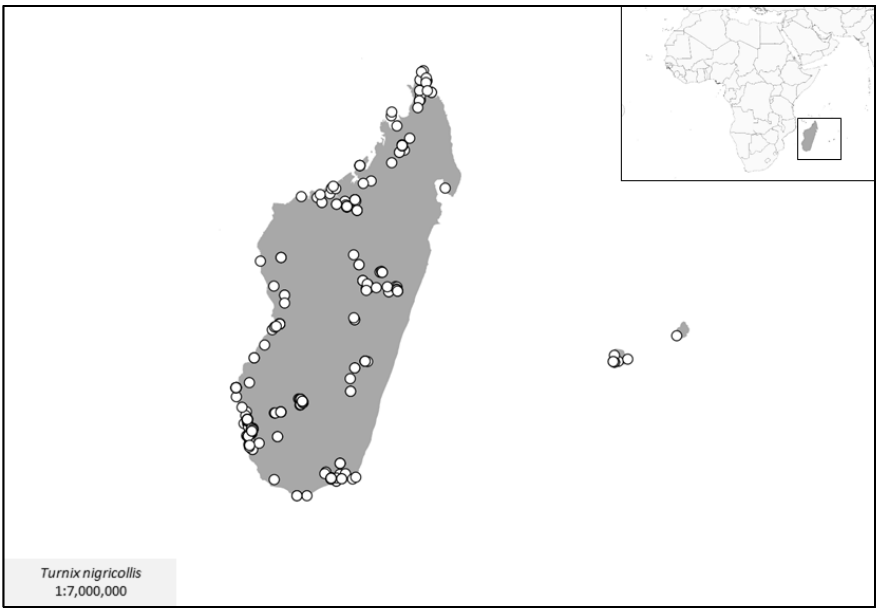


Figure 1.17. Madagascar Buttonquail (*Turnix nigricollis*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

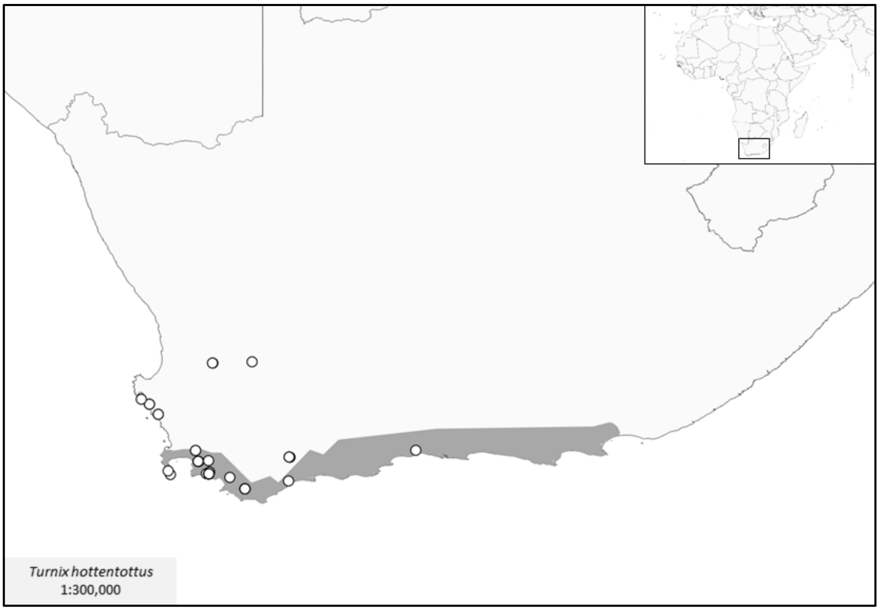


Figure 1.18. Hottentot Buttonquail (*Turnix hottentottus*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

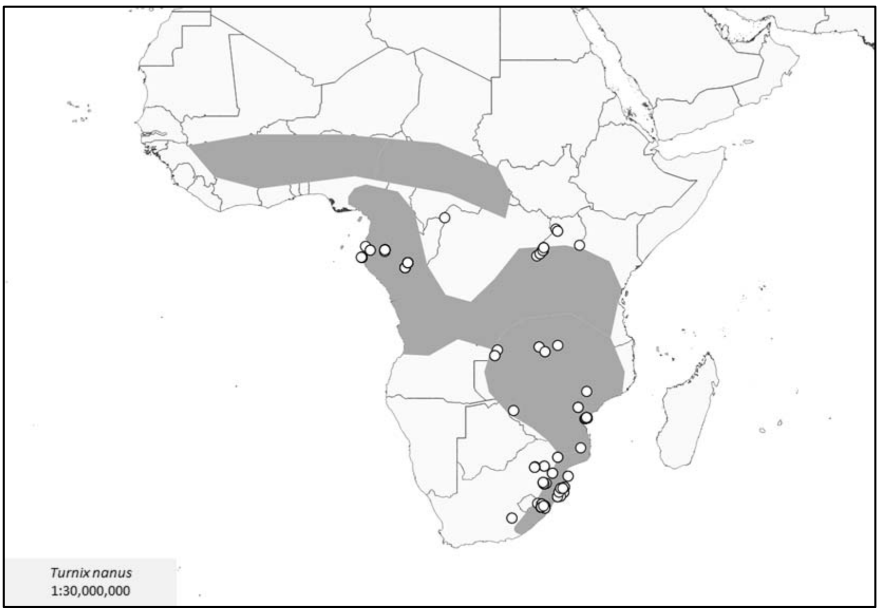


Figure 1.19. Quail Plover (*Ortyxelos meiffrenii*) distribution area based on BirdLife International and Handbook of the Birds of the World (2018) (grey shaded area) and eBird data (white dots).

Together with the monotypic Luzon and New Caledonia Buttonquails, up to 26 buttonquail subspecies have not a single observation in the eBird database (Table 1.2). Apart from the monotypic Little and Painted Buttonquails, three subspecies or subspecies groups of Barred Buttonquail had more than 1,000 observations: Taiwan (*T.s. rostratus*) (N = 4,289, 19.9 %), Indian (*T.s. taigoor* and *bengalensis*) (N = 4,185, 19.5 %) and Indochinese (*T.s. blackistoni, pallescens, thai* and *plumbiceps*) (N = 1,061, 4.9 %), together with the Kurrichane Buttonquail (*T. sylvaticus lepuranus*) (N = 1,327, 6.2 %) (Table 1.2). Up to 13 subspecies or monotypic species (23.6 %) have all their eBird observations within the BirdLife International corresponding distribution area, while for the rest exists a great variation, ranging from 0 % in the Buff-breasted Buttonquail to 99 % in the Madagascar Buttonquail (*Turnix nigricollis*). The highest effort density is found in the distribution area of the Taiwan Barred Buttonquail (*T.s. rostratus*) with up to 1,323 checklists/100 km^2.

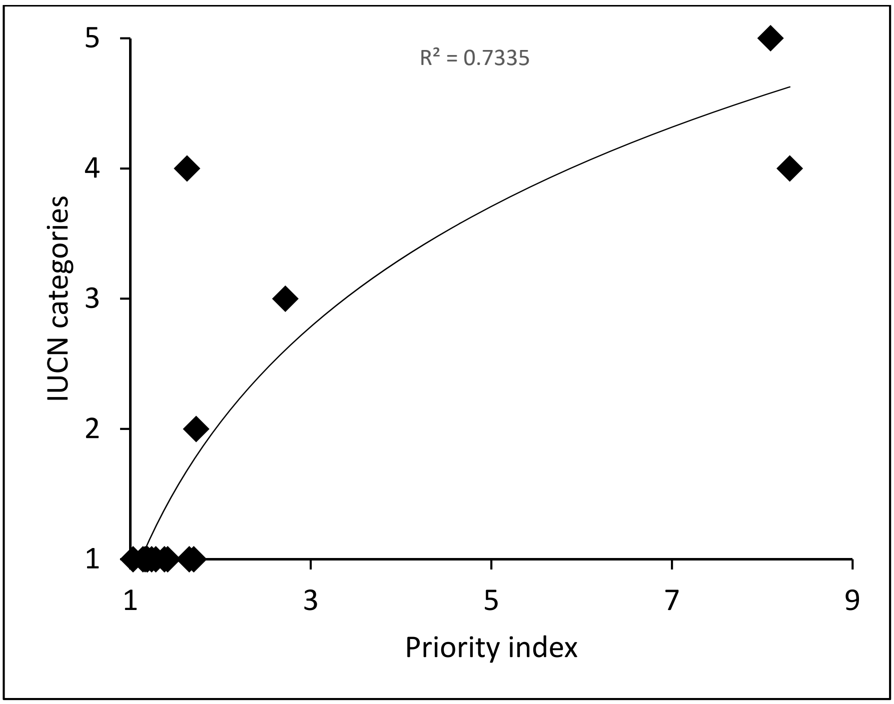


Figure 1.20. Logarithmic correlation between the priority index and the scaled IUCN extinction risk categories for all buttonquail species.

Rarity index

The rarity index ranked all buttonquail species between 1.00 and 8.30, and have a significant correlation with the IUCN categories (R^2 = 0.73) (Figure 1.20). Lower values correspond to the commonest and widespread species such as Barred Buttonquail, Painted Buttonquail, Common Buttonquail, Red-backed Buttonquail (*Turnix maculosus*) or Little Buttonquail.

Species	eBird total	eBird in IUCN	eBird checklists	Extent of occurrence	IUCN	Monitoring priority
Turnix sylvaticus	1,964	1,857	1,531,808	22,843,450	LC	1.19
Turnix maculosus	741	680	425,389	1,139,432	LC	1.16
Turnix tanki	537	492	958,809	9,316,208	LC	1.28
Turnix nanus	211	138	125,697	6,616,766	LC	1.65
Turnix hottentottus	51	40	16,221	333,360	EN	1.63
Turnix ocellatus	171	171	10,503	106,158	LC	1.38
Turnix suscitator	1,1314	8,346	1,122,928	9,066,182	LC	1.03
Turnix nigricollis	676	675	12,807	61,661	LC	1.19
Turnix melanogaster	473	66	3,627	5949	NT	1.73
Turnix novaecaledoniae	0	0	1,068	16,389	CR	8.09
Turnix varius	2,929	2,858	906,111	2,276,774	LC	1.00
Turnix olivii	11	0	1,777	2,066	EN	8.30
Turnix castanotus	149	146	33,112	419,636	LC	1.42
Turnix pyrrhothorax	430	419	886,925	4,284,398	LC	1.24
Turnix everetti	36	36	335	2065	VU	2.72
Turnix worcesteri	0	0	10,801	105,070	DD	7.83
Turnix velox	1,783	1,743	761,408	6,979,269	LC	1.14
Ortyxelos meiffrennii	35	24	14,455	295,158	LC	1.70

Table 1.2. Number of total eBird observations, number of observations and checklists within the BirdLife International distribution area, extent of occurrence area in km^2, IUCN category and monitoring priority index for every buttonquail species, by systematic order (del Hoyo and Collar 2014).

Highest values classified highly threatened species with a small distribution area, such as New Caledonian Buttonquail (*Turnix novaecaledoniae*), Luzon Buttonquail (*Turnix worcesteri*) and Buff-breasted Buttonquail, classified by IUCN as Critically Endangered, Data Deficient and Endangered, respectively (Table 1.2, Figure 1.21).

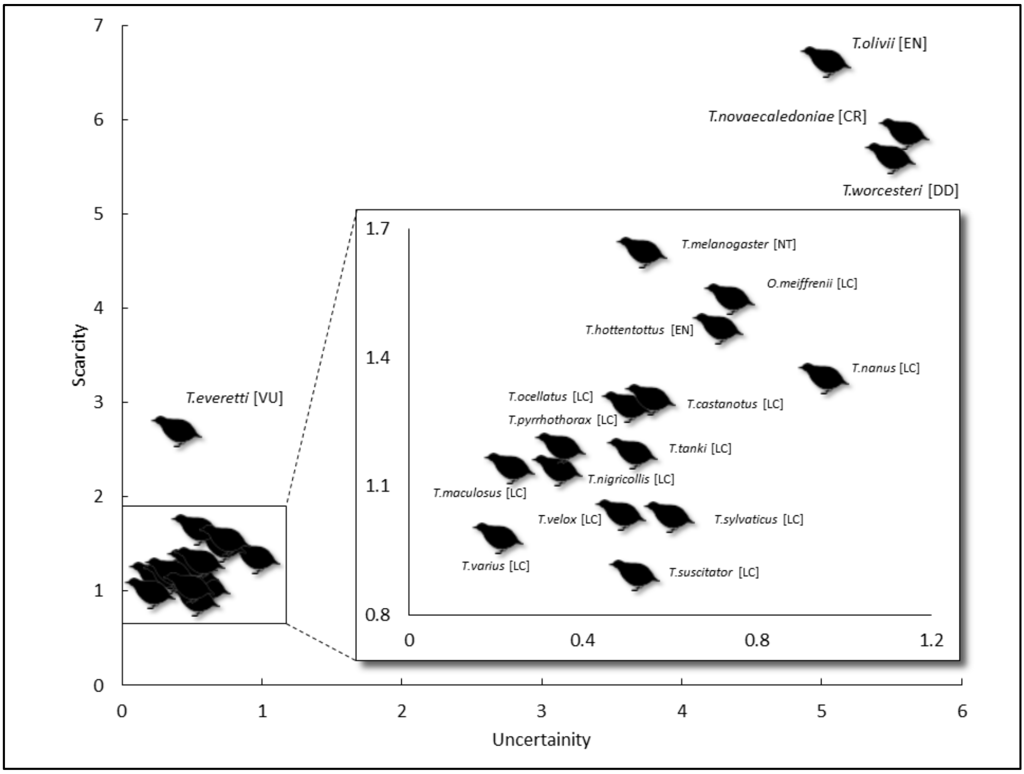


Figure 1.21. Rarity status of all buttonquail species. with IUCN risk extinction category in brackets. For a better understanding the lower monitoring priority index zone has been enlarged.

At subspecific level, lower values were 1.81, while highest rarity index reached 14.14. The four subspecies which was found to be the rarest were the Bawean Barred Buttonquail (*Turnix suscitator baweanus*), Savu Red-Backed Buttonquail (*Turnix maculosus savuensis*), Sulu Common Buttonquail (Turnix *sylvaticus suluensis*) and Banggai Red-Backed Buttonquail (*Turnix maculosus kinneari*). All of them endemics of small islands in Indonesia and the Philippines (Table 1.3, Figure 1.22).

Subspecies		Priority index	Subspecies		Priority index
Bawean Barred Buttonquail	*T. suscitator baweanus*	14.14	*Palawan Barred Buttonquail*	*T. suscitator haynaldi*	2.79
Savu Red-backed Buttonquail	*T. maculosus savuensis*	12.36	*Sumba Buttonquail*	*T everetti* *	2.78
Sulu Common Buttonquail	*T. sylvaticus suluensis*	12.20	*Dusky Barred Buttonquail*	*T. suscitator powelli*	2.77
Banggai Red-backed Buttonquail	*T. maculosus kinneari*	12.12	*Sulawesi Barred Buttonquail*	*T. suscitator rufilatus*	2.77
Louisiade Red-backed Buttonquail	*T. maculosus mayri*	9.58	*Timor Red-backed Buttonquail*	*T. maculosus maculosus*	2.73
Giluwe Red-backed Buttonquail	*T. maculosus giluwensis*	9.13	*Okinava Barred Buttonquail*	*T suscitator okinavensis*	2.72
Obi Red-backed Buttonquail	*T. maculosus obiensis*	8.74	*Black-breasted Buttonquail*	*T. melanogaster* *	2.67
Huon Red-backed Buttonquail	*T. maculosus furvus*	8.73	*Greater Sundas Barred Buttonquail*	*T. suscitator suscitator*	2.67
New Britain Red-backed Buttonquail	*T. maculosus saturatus*	8.59	*Kra Barred Buttonquail*	*T. suscitator interrumpens*	2.64
Negros Common Buttonquail	*T. sylvaticus nigrorum*	8.53	*Black-rumped Buttonquail*	*T. nanus* *	2.64
Buff-breasted Buttonquail	*T. olivii* *	8.52	*Luzon Barred Buttonquail*	*T. suscitator fasciatus*	2.52
New Caledonia Buttonquail	*T. novaecaledoniae* *	8.52	*Siberian Yellow-legged Buttonquail*	*T. tanki blanfordi*	2.47
Visayan Common Buttonquail	*T. sylvaticus celestinoi*	8.26	*Southern Spotted Buttonquail*	*T. ocellatus ocellatus*	2.46
Luzon Common Buttonquail	*T. sylvaticus whiteheadi*	8.15	*Chestnut-backed Buttonquail*	*T. castanotus* *	2.45
Luzon Buttonquail	*T. worcesteri* *	8.15	*Indian Common Buttonquail*	*T. sylvaticus dussumier*	2.35
Abrolhos Painted Buttonquail	*T. varius scintillans*	3.69	*Indian Yellow-legged Buttonquail*	*T. tanki tanki*	2.35
Andalusian Buttonquail	*T. sylvaticus sylvaticus*	3.53	*Indochinese Common Buttonquail*	*T. sylvaticus davidi*	2.35
Sumba Red-backed Buttonquail	*T. maculosus sumbanus*	3.46	*Red-chested Buttonquail*	*T. pyrrhothorax* *	2.24
Guadalcanal Red-Backed Buttonquail	*T. maculosus salomonis*	3.35	*Indochinese Barred Buttonquail*	*T. suscitator blackistoni, plumbipes, pallescens, thai*	2.20
Indonesian Common Buttonquail	*T. sylvaticus bartelsorum*	3.17			
Papuan Red-backed Buttonquail	*T. maculosus horsbrughi*	3.15	*Malay Barred Buttonquail*	*T. suscitator atrogularis*	2.18
Visayan Barred Buttonquail	*T. suscitator nigrescens*	3.07	*Australian Red-backed Buttonquail*	*T. maculosus melanotus*	2.16
Flores Barred Buttonquail	*T. suscitator floresianus*	3.06	*Kurrichane Buttonquail*	*T. sylvaticus lepuranus*	2.15
Northern Spotted Buttonquail	*T. ocellatus benguetensis*	3.04	*Madagascar Buttonquail*	*T. nigricollis* *	2.14
Quail Plover	*O. meiffrenii* (monotypic)	2.93	*Little Buttonquail*	*T. velox* *	1.97
Sulawesi Red-backed Buttonquail	*T. maculosus beccarii*	2.87	*Taiwan Barred Buttonquail*	*T. suscitator rostratus*	1.85
Hottentot Buttonquail	*T. hottentottus* *	2.82	*Common Painted Buttonquail*	*T. varius varius*	1.81
Sri Lanka Barred Buttonquail	*T. suscitator leggei*	2.82	*Indian Barred Buttonquail*	*T. suscitator, taigoor, bengalensis*	1.81

Table 1.3. Priority index for all buttonquail subspecies, subspecies groups and monotypic species (*) with the proposed English names, mostly based on Gutiérrez-Expósito et al. 2011 and del Hoyo and Collar 2014.

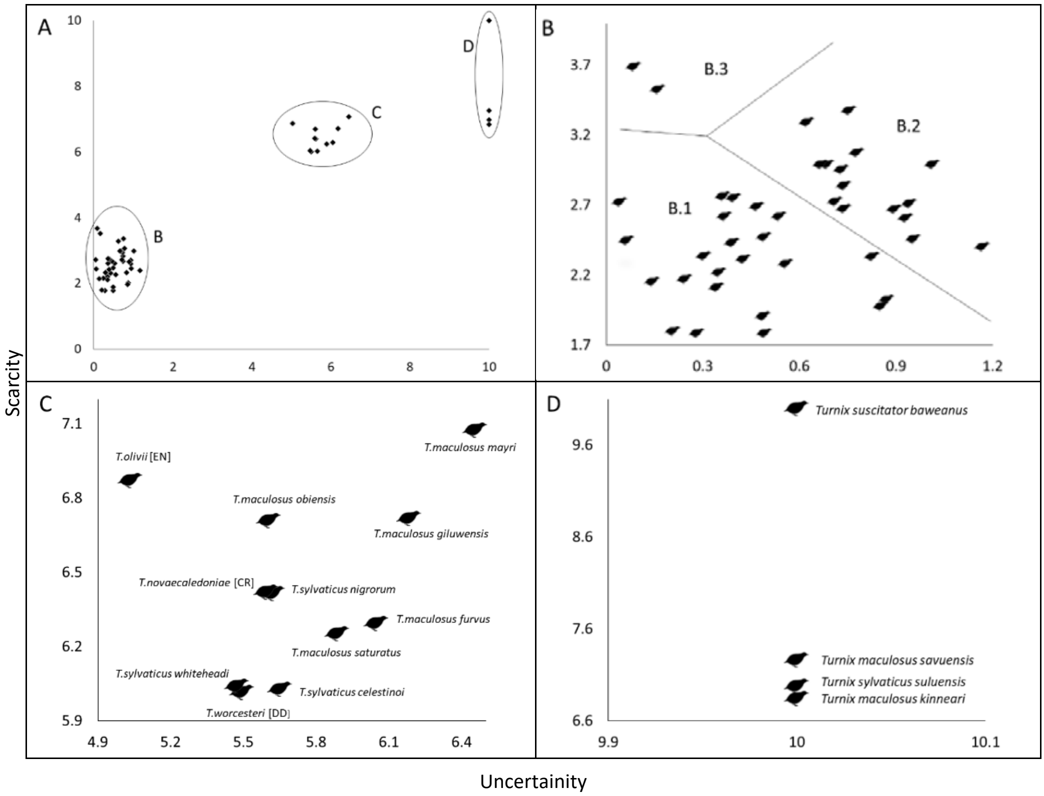


Figure 1.22. Concern status of all buttonquail subspecies and monotypic species (A), with detailed view of the lower (B), higher (C) and very high (D) rarity index groups. Group B has been divided in still common subspecies (B.1), reasonably common but not well known subspecies (B.2) and well known but scarce subspecies (B.3).

Discussion

By using data from a single citizen science birding platform and the published distribution areas for every species and subspecies of buttonquails, we have been able to create a simple index to rank monitoring and conservation efforts priorities. The index correlates with the already published IUCN red list categories for every species (IUCN 2019). Higher values match with the most endangered species: Buff-breasted, New Caledonia and Luzon Buttonquails. The Buff-breasted Buttonquail is in fact classified as Endagered by the IUCN (2019), but also by the Australian environmental authorities (Mathieson and Smith 2009), still remaining as the only Australian bird species never properly photographed alive in the wild (AWC 2018). Currently (2018 - 2020) there is a running research project by the University of Queensland, but up to date no results have been published (National Environmental Science Program 2019). New Caledonian Buttonquail is listed as Critically Endangered (IUCN 2019). The species is only known by the type specimen when the species was described in 1889 (Ogilvie-Grant 1889), so due to the absolute lack of sightings, it must be almost certainly extinct (del Hoyo and Collar 2104). The Luzon Buttonquail is barely known from a few localities in the mountains of central Luzon (Collar et al. 1999). Due to the lack of information it is listed as Data Deficient (IUCN 2019). In 2009, after two nights of bird trapping in Dalton Pass, one bird was trapped and sold for food, being the only living specimen of this species ever photographed (Allen 2009), a sad record that still provides some hope for the survival of the species. However, this is the only record in the 21st century. Historically the species is only known from 6 localities, and 79 % of all 43 existing museum specimens were trapped at a single location: Dalton Pass, where a very heavy huntig pressure is performed by locals (Collar et al. 1999, Round and Allen 2010). Although more data are needed; the species should be better listed as Endangered or Critically Endangered. The South African fynbos endemic Hottentot Buttonquail (*Turnix hottentottus*) is listed as Endangered, However, recently Lee et al. (2018) found it to be more common and widspread than previously thought, thus proposing to downlist the species to Vulnerable. Assuming the classification of Luzon Buttonquail as Endangered and Hottentot Buttonquail as Vulnerable, the logarithmic correlation between our priority index and the IUCN categories is even stronger (R^2 = 0.86)

Due to the good correlation between our rarity index and the classification by the IUCN (2019) in its red list (Figure 1.20) we are very confident that our rarity index will work properly also at subspecific level. We obtained very high values for highly unmonitored small island endemic subspecies as Bawean Barred, Savu Red-Backed, Sulu Common and Banggai Red-backed Buttonquails (Table 1.2. and Figure 1.3.D). Together with New Caledonian and Buff-breasted Buttonquails, nine more subspecies have high priority index values, and thus could be regarded as Endangered (Table 1.2. and Figure

1.3.C). From these 15 taxa, Buff-breasted Buttonquail is present in Australia and New Caledonian Buttonquail in New Caledonia, one of the overseas territories of France. So, both species are under the protection of wealthy countries, which means that legislative and economic resources for monitoring and conservation can be at some point guaranteed. However, the remnant 13 taxa depend on just three countries: five in the Philippines and four in Indonesia and Papua New Guinea respectively. In these countries the conservation of these potentially highly threatened taxa is compromised by the lack of economic and human resources for population monitoring and the design and implementation of effective conservation measures. Among the subspecies with lowest priority index values, three groups can be identified. Most of them show very low values for both uncertainity and scarcity, and consequently can be considered to be safe taxa (Figure 1.22.B.1). Among all taxa classified at the lower rarity index values, those with higher values are Abrolhos Painted Buttonquail (*Turnix varius scintillans*) and the Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*) (Table 1.2 and Figure 1.3.B.3). The first one is an endemism of the Houtman Abrolhos islands, a small archipiealgo in West Australia and is classified as Vulnerable by the Australian Government, while the second one is the only buttonquail species present in the Western Palearctic. Although there’s not an assessment at the entire taxon, it’s has been classified as Critically Endangered at European level (BirdLife International 2015), recently considered exctinct in Spain, its last stronghold in Europe, by the Spanish Government, with just a single population known to persist in west Morocco (Gutiérrez-Expósito et al. 2019).

A similar assessment should be afforded at population levels, many of which could be locally highly endangered or in the verge of extinction as could be the case of the Taiwan population of the Indochinese Common Buttonquail. Dispite the very high eBird sampling effort made in the island (345,594 checklists), not a single sight of this species has been obtained, while under the same effort, up to 4,290 observations are found for the endemic Taiwan Barred Buttonquail.

The secretive habits of the buttonquails make them to be easily overlooked. As a consequence, silent extinction processes can occur almost with no sign, as happened with the Andalusian Buttonquail (Gutiérrez-Expósito et al. 2019), and could be the case of those taxa with high rarity index. However, as research on them goes on, more detailed knowledge is coming to light, allowing to downlist the Black-breasted Buttonquail from Endagered in the 90's to Vulnerable in 2000, to be currently listed as Near Theratened (Lees and Smith 1999, Smyth and Pavey 2001, IUCN 2019), or propose a similar change for the Hottentot Buttonquail (Lee et al. 2017, Lee et al. 2019), giving some hope for those understudied species and subspecies.

Our priorization approach is a very simple and fast monitoring and conservation needs evaluation for taxa lacking a formal assessment, and it is especially useful as it can be applied to bird species at different levels: populations or subspecies of a given species, or species within a genus or family.

Andalusian Buttonquail in the 1806 Dictionaire Universel d'Histoire Naturelle. Races humaines, mammiferes et oiseaux of Charles Dessalines D'Orbigny, named here as *Turnix tachydroma*.

Chapter II

Asymmetric heterochromia in birds: the dark crescent of buttonquails

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Introduction

A precise adjustment of the light entering the eye is essential in the life cycle of vertebrates and is in general modulated by changing the pupil size due to iris contraction or dilation, sometimes aided by other structures as pecten or ciliary body (Archer et al. 1999). The presence of darkened areas near or around the eyes of several vertebrates has been proposed as effective vision help systems (Ortolani 1999, Ficken et al. 1971). An experiment found that Willow Flycatchers (*Empidonax traillii*) tended to forage in the shade when its naturally dark upper mandible was painted white, due to the loss of the antiglare effect (Burtt 1984). In an analogy with the dark designs that some vertebrates have around the eyes, human cultures have also a long tradition in the use of ocular cosmetics for sun light absorption, such as Kohl used in some desert areas of Asia and Africa (Tapsoba et al. 2010, Murube 2013). After observing the eyes of buttonquails (Family Turnicidae), I here propose that body coloration patterns improving vision might have evolved not only near or around the eye but also within the eye, and specifically within the iris itself.

Material, methods and results

Buttonquails are very skulking birds that are rarely well observed on sight and even more rarely studied in hand. By close examination of the eye of buttonquails, I noted that some Turnix species shared a common feature in their iris colouration: a dark brown, crescent shaped mark below the rounded pupil, to which I hereafter refer as dark-crescent. I made in-hand examinations of the eyes of 21 individuals of two species: Common Buttonquail (*Turnix sylvaticus*; 4 adults and 7 chicks) and Barred Buttonquail (*Turnix suscitator*; 8 adults and 2 chicks). I found it to be present in all adults and chicks, even though it was much more evident in the paler eyes of adults. The dark-crescent is very difficult to detect and is more clearly perceived when treating the photographs by increasing its brightness (Figure 2.1). Its shape changes with the response of the iris to light conditions, being very narrow and almost unnoticeable in poor light conditions, when the radial muscle fibers of the iris remain contracted (mydriasis) (Figure 2.2.A) and wide and very evident under direct sun or lamp light, when the circular muscle fibers of the iris contract (miosis) (Figure 2.2.B).

Encouraged by this finding, I've checked the eyes of all World bird species listed by Gill & Donsker (2018) (N = 10,669) in search of structures equivalent to buttonquail's dark crescent. Including all buttonquail species, adult bright-eyed birds (those for which color marks in the iris would be visible) comprised 1,684 species (15.8 %).

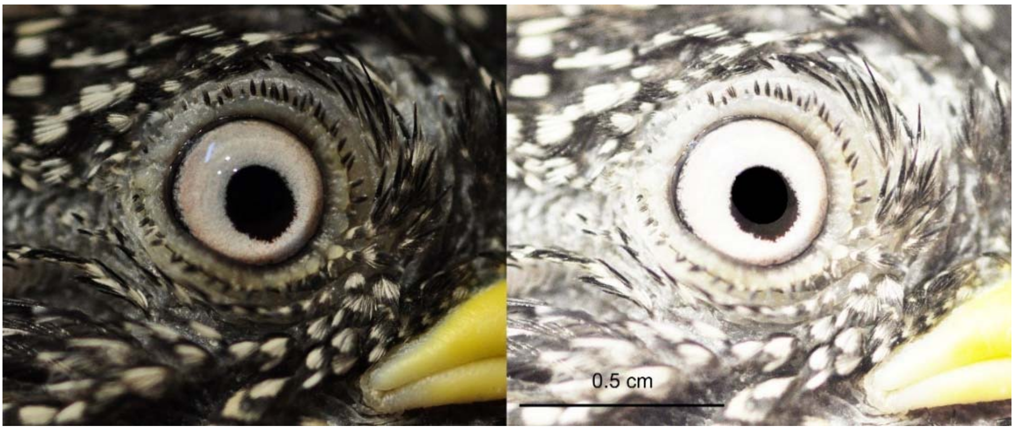

Figure 2.1. Eye of an adult captive Barred Buttonquail (*Turnix suscitator*) showing the iris dark-crescent, before (left) and after (right) picture treatment by increasing brightness. The dark-crescent is orientated towards the bill gape. Zoobotánico Jerez (Spain).

I could examine high-definition pictures of 1,570 (93.2 %) of them. Asymmetric heterochromia within the iris was found to be present only in 85 species (5.4 %) belonging to 9 families and 24 genera (Tables 2.1 and 2.2).

Family	FHT	FT	FPE	FE	FH
Ardeidae	rear spot	66	57	56	4
Threskiornithidae	fore spot	35	13	13	1
Haematopodidae	fore spot	11	11	11	11
Pedionomidae	crescent	1	1	1	1
Turnicidae	crescent	17	17	16	15
Columbidae	fore spot	331	149	118	37
Nyctibiidae	fore spot	7	7	7	1
Ramphastidae	double spot	43	13	13	6
Picidae	fore spot	235	42	41	9

Table 2.1. Number of species with dark iris heterochromia by Family: FHT (Heterochromia type), FT (Total number of species within the Family), FPE (Number of pale-eyed species within the Family), FE (Number of pale-eyed species examined within the Family), FH (Number of pale-eyed species with dark heterochromia within the Family).

Unlike buttonquails, the asymmetry found is a small circular trapezoid shaped dark area next to the pupil. Its shape and size had little variation among species and individuals, however, differences have been found on its relative position in relation to head and bill, being usually situated at the fore area of the iris, in the line that goes from the pupil center to the chin (N = 58). This mark is present in one ibis species (Threskiornithidae): the white-eyed Malagasy Sacred Ibis (*Threskiornis bernieri*), all oystercatcher (Haematopodidae) species (N = 11), up to 37 species of 10 different genera of pigeons and doves (Columbidae) and 9 woodpecker species belonging to 4 genera (Picidae) (Figure 2.2.C). I've also found a similar spot, but opposite in location, in a few heron species (Ardeidae): the enigmatic African White-crested Tiger Heron (*Tigriornis leucolopha*), the Black Bittern (*Dupetor flavicollis*) and two *Ixobrychus* species: Von Schrenck's Bittern (*I. eurhythmus*) and Cinnamon Bittern (*I. cinnmamomeus*) (Figure 2.2.D), but not being present in any of the other 52 pale-eyed heron species examined. A rather similar spot is present in the Rufous Potoo (*Nyctibius bracteatus*) (Nyctibiidae) but located in the lower part of the iris (Figure 2.2.E). Finally, I found it to be present in the form of a double spot: fore and rear of the pupil, in 6 toucanet species (Ramphastidae) of the genus *Pteroglossus* (N = 3) and *Selenidera* (N = 3) (Figure 2.2.F).

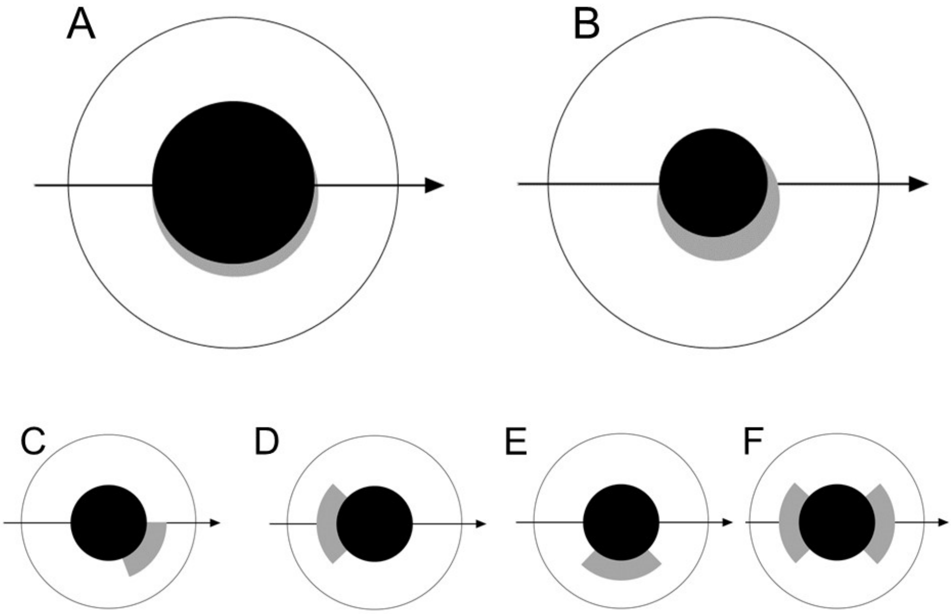

Figure 2.2. Schematic drawing of type and position of dark heterochromia in birds. Buttonquail and Plains wanderer dark-crescent during (A) mydriasis and (B) miosis. Position of dark area in: (C) Sacred Malagasy Ibis, Oystercatchers, Woodpeckers, Pigeons and Doves, (D) Tiger Heron and Bitterns, (E) Rufous Potoo and (F) Toucanets. Arrows show the line between the center of the pupil and the bill tip (Carlos Gutiérrez-Expósito).

I found the dark-crescent to be a common feature to almost all species in the genus *Turnix* (N = 15). Although no pictures exist of the critically endangered Buff-breasted Buttonquail (Matthieson & Smith 2009), it's also expected to be present due to its close relationship to the Chestnut-backed Buttonquail, with which it has considered to be conespecific (Madge & McGowan 2002). I was not able to identify it in the few available high-resolution pictures of the Quail-plover, the sole Turnicidae species not included within the genus Turnix. I also found this dark-crescent in both adult and chicks of the Plains-wanderer, the only member of the family Pedionomidae. This species shares lifestyle with buttonquails, but both families do not seem to be closely related (Baker et al. 2007). Whether this common eye structure is a case of evolutionary convergence or indicates a closer phylogenetic relationship between these families than previously suggested remains a matter for future research.

Genus	Family	GHT	GT	GPE	GE	GH
Ixobrychus	Ardeidae	rear spot	8	8	8	2
Dupetor		rear spot	1	1	1	1
Tigriornis		rear spot	1	1	1	1
Threskiornis	Threskiornithidae	fore spot	5	1	1	1
Haematopus	Haematopodidae	fore spot	11	11	11	11
Pedionomus	Pedionomidae	crescent	1	1	1	1
Turnix	Turnicidae	crescent	16	16	15	15
Columba	Columbidae	fore spot	33	21	16	5
Reinwardtoena		fore spot	3	2	1	1
Columbina		fore spot	9	1	1	1
Uropelia		fore spot	1	1	1	1
Geotrygon		fore spot	9	7	5	1
Leptotila		fore spot	12	8	1	1
Ptilinopus		fore spot	54	36	33	21
Ducula		fore spot	39	13	12	4
Lopholaimus		fore spot	1	1	1	1
Gymnophaps		fore spot	4	2	1	1
Nyctibius	Nyctibiidae	fore spot	7	7	7	1
Pteroglossus	Ramphastidae	double spot	14	5	5	3
Selenidera		double spot	6	6	6	3
Geocolaptes	Picidae	fore spot	1	1	1	1
Piculus		fore spot	7	2	2	2
Dryocopus		fore spot	6	6	3	3
Mulleripicus		fore spot	3	2	2	2

Table 2.2. Number of species with dark iris heterochromia by Genus: GHT (Heterochromia type), GT (Total number of species within the Genus), GPE (Number of pale-eyed species within the Genus), GE (Number of pale-eyed species examined within the Genus), GH (Number of pale-eyed species with dark heterochromia within the Genus).

Discussion

Unlike buttonquail's dark-crescent, the dark area found occasionally in the eyes of most individuals of these species is not a regular feature within age classes, sexes and/or species or higher taxonomic groups. Guzzetti et al. (2008) found it to be present in all adult females, but only in 65 % of adult males Black Oystercatchers (*Haematopus bachmani*) studied in Alaska. Morris & Morris (2014) described the same type of dark spot as sectorial heterochromia in captive adults Rose-crowned Fruit Dove (*Ptilinopus regina*) and Topknot Pigeon (*Lopholaimus antarcticus*) but being absent in the only juvenile examined of the later species. Gorman (2011) found a black spot to be present in up to 85% of Black Woodpeckers (*Dryocopus martius*), a feature I've found to be shared with the White-bellied Woodpecker (*Dryocopus javensis*) and the Andaman Woodpecker (*Dryocopus hodgei*), but not found in other big black-and-white woodpeckers (*Campephilus, Hylatomus*). Although I was able to detect it in high resolution pictures of juveniles of Black Woodpecker and Woodpigeons (*Columba palumbus*), it was not present in recently born chicks of Woodpigeon, and American (*Haematopus palliatus*), Black and Eurasian (*Haematopus ostralegus*) Oystercatchers.

As proposed by Morris & Morris (2014) these spots could act as vision facilitators. As far as there's a consistency on the location of the dark area in the iris, opposite from where the main source of light is expected to come and especially in the direction where the bird uses to watch while foraging, it is possible that these spots have a functional role regarding vision and/or light regulation. The highly pigmented internal epithelial layer of the iris is a very efficient barrier to light penetration in the eye, especially considering that part of the light reaching the retina travels through the iris. Extra light absorption occurs by the presence of melanophores in the stroma and anterior border, where iris colour is determined (Thuman 2001). Bright-coloured irises of birds are mainly pigmented by purines and pteridines that form reflecting granules in the iris stroma (Oliphant & Hudon 1993). Thus, the presence of dark areas in a pale iris can arguably be hypothesized as a minimization system of the light entering through the iris by light absorption, but also as a reduction of the glare produced by these reflecting organules during foraging action.

Although there is no direct evidence on the function of the iris dark-crescent of buttonquails, but since these birds usually dwell in shady cover of low and slightly open scrubland, grass and farmland, it can be argued that the dark-crescent could be an adaptation to sudden light exposure changes when foraging between dark-shade beneath full cover and full sunny conditions. This argument seems reinforced by the adaptability of the size and form of the dark-crescent, and thus its suggested functionality, in response to light intensity changes. In summary, the iris dark-crescent could be a more sophisticated and improved vision facilitation system in certain light exposures circumstances (Mainster & Turner 2012). In any case, the presence of asymmetric iris herechromia in such taxonomically unrelated bird families and the omnipresence in all age classes of the eye's dark-crescent across the Turnix genus suggests a relevant role of this structure and inspires future research on its function.

Asymmetric heterochromia in oystercatchers: Blackish Oystercatcher (*Haematopus ater*) left and American Oystercatcher (*Haematopus palliatus*) right in Paracas National Park (Peru).

SECTION 2

Chapter III

Vanishing wildlife in populated areas: the demise of the Andalusian Buttonquail

Gutiérrez-Expósito, C., Revilla, E., Clavero, M. (accepted) Journal of Ornithology

Introduction

Species extinction risk is usually modulated by interactions among extrinsic and intrinsic factors (Fisher et al. 2003). Habitat loss, overexploitation, introduction of alien species and climate change are often identified as typical extrinsic drivers of species declines and eventual extinctions (Hoffman et al. 2010, Foden et al. 2019). Traits such as large body size, high trophic level, narrow habitat niche or small distribution area are associated with higher vulnerability to extinction (Davidson et al. 2009, Lee and Jetz 2010), with species not exhibiting these traits usually being common and widespread (González-Suárez et al. 2013). However, rapid declines and extinctions have also affected species with apparently low vulnerability. For example, the extinction of the Passenger pigeon (Ectopistes migratorius), a medium-sized frugivorous bird that was once widespread and abundant in North America, has been linked to habitat loss and extremely high direct human pressure (Bucher 1992). In this sense, identifying vulnerability drivers affecting common and apparently safe species is very relevant in the current mass extinction process (Dirzo et al. 2014, Ceballos et al. 2015).

The Common Buttonquail (Turnix sylvaticus) is a small frugivorous and insectivorous bird species that may inhabit natural grassland and scrubland as well as pastures and agricultural areas (Madge and Mc Gowan 2002). Contrary to the common sex-role pattern in birds, female buttonquails lead the courtship and males perform all incubation and chick rearing tasks. This breeding system gives the species a formidable breeding potential in optimal conditions (Hoesch 1960, Flieg 1973). The Common Buttonquail is widely distributed in sub-Saharan Africa and south-east Asia, a vast range within which up to nine subspecies have been described, some of which are endemics of small territories, such as different islands in Indonesia and the Philippines (Gutiérrez-Expósito et al. 2011). The nominate subspecies (the Andalusian Buttonquail, Turnix sylvaticus sylvaticus) is endemic to the western Mediterranean basin. It was once distributed in seven countries in southern Europe and the Maghreb, but its known extant range is confined to a small agricultural area on the Moroccan Atlantic coast (Gutiérrez-Expósito et al. 2019). The decline of the Andalusian Buttonquail seems to have started around the early 20th century. It went extinct in Sicily around 1920, probably due to hunting and land reclamation (Violani and Massa 1993). The decline of the Andalusian Buttonquail has been generalized across all countries in its former distribution range, leading to the taxon's current critical situation (Gutiérrez-Expósito et al. 2011, 2019), but has passed largely unnoticed, due to the secretive nature of buttonquails. In this context, describing the generalised collapse of the Andalusian Buttonquail is relevant for three main reasons: i) to plan and implement conservation measures for this subspecies itself; ii) to provide a framework to study other possibly declining, though largely unknown, buttonquail species (e.g. Sumba Buttonquail Turnix everetti, Luzon Buttonquail Turnix worcesteri); and iii) to identify extinction drivers that affect species which do not match the vulnerability syndromes described in the literature.

In this paper, we describe how a taxon with a formerly wide distribution range, low trophic level in the food chain, small size and apparently coarse habitat requirements, has become nearly extinct. After a thorough compilation of historical records of the Andalusian Buttonquail, we used a modelling approach to estimate the former distribution area of this subspecies. We then analysed which anthropogenic factors have likely acted as drivers of the Andalusian Buttonquail's generalized decline.

Methods

By compilation of Andalusian Buttonquail presence records, we use environmental variables to define its historic distribution area and estimate the probabilities of presence in a grid of 100 Km2 cells. These probabilities will be used as dependent variable to analyse the effect of land use and human population changes in the decline process of the species.

Compilation of records

We made an exhaustive collection of reports of Andalusian Buttonquail presence, both in the present and in the past, largely based on Gutiérrez-Expósito et al. (2011). Starting with GBIF (www.gbif.org) and Vert Net (www.vertnet.org), we consulted all major natural history museums and scientific collections in search of Andalusian Buttonquail specimens (see all specimens listed in Supplementary Material S.3.1). We also conducted an extensive search of records in bibliographic sources, including historical works (Irby 1875, Saunders 1871, López Seoane y Pardo de Montenegro 1861, Reyes Prósper 1885, Giraldes 1879, Chapman & Buck 1893, Arévalo-Baca 1887), regional bird books and atlases (Étchecopar & Hüe 1964, Heim de Balsac & Mayaud 1962, Pineau & Giraud-Audine 1979, Isenmann et al. 2005, Thévenot et al. 2003), recent reviews (Catry 1999, Violani & Massa 1993, Pratesi 1974) and technical reports (Solís 1995, Urdiales 1994). Whenever specimens or sightings were not precisely dated, we assigned them to a period based on the collector's activity time or publication dates. For recent records, only documented sightings were taken into account in order to avoid the false positives that often arise when rare or mystery species vanish (Carlson et al. 2018, Brook et al. 2018, Solow & Beet 2014, Collins 2018). We classified each buttonquail record as historical (before 1940), old (between 1941 and 1970), recent (between 1971 and 2000) or current (from 2001 onwards) and we georeferenced them following the information obtained from the bibliography and specimen labels. As most records refer to municipalities (Figure 3.1, all localities are listed in Supplementary material S.3.2), coordinates were defined as those of the town center, following Clavero and Hermoso (2015).

Whole-range analyses

We used the spatial distribution of localities with presence of Andalusian Buttonquails to define a study area in which to analyze the relationships between buttonquail presence and environmental features. We generated a non-parametric kernel around presence records by using a local convex hull method with an adaptive sphere-of-influence (a-LoCoH, Getz et al., 2007), and expanded the resulting area by applying a 1.5° buffer (Figure 3.1). We assumed that the land area generated in this way included all or most of the historical range of the Andalusian Buttonquail. We intersected this range with the global 10 x 10 km grid provided by the International Union for Conservation of Nature, IUCN (Murray 2017). Since buttonquails are terrestrial birds, all grid-cells with a proportion of land less than 0.1 were excluded from any further analysis. We also excluded all cells lying on mainland Italy, where the presence of buttonquails has never been reported. As a result, our whole-range study area had a total of 10,983 100 km2 grid-cells, 106 of which contained Andalusian Buttonquail records (Figure 3.1).

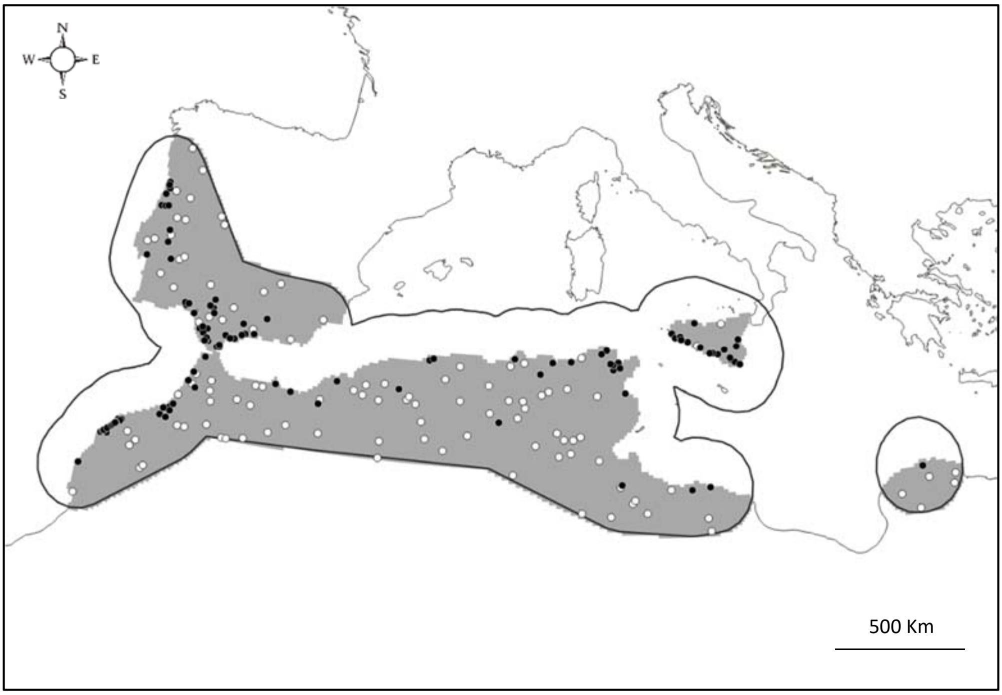

Figure 3.1. Geographical distribution of 100 km^2 squares at general scale, with black lined polygon and grey shaded area showing the buffered areas and study areas grids. Black dots show historic, old, recent and current buttonquail presence, while white dots are pseudoabsences used in modelling.

We described the main environmental gradients within our whole-range study area by means of a principal components analysis (whole-range PCA) applied to a set of 54 environmental variables. The variables included descriptions of topography (Amatulli et al. 2018), solar radiation (World Bank Group 2016), soil characteristics (Fischer et al. 2008) and temperature and precipitation regimes, as well as different bioclimatic indices (Fick & Hijmans 2017, Title and Bemmels 2018, Rivas-Martínez et al. 2011) (see Supplementary Materials S.3.3 and S.3.4 for full accounts of these variables). Mean values of every variable within each 100 km2 grid-cell was obtained by zonal statistics algorithm in QGIS 3.6.2. The whole-range PCA produced two principal components (PCs) that accounted for 63% of the variation in the original set of 54 variables (Figure 3.2). The first PC, hereafter continentality (PC1, 42% of the original variance), represented a gradient going from coastal and rainier areas in its negative extreme to more continental and drier areas in its positive end. PC2, hereafter elevation (21% of the original variance), had cold highlands towards its negative extreme and warmer lowlands towards its positive end (see supplementary materials S.3.5 for detailed relationships of each original variable with the two PCs and its spatial patterns and variability).

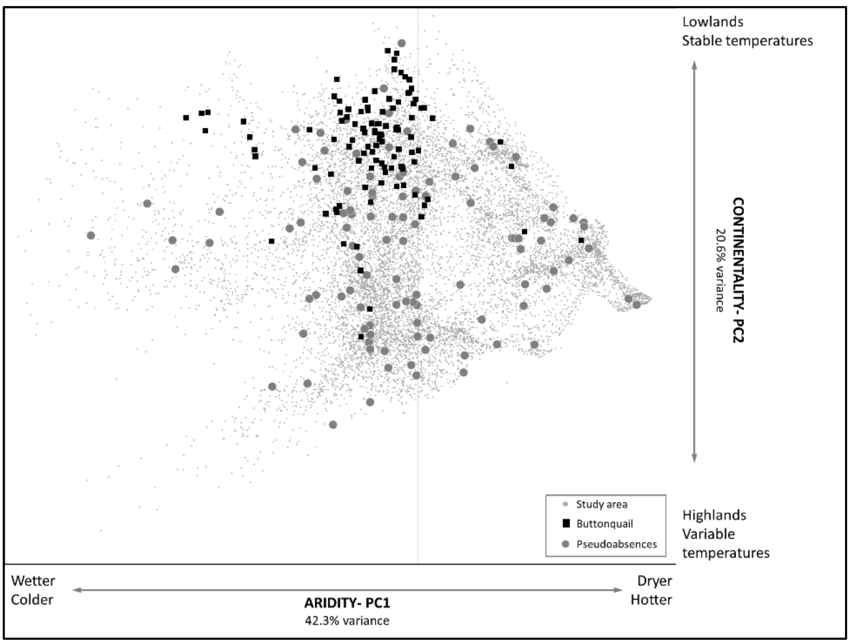

Figure 3.2. PCA space showing the distribution of the 100 km^2 squares within the general area environmental gradient.

We used the continentality and elevation gradients to model the historical distribution of the Andalusian Buttonquail. Since our dataset of buttonquail records only included presences, we generated an equal number of pseudoabsences by randomly selecting 106 grid-cells within the whole-range study area (Figure 3.1; Barbet-Massin et al. 2012). By means of logistic regression (logit link), we first modelled the probability of presence of the Andalusian Buttonquail through a full model, including as predictors the continentality and elevation gradients, the squared values of both PCs (to allow for possible unimodal relationships) and the interaction between the PCs. We then reduced this model by comparing the AICc values of the models by deleting uninformative effects, and with the condition that the squared PC values were included in models only together with their linear effect. We used the coefficients of the selected model to calculate the probability of buttonquail presence for each grid-cell in the whole-range.

Andalusian-scale analyses

Detailed historical and recent land use information within the historical Andalusian Buttonquail range was available only for Andalucía (Spain) (Moreira et al. 2007), and thus we focused on this territory to analyse the influence of land use changes in the buttonquail extinction process. The Andalusian study area was defined by the intersection of the global IUCN grid (Murray 2017) with a 10 km-buffered polygon created through a 0.5 threshold concave hull (alpha shapes) algorithm in QGIS around the 31 records within the region of Andalusia (Figure 3.3). Coastal grid-cells with a proportion of land lower than 0.1 were excluded, resulting in a grid of 281 100 km^2 grid-cells, of which 28 included Andalusian Buttonquail records.

Information on land uses in Andalusia for 1956 and 1999 (REDIAM https://descargasrediam.cica.es/repo/s/RUR), were used to describe pre- and post-extinction land use scenarios, respectively. We grouped the 112 uses and coverages defined by Moreira et al. (2007) into 12 classes: bare land, grasslands, open scrub, dense scrub, irrigated and rain-fed herbaceous crops, green-house crops, irrigated and rain-fed wood crops, flooded, wooded and urbanized areas (See Supplementary material S6). We used the area occupied by each land use type in 1956 and 1999, on every grid-cell of the Andalusian study area to describe the land use changes within the Andalusian Buttonquail's former distribution by means of PCA. The two PCs obtained in the Andalusian PCA accounted for 45% of the variation in the original land use data. PC1, hereafter afforestation, (25% of the original variance) represented a gradient running from forested and densely-covered shrubby areas in the positive extreme, to open, rain-fed agricultural areas in the negative extreme, while PC2, hereafter intensification, (20% of the original variance) defined a gradient going from natural shrubby vegetation in the negative extreme to intensive agricultural areas and urbanization in the positive extreme (Figure 3). We calculated the changes along the afforestation and intensification gradients for each grid-cell as the difference between PC scores in 1999 and 1956 and estimated the overall magnitude of land use change for every grid-cell as the Euclidean distance between its 1956 and 1999 values in the PCA space (Figure 3.3). Note that while changes along a particular PC have a sign and can thus be interpreted as a movement to one of the extremes of an environmental gradient, the overall change only informs about the magnitude of the change, not about its direction.

We obtained human population data from 1900 to 2010 from the Spanish National Statistical Institute (www.ine.es) at the municipality scale. Population data was available on a ten-year interval basis, and we regressed the logarithmic value of these decadal population values with the year, using 1900 as zero (i.e. 20 for 1920), in order to obtain a slope value to inform about population changes (i.e. increases or decreases and their magnitude). For every grid-cell in the Andalusian study area we estimated the probability of historical buttonquail presence by using the probabilities resulting from the whole-range model described above.

We described the relationship between buttonquail presence and environmental gradients (continentality and elevation), anf the probabilities obtained with the whole-range niche model with the changes in land uses (afforestation and intensification) and the human population by means of generalized linear models.

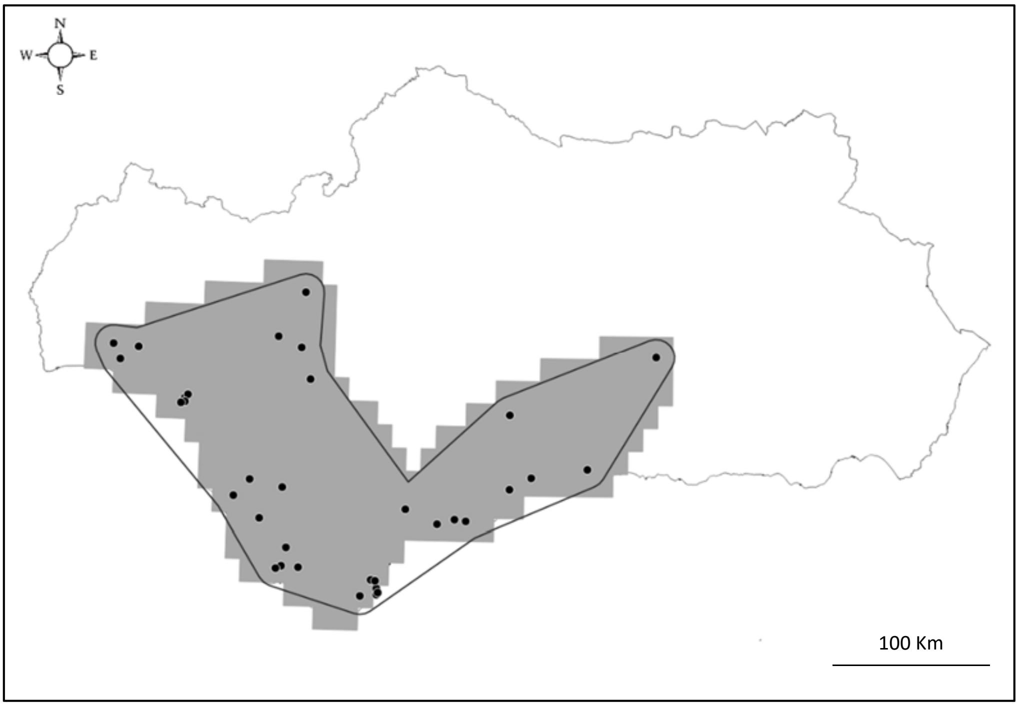

Figure 3.3. Geographical distribution of 100 km^2 squares at regional scale, with black lined polygon and grey shaded area showing the buffered areas and study areas grids. Black dots show historic, old, recent and current buttonquail presence.

For the whole-range and Andalusian scales, we used the European Terrestrial Reference System 1989 Lambert azimuthal equal-area (EPGS: 3035) and the European Datum 1950 UTM zone 30N (EPGS: 23030) projections, respectively.

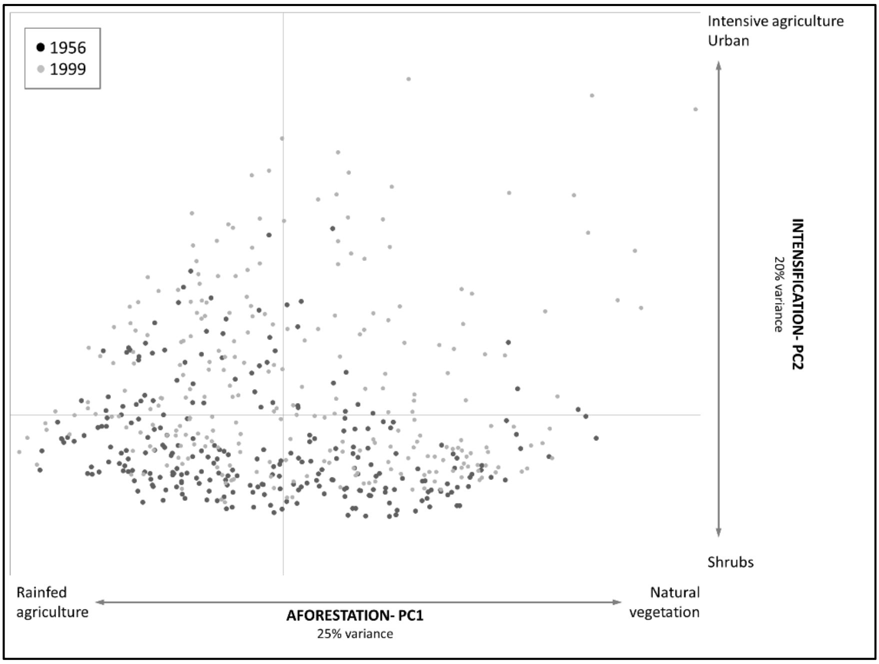

Figure 3.4.PCA space showing the distribution of the 100 km^2 squares within the regional land use changes between 1956 and 1999.

Results

We found data from 254 Andalusian Buttonquail specimens and 30 clutches (totaling 63 eggs) in 51 scientific and naturalistic collections. In total, 71 specimens and clutches were of Iberian origin (Spain, Portugal and Gibraltar), 32 were collected in Sicily (Italy) and 111 were obtained in the Maghreb (Tunisia, Algeria and Morocco). We could not assign the remaining 40 specimens and clutches to any of these areas. We identified 46 different localities with Andalusian Buttonquail presence from museum specimens and clutches (Supplementary material S1). Additionally, we found 75 localities documented in the literature, of which 17 were coincident with the information provided by scientific collections. Overall, we compiled 114 localities where the Andalusian Buttonquail was or still is present (Table 3.1, Supplementary material S.3.2). Localities cited in Catalonia and Valencia (Spain), Sardinia (Italy) and Oxfordshire (UK) were not considered here, as they have already been recognized as imported or mislabeled specimens (Matthews and Matthews 1849, Violani and Massa 1993, Gordo et al. 2006).

Population	Country	Historical < 1940	Old 1941-1970	Recent 1971-2000	Current > 2001	Total
Sicily	Italy	17	-	-	-	17
Iberia	Portugal	11	-	-	-	11
	Spain	18	8	7	-	33
	Gibraltar	2	-	-	-	2
Maghreb	Lybia	2	1	-	-	3
	Tunisia	6	-	3	-	9
	Algeria	8	-	3	-	11
	Morocco	12	-	3	13	28
Totals		**75**	**9**	**16**	**13**	**114**

Table 3.1. Number of Andalusian Buttonquail documented localities sorted by country and time.

The estimated extent of occurrence of the historical distribution area of the Andalusian Buttonquail was 429,887 km2 (Figure 3.1). The best model describing the distribution of the Andalusian Buttonquail included both environmental gradients (continentality and elevation) and the quadratic term of continentality (Table 3.2).

<table>
<tr><th>Variable</th><th>Estimate</th><th>St.Err</th><th>z value</th><th>Pr(>|z|)</th></tr>
<tr><td>(Intercept)</td><td>-1.2929</td><td>0.3135</td><td>-4.124</td><td>>0.001***</td></tr>
<tr><td>continentality</td><td>-0.8233</td><td>0.3451</td><td>-2.386</td><td>0.017*</td></tr>
<tr><td>continentality^2</td><td>-0.4512</td><td>0.2037</td><td>-2.215</td><td>0.027*</td></tr>
<tr><td>elevation</td><td>1.6958</td><td>0.2509</td><td>6.759</td><td>>0.001***</td></tr>
</table>

Table 3.2. Output coefficients of the logistic regression model for the whole-area niche modelling.

These results suggest that the Andalusian Buttonquail avoided areas with continental and arid climates with high annual temperature variations and tended to be present in relatively wet and warm lowland areas with buffered oceanic climatic conditions (Figure 3.5). A probability threshold of 0.7 resulted in the model's correct classification (as presence or (pseudo)absence) of 78.8 % of the localities and in an estimated historical distribution area of 125,716 km2 (Figure 3.6).

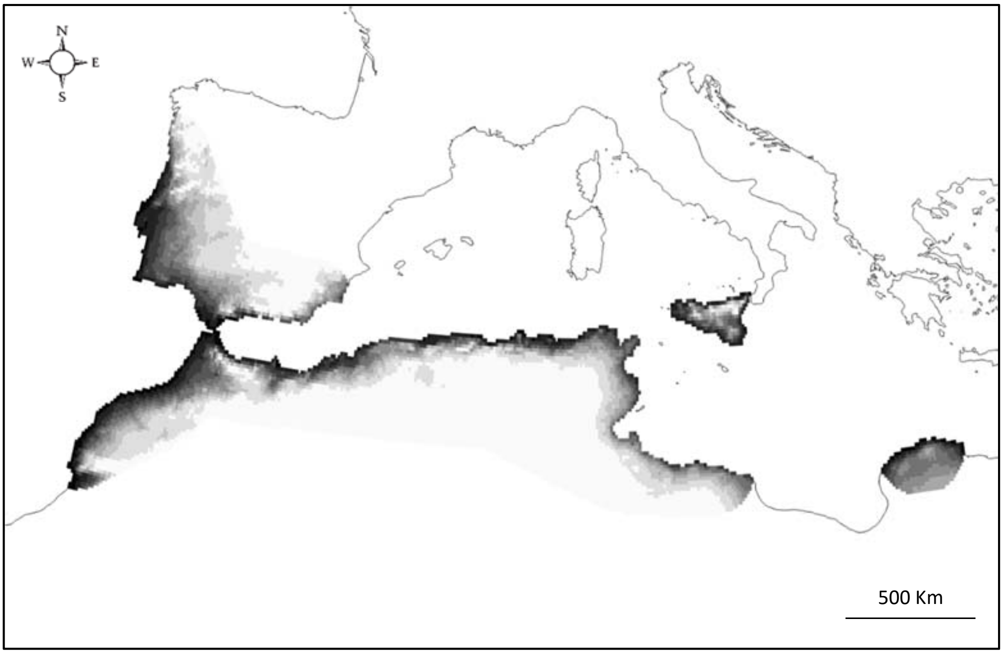

Figure 3.5. Sparially explicit distribution of buttonquail presence probabilities

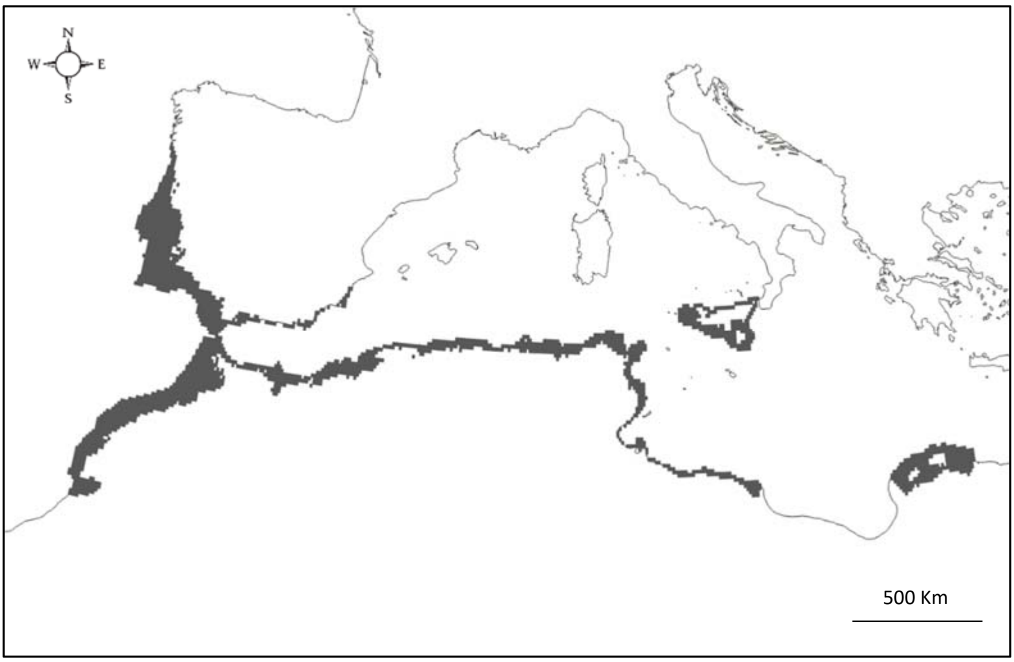

Figure 3.6. Historic distribution of the Andalusian Buttonquail based on an 0.7 probability threshold of our whole range modelling.

Land use changes in the historical range of Andalusian Buttonquail in Andalusia between 1956 and 1999 were characterized by an increase of forested and natural vegetation and a decrease of rain-fed agriculture (increases in afforestation) and by an increase of urbanized areas and intensive farming (irrigation and green-house crops) and a loss of shrubby areas (increases in intensification) (Figure 3.4). Changes along both land use gradients as well as overall land use change were more intense in areas where the probability of buttonquail presence was higher (Figure 5). In the same way, municipalities with higher probabilities of historical buttonquail presence had more pronounced increases in the human population throughout the 20th century (Figure 3.7).

Discussion

As with other common farmland species that are currently in serious decline (i.e. Gregory et al. 2019, Traba and Morales 2019), the Andalusian Buttonquail was once a common and widely distributed bird in the western Mediterranean basin. The present range of the Andalusian Buttonquail, estimated to be 4675 ha by Gutiérrez-Expósito et al. (2019), represents, however, only a small fraction of its historical range. The reduction in the range of the taxon is thus greater than 99.99%, independent of which scenario is used as a reference, either the larger extent of occurrence (Figure 3.5) or the smaller range estimated from the model outputs (Figure 3.6).

The environmental niche of the Andalusian Buttonquail seems to be mainly linked to climatic features, such as temperature and rainfall. Across its original range, the Andalusian Buttonquail tended to inhabit temperate lowlands with a certain degree of humidity, mainly in coastal areas. The current scenario of global warming might have broadened the Andalusian Buttonquail distribution range within the last century (Lovejoy and Hannah 2019), by allowing higher elevations or localities farther from the sea to be colonized. It can thus be assumed that the collapse of this species has not been driven by climate change.

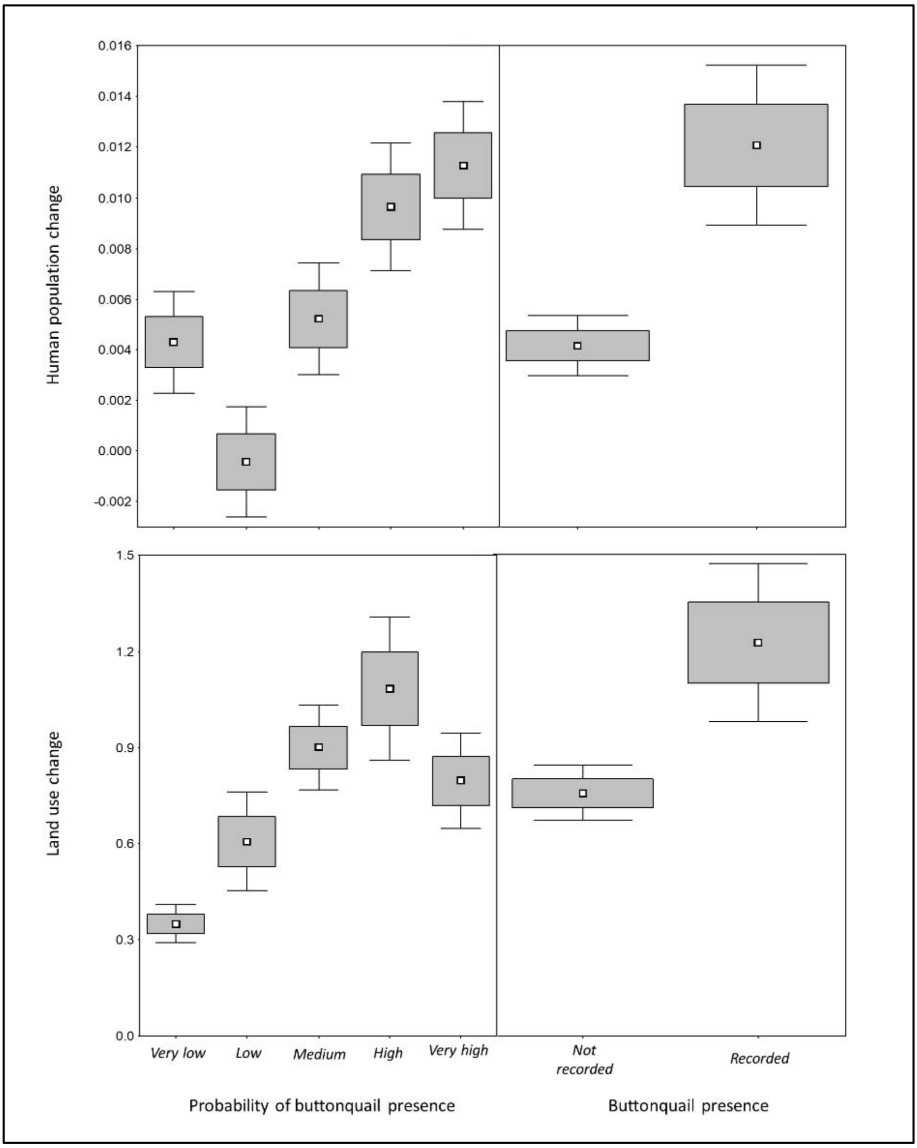

Figure 3.7. Magnitude of Human population in municipalities (up) and land use change in 100 km^2 squares (down) in Andalucía by 0.2 step of buttonquail historic presence probability (left) and presence and absence of Andalusian Buttonquail records (right).

The silent demise of the Andalusian Buttonquail, therefore, seems to have been driven directly by anthropogenic factors. Our results for the Andalusian study area clearly show that the most suitable areas for the Andalusian Buttonquail are those in which more intensive land use changes and larger human population increases have occurred. Unfortunately for this species, its narrow environmental niche matches with areas of high and increasing human activity in the Western Mediterranean. In the Andalusian area there has been a generalized substitution of Mediterranean scrubland and traditional agricultural by urban areas along Andalusian coasts from the 1950s onwards, especially intensified by the development of the tourism industry (Málvarez et al. 2000). But land use changes in the former buttonquail range go beyond urbanization. For example, the vast coastal lowlands along the right bank of the lower Guadalquivir, where the last Iberian sightings of Andalusian Buttonquails were recorded at the beginning of the 1980s (Gutiérrez-Expósito et al. 2011), have also experienced intense changes, in spite of being largely protected by Doñana National and Natural Parks (Mose 2016). Prior to the establishment of these protected areas, massive afforestation works involving mostly pinyon pine (*Pinus pinea*) and eucalyptus trees (*Eucalyptus camalduensis*) were performed, destroying the original shrubby communities (Sousa and García-Murillo 1998). As a result, suitable habitat for the Andalusian Buttonquail was reduced to a few unprotected areas. In the 1970s, an ambitious irrigation plan was implemented for the economic development of the region (Llamas 1988), which has resulted in the creation of up to 6000 ha of greenhouse intensive cultivation (mainly strawberry, blackberry, raspberry and orange trees) (Pérez-Díaz 2014). Therefore, the species has been affected not only by the expansion of irrigated agriculture but also mostly by its intensification in recent years (Kehoe et al. 2017). Recent studies of the last known population in Morocco found that breeding stages from mating to clutch hatching were doing well in terms of clutch size and hatch rate (Gutiérrez-Expósito et al. in press). Therefore, the mechanism driving the extinction of the species must lie in more advanced stages of the reproductive cycle, most likely affecting chick survival due to the absence of the optimal density of insects on which to feed, but this latter proposition needs further research.

Although not studied here, the effect of hunting as a cause of extinction has also been flagged as a reason for the very early extinction in Sicily (Violani and Massa 1993) when agricultural intensification and human population increase were still not a severe impact. In Doñana National Park (Spain) and surrounding areas, hunting probably delivered the final blow when the species was cornered in a few hunting areas due to agriculture expansion and massive forestry cultivation. The last known bird to be hunted in Doñana was in 1981, eight years before the species was protected under Spanish law. Since then no subsequent documented records have been produced in the area (Gutiérrez-Expósito et al. 2011).

Contrary to what one can infer from a formerly widely distributed species with small body size, which is low in the trophic chain, apparently flexible in its habitat requirements and unaffected by alien species or climate change, the Andalusian Buttonquail has become a critically endangered taxon. Our findings show that the narrow climatic niche of the species overlaps with the most densely populated and intensively used areas by humans. The Andalusian Buttonquail possibly collapsed because of land reclamation and agriculture intensification together with synergies with other minor drivers such as hunting (Brook et al. 2008). In the current context of global agricultural expansion and intensification (Ramankutty et al. 2018), the extinction of the Andalusian Buttonquail should act as a warning signal of what is currently occurring with other understudied fauna all over the World. the World.

Chapter VI

The farmland refuge of the last Andalusian Buttonquail population

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Introduction

In the current human-induced mass extinction and land transformation (Allan et al. 2017), declining species tend to find refuge in remnant unaltered patches of their natural habitats (Dirzo et al. 2014, Ceballos et al. 2017). These areas are characterized not only by the presence of the habitats that fulfil the ecological requirements of species (Kerr and Deguise 2004), but also for being large enough to hold self-sustaining populations and not being affected by direct threats (e.g. Woodroffe & Ginsberg 1999). However, there are cases in which the extant populations of declining species do not survive in patches of their original habitat, but in suboptimal or marginal environments, a situation that gave birth to the concept of refugee species (Kerley et al. 2012). Some refugee species can use human-made habitats, such as waste water treatment plants and irrigation ponds (Murray & Hamilton 2010, Sebastián-González et al. 2010). The use of human-made environments is particularly noteworthy among steppe and grassland birds, many of which currently occupy open farmland habitats (O'Connor & Shrubb 1986). The current agricultural intensification and industrialization occurring at a global scale are behind the dramatic population declines of farmland birds (Donald et al. 2002, Arroyo et al. 2002, Inchausti & Bretagnole 2005). The implementation of conservation measures in these intensively managed areas is conditioned by non-biological factors associated with human land-uses. For example, the choices that farmers make on crop and cropping practices are determined by factors such as market demand, price or agricultural policies, which can only be modified at much larger scales. These factors eventually define the structure of agricultural landscapes (Donald et al. 2002, Wilson et al. 2009).

Buttonquails (Turnicidae) form a family of ground-dwelling small birds most often linked to grassy or low shrubby habitats. However, a few species (i.e. Barred Buttonquail *Turnix suscitator*, Madagascar Buttonquail *Turnix nigricollis* or Common Buttonquail *Turnix sylvaticus*) can also live in farmland habitats, occupying crops, fallow land or pastures (Debus 1996, Madge & MacGowan 2002). As for other species, the historical loss of natural habitats in favour of agriculture has been an opportunity for these adaptable buttonquail species. However, the intensification of agricultural practices poses a threat to those populations that inhabit agricultural systems. Due to the unobtrusive nature of buttonquails, there is a notable lack of field-based studies (Lee et al. 2017) and thus most of the knowledge about their basic biology has originated from observations on captive individuals (i.e. Bell & Bruning 1974, Flieg 1973). Buttonquails have a sequential polyandry breeding system, in which females lead the courtship, while parental care is performed by males. Chicks have a very fast development being fertile and able to breed a few months after hatching (i.e. Bell & Bruning 1974, Butler 1905, Flieg 1973, Cramp & Simmons 1980).

The Common Buttonquail has a wide distribution range, from the Philippines in the East, through south Asia to sub-Saharan Africa and the South-Western Palearctic (Madge & McGowan 2002). The Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*) is the largest Common Buttonquail subspecies and is an endemism of the Western Mediterranean (Madge & McGowan 2002). It formerly inhabited lowlands of up to seven countries, being present in Sicily (Italy) and the Iberian Peninsula (Spain and Portugal) and from Libya to Morocco in North Africa. The Andalusian Buttonquail is currently highly threatened, officially considered extinct in Europe and with the only population known to persist being confined to a small area in Morocco (Gutiérrez-Expósito et al. 2011).

In this work we aim to 1) define the current global range of the Andalusian Buttonquail; 2) describe its habitat selection along the annual cycle; and 3) analyse possible inter-annual variability in habitat selection. Finally, using all this information, we estimate the population size of the Andalusian Buttonquail, both seasonally and on a yearly basis, and evaluate the conservation status of this subspecies living in a human-dependent refuge.

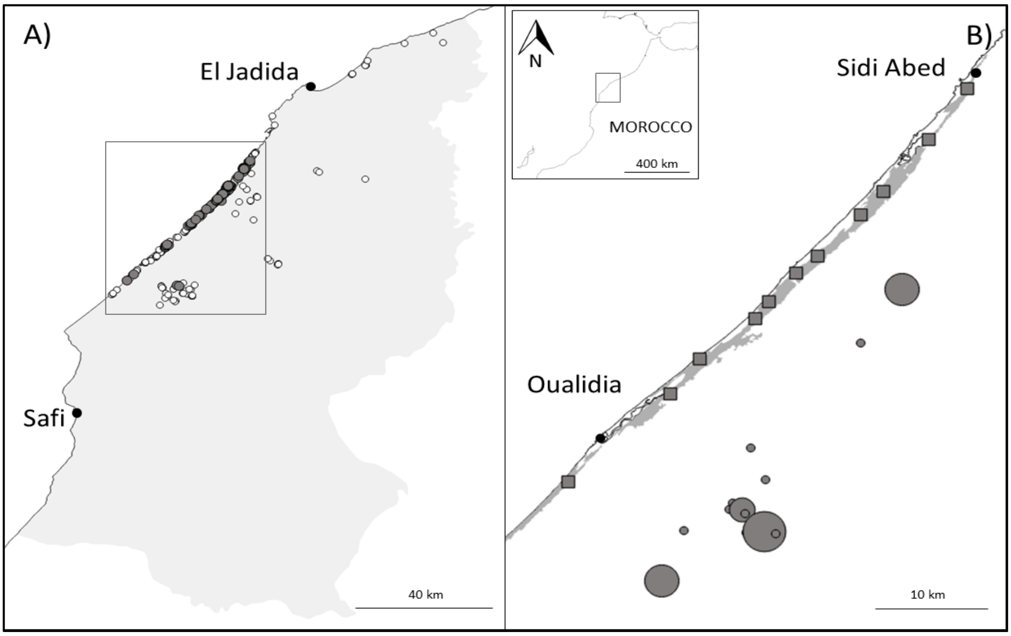

Figure 4.1. Study area and sampling areas. A) Non-systematic surveys in the region of Doukkala-Abda (light grey shaded area) between 2002 and 2010. Grey dots are positive results and blank dots those negative B) Systematic surveys sampling sites (grey squares) in the cultivated strip (dark grey shaded area) and in the natural habitat (grey circles proportional to the surface of the surveyed site).

Material and methods

Study area

Our study area covers the shire where the Andalusian Buttonquail is known to occur in the Doukkala-Abda region (Morocco, Figure 4.1). It includes a narrow coastal sandy agricultural area between Sidi Abed (33.047 N, 8.688 W) and Cap Bedouzza (32.571 N, 9.243 W) (hereafter cultivated strip; Figure 4.2) and some remnants of mediterranean scrubland, hereafter scrubland, characterised by palmetto (*Chamaerops humilis*), bridal broom (*Retama monosperma*) and Moroccan spiny broom (*Chamaecytisus mollis*), embedded within a calcareous plateau of highly degraded arid pastureland (Figure 4.3; see Gutiérrez-Expósito et al. 2011 for more information).

Figure 4.2. Cultivated habitat. A) Recently prepared plot (stage 0, not suitable for buttonquails). B) Alfalfa in stage 4 and carrot in stage 2. C) Pepper in stage 4. D) General perspective of multiple plots in the cultivated strip, with the dune system separating it from the Atlantic Ocean in the background.

Buttonquail and habitat surveys

We sampled the presence of the Andalusian Buttonquail by walking the area and scanning the ground for its faeces, together with other signs, such as feeding platelets, footprints or feathers (Lees & Smith 1998, Gutiérrez-Expósito & Qninba 2010). Very rarely by direct sight or hearing the typical female booming call (Madge & McGowan 2002). Searching was performed until all walkable area was visited at least by one observer. Given the high effectiveness of this sampling method, no false negatives have considered to occur in our data base (see details on sampling effort under methods in the General Introduction). In the cultivated areas, we used whole individual cultivated fields, hereafter plots, as sampling units (Figure 4.2), while in the scrubland we performed linear transects. Our sampling was based in non-systematic and systematic surveys.

Figure 4.3. Natural habitat. A) The overgrazed calcareous plateau. B) Palmetto scrubland. C) Spiny broom scrubland.

Non-systematic buttonquail searches consisted in plot or transect searches in sites selected in the field where presence of buttonquails was expected. Between 2010 and 2015, 627 plots were surveyed within the cultivated strip, plus 40 agricultural sites outside this cultivated strip, where the species was suspected to be present. Scrubland sites were visited 32 times in total between 2006 and 2014. Together with our non-systematic sightings, we compiled the few opportunistic buttonquail records produced by local and visiting birdwatchers in the study area since 2000 (Figure 4.1.A), when this population was re-discovered (Gutiérrez-Expósito et al. 2011). Additionally, we sampled the scrubland in March 2017 (late winter, early spring), when highest activity is expected in this type of vegetation. This survey covered 14 patches of scrubland comprising 887.7

ha, in which we performed transects searching for buttonquail's signs of presence covering a total of 100.1 km (Table 4.1, Figure 4.1.B).

In order to study the buttonquail population and the farming practices and its evolution along time, a long-term monitoring plan was established in the cultivated strip, by performing systematic surveys on both inter- and intra-annual basis, in previously defined and fixed areas (Figure 4.1.B).

Habitat	Surface (Has)	Distance (Kms)	Time (min)	Km/Ha	Min/Ha
bridal broom	12.48	2.91	144	0.23	11.54
dense palmetto	58.93	29.01	1228	0.49	20.84
open palmetto	492.61	35.72	880	0.07	1.79
open palmetto with spiny broom	142.52	9.60	320	0.07	2.25
spiny broom	10.03	0.86	60	0.09	5.98
spiny broom with palmetto	171.11	22.00	1020	0.13	5.96

Table 4.1. Effort by habitat type in the scrubland.

As a surrogate of the whole cultivated area, systematic surveys in the coastal strip were performed in 11 fixed sampling sites evenly distributed along the strip covering a total area of 86.9 ha (1.8 % of the cultivated strip, Figure 4.1.B). These sites contained on average 30 plots (± 11.6 SD) (N = 330). Mean plot size was 0.26± 0.32 ha, with a maximum of 2.1 ha and a minimum of 0.01 ha. All crop types found in the cultivated strip were represented in the 11 sampling sites. Surveys aimed at assessing inter-annual trends were performed in mid-June (hereafter, summer surveys), when, according to the reports by local farmers, maximum breeding activity was expected. These surveys took place in 2011, 2014 and 2017. In order to study the seasonal variation in buttonquail habitat use and population numbers, we also surveyed in early March (winter), April (spring), mid-June (summer) and late September (autumn) during 2017.

In each plot, we recorded the number of observers, the time in minutes to the first evidence of buttonquail presence, the total sampling effort in minutes, area in hectares and perimeter in meters of plots were calculated by using QGIS 2.18 (QGIS Development

Team 2018). As habitat descriptors for each surveyed plot we recorded the identity of the cultivated species (*crop*), mean height (*height*, in cm) and coverage (*cover*, in %), the cultivation stage (*stage*) and the presence of irrigation (*irrigation*) and, when present, its type (*irrigation type*). *Cover* was defined as the proportion of the plot covered at both crops and weeds levels, and thus the total cover can exceed 100%. Cultivation *stage* was defined as: i) 0 arable land with no vegetation cover; ii) 1 recently planted plots with very low cover; iii) 2 growing plants with no flowers; iv) 3 most of the plants have flowers or are starting to develop its harvestable parts (e.g. fruits, roots etc.); v) 4 most of the crop is ready to be harvested; and vi) 5 harvest finished and the cultivation is abandoned. When the plot was irrigated, we noted the method used: i) *flooding* the *plot*, ii) *watering* individual plants, iii) *sprinkling* and iv) *dripping*. In 2017 we also recorded the proportion of bare ground as the proportion of nude soil at ground level. Due to the high diversity of cultivated species (Table 4.2), they were assorted in groups with similar cultural characteristics, phenology and treatments, reducing the 25 cultivated species into 8 types within *crop type*: *unvegetated* (ploughed land or recently planted still no identifiable crop), *carrot*, *cereal*, *grass* (broad bean, clover, fennel, vetch, alfalfa, wasteland and fallow land), *maize*, *ground* (artichoke, beet, cauliflower, potato, turnip, cabbage and radish), *pumpkin* (pumpkin, zucchini, gourd, cucumber and watermelon) and *staked* crops (tomato, pepper and aubergine).

As survey results, we noted the presence/absence of buttonquails and presence/absence of reproduction, as well as an estimation of the minimum number of individuals present. We considered a plot as occupied when we found signs of presence. We considered that breeding activity was occurring in a plot when we detected singing females and/or when we found nests or chicks. We assigned a minimum of a single individual (adult or independent juvenile) to plots where presence was probed but no signs of reproduction were found (plots adjacent to those with presence where normally not occupied). For plots with breeding activity, the minimum number of females was estimated as the number of singing females heard and we assumed the presence of one adult male per female, even though this might underestimate the number of males in a polyandric breeding species. When we found a nest or chicks, we conservatively assumed the presence of a single female and the corresponding male.

Crop	Crop type	Surveyed	Positive
wheat	cereal	288	21
carrot	carrot	119	13
broad bean	grass	2	1
clover	grass	3	1
fallow	grass	244	24
fennel	grass	1	0
lucerne	grass	562	165
vetch	grass	2	0
wasteland	grass	7	3
artichoke	ground	12	7
beet	ground	2	0
cabbage	ground	62	4
cauliflower	ground	42	11
potato	ground	35	9
radish	ground	1	0
turnip	ground	54	8
watermelon	ground	2	0
maize	maize	197	53
cucumber	pumpkin	35	1
gourd	pumpkin	19	4
pumpkin	pumpkin	145	44
zucchini	pumpkin	66	11
aubergine	staked	23	2
pepper	staked	107	25
tomato	staked	217	25

Table 2. Number of surveyed plots and positive plots of crops sorted by crop type during both systematic and non-systematic surveys

Analyses

Statistical analyses have been done with the R computing environment (R Core Team 2017). Prior to modelling process, a correlation matrix was constructed by means of “GoodmanKruskal” package (Pearson 2016). Variables were considered correlated with correlation values of 0.7 or higher. We analysed habitat occupancy by means of generalized linear mixed models (binomial distribution with a logit link) with the “lme4” package (Bates et al. 2015), using the presence or absence of buttonquails as the dependent variable. Habitat descriptors were used as predictors and sampling site as a random factor. We constructed models using either seasonal (2017) or annual data (mid-June surveys in 2011, 2014 and 2017), hereafter seasonal and year models, respectively. To study the seasonal and year-to-year variations, we forced the variables *season* and *year* while modelling its respective data-sets. Model selection was done by step-wise variable addition to the null models, selecting those with smaller Akaike information criterion for small samples (AICc) values (Hurvich & Tsai 1989) and not considering the correlated ones in the next step. Variable addition finished when no improvement on the AICc values was obtained.). Predictor’s multi-collinearity has been assessed by calculation of the variance inflation factor with “car” package (Fox & Weisberg 2011). Fitness of the models were calculated by means of AUC values obtained from ROC curves with the “pROC” R package (Robin et al. 2011).

Confidence intervals were calculated by adding and resting the standard error to every predictor’s estimate. Based on the presence probabilities obtained by applying the inverse of the logit function to the predictor’s parameters in the different models, population estimates were obtained using the equation:

$$N = \sum p_i \cdot \frac{N_i}{Sp_i} \cdot \frac{Ss_i}{S} \cdot A$$

where N is the number of buttonquails estimated, p_i is probability of presence in the type of *plot i* estimated with the selected models (the type differs between models depending on the results), N_i is the number of buttonquails observed in the type of *plot i*, Sp_i is the sampled area with presence of the type of plot *i*, Ss_i is the total area sampled of the type of plot *i*, S is the total area sampled and A is the total area of the of the cultivated strip.

Results

Distribution

The area of occurrence of Andalusian Buttonquails is restricted to the cultivated strip (Figure 4.1.B). Non-systematic searches in other agricultural areas yielded no positive results (Figure 4.1.A). Only two records have been obtained in scrubland habitat since 2001, in May 2002 (Pierre André Crochet pers. comm.) and in April 2006 (José Luis Copete, pers. comm.) (Figure 4.1.A). In spite of the important search effort we made in the remnant shrub patches, we did not find any evidence of buttonquail presence. The remnant population occupies a broad variety of crops in the 4,675 ha patch of the cultivated strip (Figure 4.1.B, Table 4.2).

Patterns of occupancy and seasonal crop use

In total, 91.6 % of the plots in the systematic survey sampling sites (N = 301) were covered by arable land, while 4.1% was occupied by buildings (N = 16) and 4.3% by paved and dirt roads (N = 13). Apart from the human-made structures, we found no sign of presence in any plot at initial stages of the crop cycle, coinciding with phenological stages 0 (nude land) and 1 (planting) and thus we considered them as unsuitable for buttonquails (Figure 4.2.A). The number and distribution of suitable plots (those above stage 1) varied along the year due to the agricultural dynamics, with a maximum in winter and spring, when cereal crops cover almost half of the cultivated strip. In summer the area suitable for buttonquails is highly reduced due to cereal harvesting and a further reduction occurs in autumn when the harvesting of summer crops ends and land preparation for winter crops starts (Figure 4.4.A).

The area with buttonquail presence within the 11 sampling sites varied seasonally between 4.24 ha in autumn and 6.01 ha in summer. The proportion of suitable area occupied by buttonquails in summer and autumn doubled that of winter and spring (18.1 % and 20.1 % versus 11.1 % and 10.1 % respectively; Figure 4.4.A). Extrapolating to the entire cultivated strip, along with the year 2017, buttonquails occupied a minimum of 228 ha in autumn and a maximum of 323 ha in summer. The same summer estimates for June 2011 and 2014 were 915 and 253 ha, respectively.

Buttonquails occupied crops offering a high vegetation cover (mean cover 86.1 %; N = 62). In total, 61.3 % of the suitable plots occupied by buttonquails were in stage 4, while only 17.7 % were in stages 3 and 5. Presence in stage 2 was very uncommon (3.2 %), corresponding to growing cereal crops in winter. *Grass* plots (mainly alfalfa) were available and used by buttonquails all along the year, comprising between 30% and 40 % of the occupied plots in every season. Carrot and cereal fields were important during winter (44% and 22% of occupied plots, respectively), and the occupation of the later increased in spring (50%). A great variety of irrigated crops were used in summer, including *staked* crops (30%) *ground* crops (17.4 %), *maize* (13%) and *pumpkin* (9%). In autumn buttonquail occurrence was mainly concentrated in *pumpkin* (15%) and *steaked* crops (45%) (Figure 4.4.B).

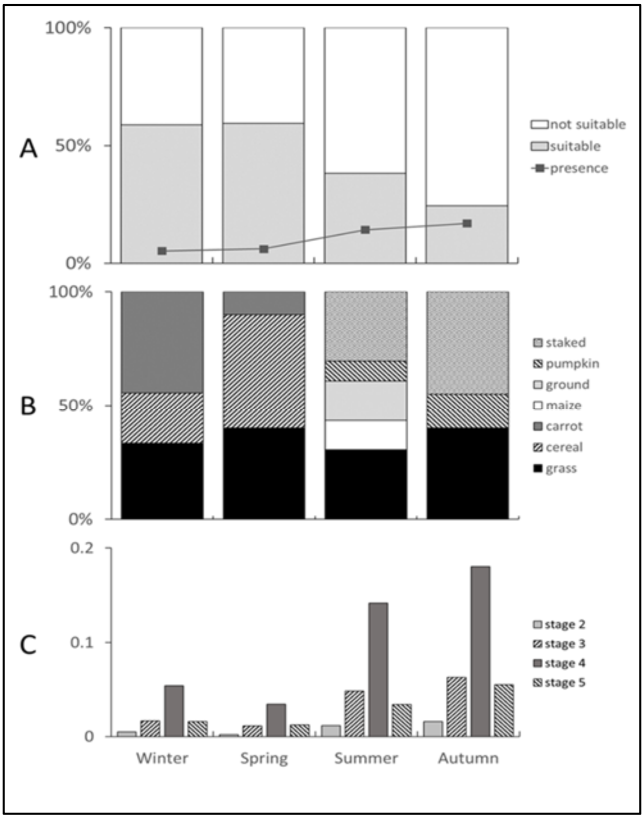

Figure 4.4. Seasonal variability in agricultural habitat characteristics and Andalusian Buttonquail occupation metrics. A) Bars: percentage of study area that is *suitable* (grey) or *not suitable* (white) for occupation by the Andalusian Buttonquail (defined by plots at stage <2 or >=2, respectively); solid line: percentage of the suitable area where the presence of Buttonquails was detected. B) Proportion of the area of different crop types among plots with presence of Buttonquails. C) Probability of presence by stages of crop phenology derived from the seasonal model.

In 2017, 53.3 % of the systematic survey sampling events (N = 1,320) occurred in plots not suitable for buttonquails (i.e., in stages 0 or 1) and thus were not informative about habitat selection, consequently, were not considered in the seasonal analyses. The best model describing seasonal presence probability included cover and the stage of the crop (AUC = 0.8469) (Table 4.5; see Supplementary Material S.4.1), with a higher probability of presence associated to high cover and to crop stage 4 (Figure 4.4.C). No multi-collinearity was found among predictors (See Supplementary Material S.4.4).

Interannual trends

The area suitable for buttonquails declined along the years, from 63.4 % in 2011 to 38.2 % in 2017, mostly due to an increase in the proportion of ploughed land (Figure 4.5.A). Proportion of suitable crops occupied by buttonquails also decrease along years, from 20,7 % (N = 227) in 2011 to just 16.5 % (N = 162) in 2017, with a minimum in 2014 with only 10.3 % (N = 165). Same calculation for coastal strip surveyed plots in 2010 yielded a proportion of 26.7 % occupied suitable plots. Almost 90 % of the positive plots were in crops at stages 3 or 4 (N = 80). Although most of the positive plots were irrigated (N = 70), one out of every 6 irrigated plots was occupied, while the proportion of occupied plots was higher in non-irrigated ones (25.8 %) due to the high presence of buttonquails in fallow plots. When irrigation was present, the preferred systems were watering the plant (36 % N = 68) and dripping (20 % positive N = 258), while plots irrigated by complete flooding were less frequently occupied (6.2 % N = 154).

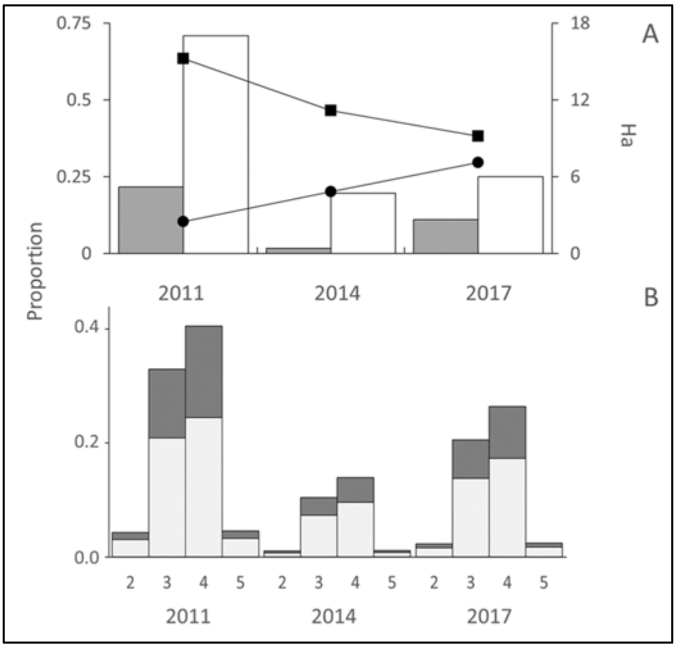

Figure 4.5. Year to year variations: A) Area (in ha) with presence of buttonquails (white) and confirmed breeding (grey), and proportion of suitable area (squares) and plough land (circles). B) Probability of presence (dark grey) and breeding (light grey) on each phenological crop stage.

We ran the analyses for the annual model using the 571 sampling events in suitable plots. The selected models included *stage* and either the presence of *irrigation* or the *irrigation type*, in addition to *year*. Due to the small differences among AICc values in the two models, the simplest model (AUC = 0.8526) (i.e., including the binary variable *irrigation* as predictor) was used to calculate presence probabilities (Table 4.3; see Supplementary Material S.4.2) (Figure 4.5.B). No multi-collinearity was found among predictors (See Supplementary Material S.4.3).

	Variable	Estimate	St.Err	z value	Pr(>|z|)
seasonal	(Intercept)	-3.434	0.837	-4.104	< 0.001 ***
	seasonSpring	-1.655	0.475	-3.483	< 0.001 ***
	seasonSummer	-0.206	0.382	-0.539	0.5900
	seasonWinter	-1.543	0.485	-3.183	0.0015 **
	stage2	-1.440	0.811	-1.775	0.0759
	stage3	-0.365	0.496	-0.737	0.4614
	stage4	0.689	0.438	1.572	0.1159
	cover	0.014	0.006	2.322	0.0202 *
year	(Intercept)	-3.020	1.016	-2.972	0.0030 **
	year2014	-1.444	0.342	-4.230	< 0.001 ***
	year2017	-0.645	0.327	-1.976	0.0482 *
	stage2	-0.070	0.943	-0.074	0.9407
	stage3	2.334	0.878	2.659	0.0078 **
	stage4	2.664	0.861	3.093	0.0020 **
	irrigationtrue	-1.280	0.415	-3.088	0.0020 **

Table 4.3. Output coefficients for seasonal (N = 616) and year (N = 571) models.

Buttonquail density and population estimates

The density of individuals within the sampled area in the 11 sites, calculated from the estimated minimum number of individuals, increased along the year with the progress of the breeding season, from 0.13 individuals/ha in winter to a maximum of 0.37 individuals/ha in summer. However, when densities were calculated in relation to the suitable area, winter density increased to 0.22 individuals/ha and the maximum value was obtained in autumn (1.14 individuals/ha). Higher breeding female densities were observed in summer, in terms of both total sampling sites area with 0.09 females/ha, and suitable area, with 0.21 females/ha. Individuals and female's densities by phenologic stage and season used in population estimates are shown in Table 4.4. Between 2011 and 2014 densities decreased from 0.72 individuals/ha and 0.12 females/ha to 0.24 individuals/ha and 0.04 females/ha respectively for total summer density and total density of females. In 2017 a slight recovery was observed, with 0.37 individuals/ha and 0.09 females/ha. Buttonquail densities by phenological stage, presence/absence of irrigation for every year are given in Table 4.5.

	Winter			Spring			Summer			Autumn		
stage	**D**	**F**	**P**	**D**	**F**	**P**	**D**	**F**	**P**	**D**	**F**	**P**
2	1.18	0.39	0.29	0.00	0.00	0.03	0.00	0	0.06	0.00	0.00	0.04
3	0.00	0.00	0.12	9.55	4.77	0.11	4.43	1.33	0.11	4.81	0.00	0.06
4	2.55	3.19	0.16	2.41	0.72	0.37	6.35	1.12	0.13	5.48	1.18	0.08
5	0.00	0.00	0.03	2.32	0.00	0.08	2.78	0.93	0.08	6.56	0.00	0.06

Table 4.4. D) Buttonquail density (number of estimated individuals per positive ha), F) breeding female density (number of breeding females per positive ha) and P) proportion of sampled surface for every season and crop stage.

		2011		2014		2017	
	Crop stage	**Non-irrigated**	**Irrigated**	**Non-irrigated**	**Irrigated**	**Non-irrigated**	**Irrigated**
Buttonquail density	2	0.00	11.07	0.97	0.00	0.00	0.00
	3	1.18	2.42	1.23	6.96	0.00	4.43
	4	2.15	5.04	2.63	6.83	8.06	5.96
	5	10.60	0.00	0.00	0.00	1.23	7.61
Breeding female density	2	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.30	0.00	1.74	0.00	1.33
	4	0.59	0.95	0.00	1.05	2.01	0.92
	5	0.00	0.00	0.00	0.00	0.00	3.80
Proportion of sampled surface	2	0.06	0.07	0.05	0.02	0.01	0.05
	3	0.02	0.13	0.04	0.07	0.00	0.11
	4	0.06	0.25	0.03	0.24	0.01	0.13
	5	0.18	0.02	0.25	0.01	0.28	0.02

Table 4.5. Buttonquail density (number of estimated individuals per positive hectare) and proportion of sampled surface for every year and presence/absence of irrigation.

The estimated number of individuals in the whole population was very variable with large uncertainties (Figure 4.6). In 2017 numbers were low in winter at the beginning of the breeding season, with 112 (15 - 834) individuals, increasing to a summer maximum with 719 (99 - 3,197) individuals. Only 16 (3 - 125) breeding females were estimated in winter, peaking in summer with 147 (21 - 672). The estimated number of individuals in 2011 was 1,890 (360 - 6,818), while in 2014 numbers went down to 492 (40 - 4,111), with a slight recovery in 2017, with 596 (59 - 3,584) estimated birds. An almost identical trend has been found in the number of breeding females, from 270 (40 - 967) estimated in summer 2011, to 70 (5 - 646) in 2014, 117 (10 - 727) breeding females in 2017.

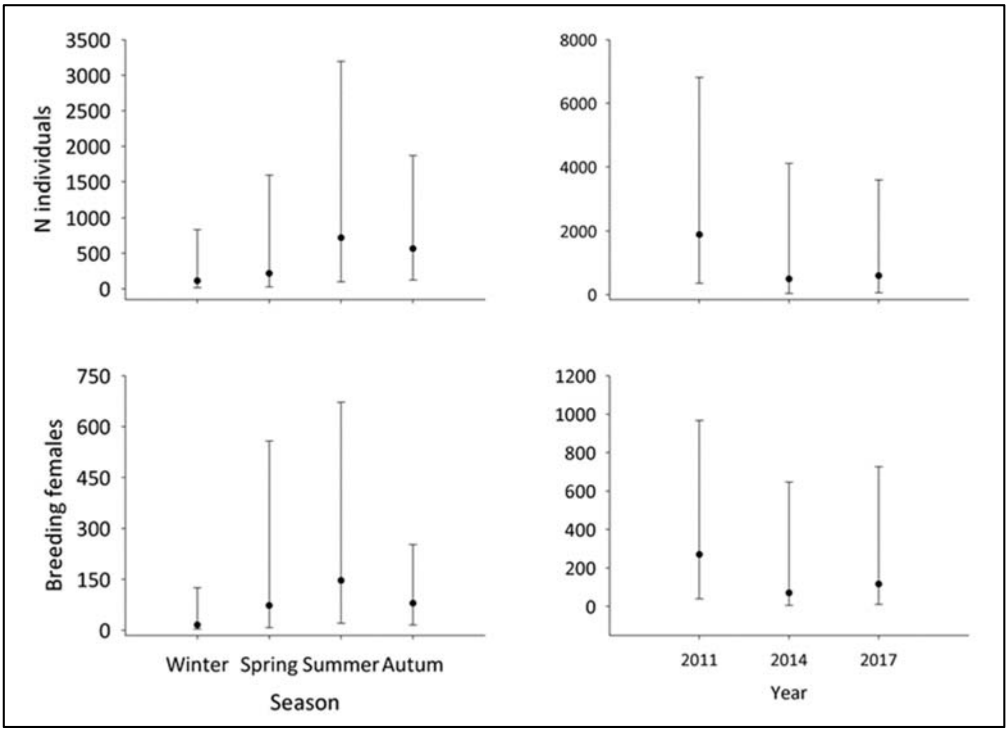

Figure 6. Mean and confidence intervals of the estimated number of individuals and breeding females for every season along 2017.

Discussion

The Andalusian Buttonquail is apparently absent from natural or semi-natural habitats, where its last record occurred in 2006, in spite of our large search effort. The large barren calcareous plain of the Doukkala-Abda region maintained until very recent times a vast extension of scrubland used mainly for livestock grazing (Gigout 1951, Michard et al. 2008). Arguably, this was the original habitat of the Andalusian Buttonquail in the area, being similar to the described habitats used by the species in other areas in its former distribution range (Irby 1895, Whitaker 1896). However, the area covered by palmetto and broom shrubs has been drastically reduced, to only 2,150 ha at the beginning of this century, barely 2.5 % of the plain (Gutiérrez-Expósito 2011) and a further reduction to the current 900 ha, which possibly precludes the permanent occupation by buttonquails. Nevertheless, these remnant areas of natural vegetation may have a role as habitat for the Andalusian Buttonquails during favorable periods such as after rain episodes, as occurs with sub-Saharan buttonquails behaving as nomadic wanderers in search of areas of high productivity in natural scrubland and savannahs (Urban et al. 1986, Debus 1996, Herholdt 2001). Therefore, the protection of the few remaining areas with natural scrubland and their continued prospection should be a conservation priority. Since we failed in detecting any sign of presence in the other agricultural areas of the region, currently the global known population of Andalusian buttonquail is confined to 4,675 ha of highly dynamic cultivated area intensively used by people.

The Andalusian Buttonquail selected crops with high vegetation cover and in advanced stages of their cultivation cycle. Buttonquails must adjust their life cycle to the fast seasonal crop rotation, leaving and colonizing plots in search of suitable conditions for breeding or feeding. In this sense, we found that the availability of suitable plots changes not only along the year but also has decreased over the years. The number of individuals increases along the breeding season, while the area occupied by crops at a suitable stage decreases in summer and autumn, resulting in higher densities in the suitable remnant plots after the main harvest in summer and autumn. The decline in the area suitable for buttonquails from 2011 to 2017 can in part explain the decline in the population estimates between 2011 and 2017. Given that there were no changes in the composition of cultivated vegetables in the summer season, this decrease in the suitable area can be explained by the increased mechanization of farming practices, which leads to an earlier land preparation for forthcoming crops and a reduction in the area of crops in the post-harvest stage. Alfalfa plots were available and positively selected by the Andalusian Buttonquail all year round, but the occupation of plots with seasonal crops was much more dynamic. Carrots are the preferred crop during winter, a preference that turns to glean wheat in spring when carrots are being harvested. In summer a great variety of irrigated crops are fully grown (e.g., maize, pumpkin, cabbage, turnip), being then occupied by buttonquails, while many plots are recently planted and have growing summer crops such as tomato and pepper. These staked crops are avoided by buttonquails at these early stages but are widely occupied at the end of summer and during autumn (Figure 4.4.B).

Estimating numbers of such a discrete creature has proven to be very difficult. Only one previous global estimate for a buttonquail species has been afforded, involving the South African endemic Hottentot Buttonquail *Turnix hottentottus* (Lee et al. 2019). Although our models have a low prediction power the significance of the selected predictors is quite high (Table 4.5). One explanation could be in the presence of multi-collinearity among predictors resulting in an inflation on the regression coefficients. Once this effect has been discarded (Supplementary Material S.4.3), the low prediction power of the models may reside in the low rate of occupancy of plots that apparently fits with the requirements of the species. As can be inferred from the dropping proportion of occupied suitable plots along the years, the current population should be very well under the optimal density. Even so, the estimates obtained for June 2017 by means of different data and different predictors do not differ that much, 719 individuals with the seasonal modelling versus 596 with the inter-annual model (see Table 4.6). Thus, in spite of the large uncertainty of our population estimates, we consider them to be a reasonable first approximation to the current status of the species in the Western Palearctic. Apart from estimating the probability of presence in different plots, our approach requires knowing the number of individuals present in occupied plots. Occupied plots are normally surrounded by unoccupied ones (i.e., with no sign of presence), which, in a predominantly ground-dwelling species such as the buttonquail, indicates that their space use is restricted to the occupied plots. We decided to use the minimum number of individuals potentially present to obtain a conservative estimate of population size. Nevertheless, future studies should aim at describing the space use of buttonquails in this area and to obtain better estimates of the number of individuals present in occupied plots, especially during the months with a reduced availability of suitable plots.

Model	Covariates	N individuals	N Breeding females	Data sets
seasonal	stage + cover	718 (99-3197)	147 (21-672)	Winter, Spring, Summer and Autumn 2017
year	stage + irrigation	596 (59-3584)	117 (10-727)	Summer 2011, 2014 and 2017

Table 4.6. Summary of number of individuals and breeding female estimations and confidence intervals for Summer 2017 by seasonal and year models.

Our estimates show a more than five-fold increase in population numbers by summer which can be explained by the reproductive capacity of the species, including early maturity and fast reproduction cycles. The breeding productivity of buttonquails can be very high due to its sequential polyandry, which, in good conditions, allows females to brood serially with different males and thanks to its precocity in sexual maturity, chicks born in winter and early spring could be breeders in summer or autumn (Cramp & Simmons 1980, Debus 1996). Population numbers in species with such fast reproduction cycles are highly dependent on the number of founders that survived the previous non-breeding period. In the case of the Andalusian buttonquail, reproduction failure on a single year could involve the collapse of its last known population and lead to a fast extinction. In this sense, the large inter-annual variability in the number of individuals in our seven-year study period seems especially worrying. Whether the reduction of summer population size from 2011 to 2014 and 2017 is a real decline or part of the long-term inter-annual variability in population size is an important issue that deserves more attention. Buttonquails seem to be subject to high seasonal population changes, mediated by breeding productivity and farming practices.

This population is affected by multiple extrinsic factors such as crops dynamics, agricultural practices, irrigation policies or vegetable market demand. Some agricultural innovations such as irrigation by dripping instead of flooding can lead to substantial water savings, while also improving the breeding success of ground nesting birds. The current promotion of dripping in Morocco might thus result in an increase in the suitability for buttonquail presence and reproduction in the area, but it could also be a first step in an intensification process of unknown consequences (Molle & Tanouti 2017). In our study area, farming intensification involves the use of agricultural chemicals, which is currently increasing (Jghalef et al. 2016). Agrochemicals, especially insecticides, can lead to collapses of invertebrate communities (Pisa et al. 2015), with cascading effects along trophic chains (Lomba et al. 2015) that would arguably have a severe impact at least in the first growing stages of buttonquail chicks, whose diet is mainly insectivorous (Cramp & Simmons 1980). Farming practices, such as plowing or harvesting, may represent an added source of mortality of both nests and chicks, with potentially more impact as agricultural modernization increases and heavier machinery is employed.

The survival of threatened species in areas intensively used or even created by humans is always a surprising result (Casas et al. 2011). The maintenance of the last known Andalusian Buttonquail population in an area intensively used by people might have been favored by a casual set of factors. The coastal strip sustaining buttonquails is rich in groundwater for irrigation and has mild climatic conditions, both factors allowing dynamic, whole-year agriculture. Also, the average cultivated plot size in the area is very small (less than 0.3 ha), favoring the dynamism of the agricultural cycles, a diversity of practices and the maintenance of small features such as stone walls, pasture margins, hedges, as well as animal fodder crops such as alfalfa and fallows, maintaining highly diverse plant and animal communities (Hunter 2016). All these factors apparently recreate the optimal conditions for buttonquails. In this sense, it is essential to promote the conservation of this traditional farming system, avoiding the consolidation processes often associated with agricultural intensification (Poschlod and Braun-Reichert 2016). In an unstoppable frame of agricultural intensification, rational land use and modernization of this agricultural area should be regarded, not only as an opportunity to conserve one of the most endangered taxa in the Western Palearctic but also to improve the living conditions in the farmer's community (Adams et al. 2004).

Conclusions

Given the currently available information, our distribution and population estimates must be considered as the global estimation for this taxon, an endemism of the Western Mediterranean basin (Pertoldi et al. 2006, Gutiérrez-Expósito et al. 2011). Persistence of such a little and declining refugee population in a very small area with a high human use seems very unlikely. In this sense, although Andalusian Buttonquail classifies as a taxon underneath species level (Gippoliti & Amori 2007), a proper conservation status assessment and conservation action plan are urgently needed (Storch et al. 2006, DBCA 2018) to face conservation measures at both in-situ and ex-situ levels.

Chapter V

Breeding ecology of the Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*)

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(accepted) Ostrich.

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 the 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 9 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.

Material and 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 5.1). 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 5.1).

Year/Season	dec-jan	feb-mar	apr-may	jun-jul	aug-sep	oct-nov	Year total
2009	0-0	0-0	0-0	1-1	0-0	0-0	1-0
2010	0-0	0-0	0-0	248-71	22-14	18-6	288-68
2011	11-4	11-3	9-2	296-65	17-11	6-6	350-51
2012	6-0	23-9	7-4	13-7	8-3	7-2	64-5
2013	12-5	29-4	63-14	48-22	0-0	21-9	173-50
2014	14-7	27-10	0-0	275-36	0-0	24-11	340-64
2015	14-3	11-4	6-4	17-12	23-16	4-4	75-43
2016	3-3	16-5	11-3	34-9	22-10	14-7	100-37
2017	0-0	218-9	252-10	238-23	203-20	0-0	911-62
Season total	60-22	335-44	348-37	1170-246	295-74	94-45	2302-343

Table 5.1. Year to year and bimonthly seasonal distribution of all sampling events (left number) and positive sampling events (right number).

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 (m2) 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. Statistical analyses were done over the 216 positive field sampling events made in early Summer (June-July) when most of the sampling effort has been done (Table 1). 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. Model significance was analysed by means of ANOVA glmm Chi-square test against the null model. 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 in 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 5.1). 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.

Figure 5.1. Complete clutches in nests of Andalusian Buttonquail, with (left) and without (right) grass roof cover.

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 to 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 5.2). 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 5.2). No differences between presence and breeding sampling events where found for any of the habitat variables analysed. In summary, buttonquails have a strong phenological pattern for breeding and have not any specific selection for those fields where breeding takes place.

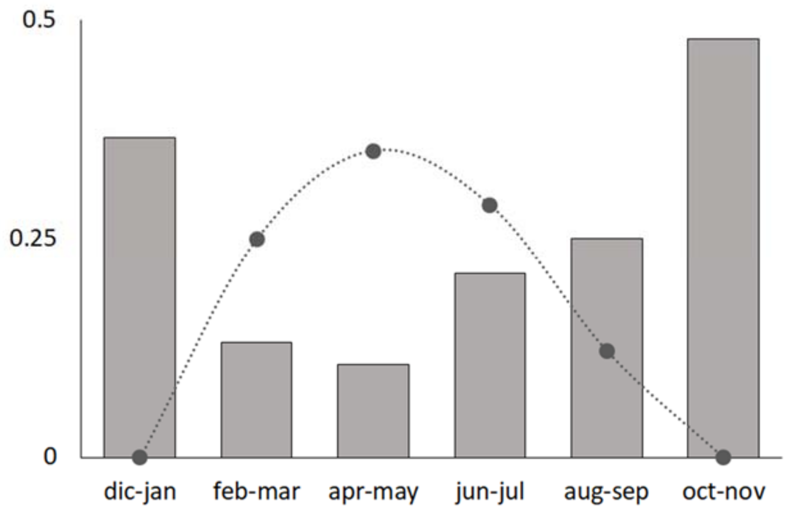


Figure 5.2. Proportion of positive sampling events (grey bars) and proportion of positive sampling events where reproduction was confirmed.

Buttonquails were found to be present in 17 different crops and breeding was recorded in all but cucumber and artichoke (Table 5.2). 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 5.3).

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 5.1).

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 3 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.

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

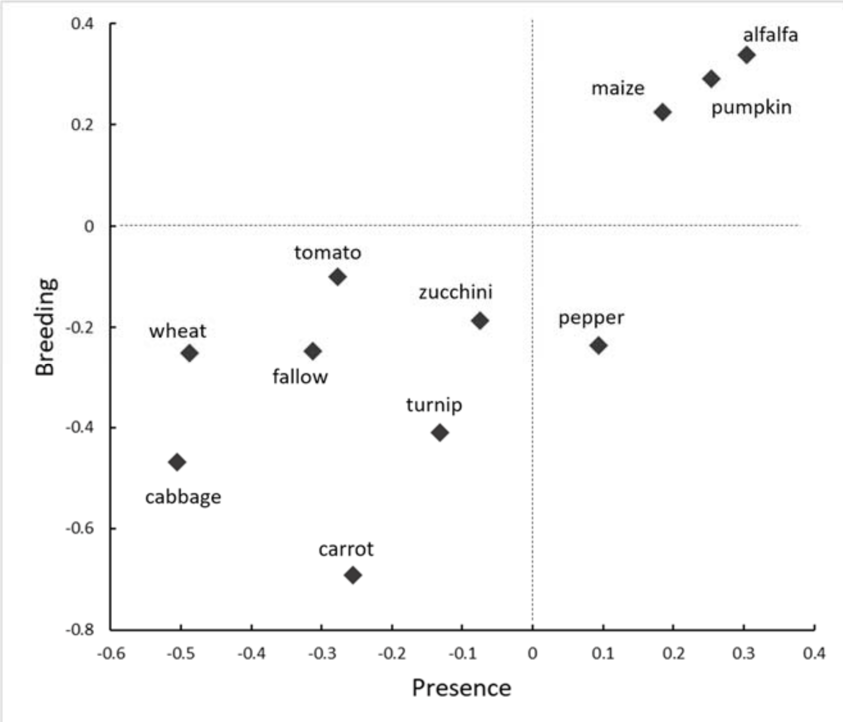


Figure 5.3. Graphic output of the application of the Ivlev's electivity index for presence and breeding.

Discussion

The breeding season of the Andalusian buttonquail probed 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 lapse 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 essay 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.

Figure 5.4. Breeding female trapped for ringing. Already performing a complete moult, still have the external unmoulted primaries and the secondaries showing juvenile pattern.

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). 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, infeering it had hatched early in the same breeding season (Figure 5.4, 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 goes by, 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 are not 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 5.3; 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 ichneumon 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 leaved 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.

Area	Subspecies	N	min[1]	mean[1]	max[1]	min[2]	mean[2]	max[2]	References
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

Table 5.3. Egg measurements for different subspecies of Turnix sylvaticus in terms of maximum lenght[1] and maximum diameter[2].

John Gould's painting of the "Andalusian Turnix" *Hemipodius tachydromus* on the 4th volume of his magnificient work Birds of Europe published in 1837.

Chapter VI

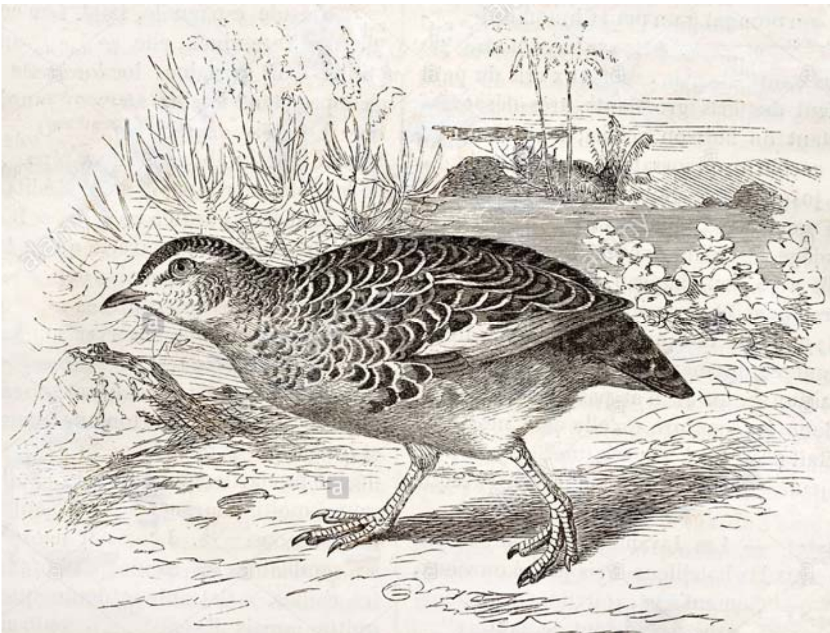
Gardens by the sea: the last Andalusian Buttonquail refuge

Gutiérrez-Expósito, C. (accepted). EcoPics. Frontiers in Ecology and the Environment

As all Turnicidae, the Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*) is a skulking creature more often heard than seen, and consequently barely studied and very rarely observed. Living individuals were never photographed on film and the first digital picture was obtained in 2007. Formerly found in up to seven countries around the westernmost part of the Mediterranean Sea, this taxon suffered a generalized, though largely unnoticed, decline. Large extensions of its natural habitat, lowland mediterranean scrubland, have disappeared due to human occupation and cattle overgrazing. Nowadays, the only known extant population of this critically endangered taxon occupies a small farmland area on the Atlantic Moroccan coast.

Breeding pair of Andalusian Buttonquail at Ouled Ghanem (Morocco) in Summer 2017.

Can we conserve this imperilled bird when the whole population lives in an area intensively used by people? How this could be done? Since the beginning of the 21th century the country is immerse in a generalized modernization affecting all aspects of human life such as communications, transport infrastructures, and, of course, agriculture. Buttonquails survived in small traditionally irrigated vegetable gardens of pumpkin, alfalfa, maize, tomato and pepper, among others. A good dose of imagination will be necessary to preserve this taxon, including a multidisciplinary approach which combines conservation biology with agronomy and social sciences. The main challenge will be improving farmer's way of life while maintaining the biological requirements of the species with good farming practices. Finding the markets for high quality ecological products with a buttonquail conservation label may result in an improvement of the sustainability of the agricultural system that can help to increase the benefits for the local farmers. In summary, nature conservation with the people and for the people.



Black and white painting by Robert Kretschmer (1861) depicting an Andalusian Buttonquail in the first ornithological to be translated into several idioms, including Spanish: Das Leben der Tiere: Die Vögel by Alfred Edmun Brehm. This drawing has been inadequately selected by a very well known food enterprise to label his tin with pickled quail.

Pair of Andalusian Buttonquails. Watercolour over 300 gr paper (100% cotton). Gema Ruiz 2019.

General Discussion

General discussion

Sentences as "small secretive quail like" (Cramp and Simmons 1980), "extremely secretive" (Urdiales 1997), "extremely secretive, rare and seldom seen" (Beaman and Madge 1998), "buttonquails are secretive and difficult to observe in the wild" (Debus 1996) … are the ones with which scientific literature introduces the buttonquails, giving an idea of the difficulty to detect them, and thus, to study them. For example, the Andalusian Buttonquail, main study subject of this thesis, had never been photographed alive until 2007 (Gutiérrez-Expósito et al. 2011) and the rare Buff-breasted Buttonquail from Australia remains as the only bird species in Australia that never has been properly photographed in the wild (Australian Wildlife Conservancy 2018).

According to this, only 183 publications specifically dealing with any buttonquail species have been found. Moreover, only 78 have been subject of a blind peer review, two of them being part of this thesis. Most publications are dedicated to threatened taxa whose distribution area lay in economically well developed countries. Almost half of the publications corresponds to the Common Buttonquail (N = 71), the more widespread species, but also the only one found in the Western Palearctic, whose nominate race is critically endangered. Only seven dealt with the Buff-breasted Buttonquail and 23 with Black-breasted Buttonquail (N = 23), both endangered Australian species, and seven more with the Hottentot Buttonquail, a South African endemism. All of them are more or less endangered species inhabiting developed countries and together sum the 60 % of all the publications found. The remaining species are barely studied as they are living in developing countries, where almost no environmental awareness and economic means devoted to wildlife conservation exist. A similar pattern is found when analysing the rarity index developed by us, with up to 12 island endemic subspecies of the Philippines, Papua New Guinea and Indonesia ranking with similar or higher values than the most endangered buttonquail species: Buff-breasted, New Caledonia and Luzon Buttonquails. None of these subspecies have been subject to a proper assessment of their conservation status, and, due to its rarity, they are expected to be en serious risk of extinction. There is one running project on the Buff-breasted Buttonquail aiming at describing its basic natural history as a basis for its future conservation (National Environmental Science Programme 2019). Urgent studies are needed for both Luzon and New Caledonian Buttonquails. In the same way, surveys should be carried out for all high rarity index island subspecies (Table 8), as these places are suffering from rampant land reclamation.

Country	Area	Taxa	
France	New Caledonia Island	*New Caledonia Buttonquail*	*T. novaecaledoniae*
Australia	York Peninsula	*Buff-breasted Buttonquail*	*T. olivii*
Indonesia	Bawean Island	*Bawean Barred Buttonquail*	*T. suscitator baweanus*
	Savu Island	*Savu Red-backed Buttonquail*	*T. maculosus savuensis*
	Banggai Islands	*Banggai Red-backed Buttonquail*	*T. maculosus kinneari*
	Louisiade Archipielago	*Louisiade Red-backed Buttonquail*	*T. maculosus mayri*
	Obi Island	*Obi Red-backed Buttonquail*	*T. maculosus obiensis*
Papua New Guinea	Papua New Guinea	*Huon Red-backed Buttonquail*	*T. maculosus furvus*
		Giluwe Red-backed Buttonquail	*T. maculosus giluwensis*
	New Britain	*New Britain Red-backed Buttonquail*	*T. maculosus saturatus*
The Philippines	Luzon Island	*Luzon Buttonquail*	*T. worcesteri*
	Negros Island	*Negros Common Buttonquail*	*T. sylvaticus nigrorum*
	Bohol and Mindanao Islands	*Visayan Common Buttonquail*	*T. sylvaticus celestinoi*
	Luzon Island	*Luzon Common Buttonquail*	*T. sylvaticus whiteheadi*
	Sulu Islands	*Sulu Common Buttonquail*	*T. sylvaticus suluensis*

Table 8. Buttonquail species and subspecies with higher rarity index values sorted by country for which studies on their ecology and conservation status are urgent.

The co-ocurrence of these threatened taxa with other commoner buttonquail species can conceal the vanishing process, as the continuous presence of other members of the family can make ornithologists and environmental authorities confident on the persistence of the rarest ones. As an example, the island of Taiwan has the highest density of eBird checklists for any buttonquail taxa (*Turnix suscitator rostratus*). Here we found a total of 345,594 eBird checklists, of which only 4,290 were positive to the presence of its endemic, but common, Barred Buttonquail subspecies. However, not a single observation was obtained for the island population of the Indochinese Common Buttonquail (*Turnix sylvaticus davidi*), which points towards the local extinction of this taxon.

Two subspecies values in their concern index in between the threatened ones and the rest of the buttonquail taxa: the Abrolhos Painted Buttonquail (*Turnix varius scintillans*) listed as Vulnerable by the Australian Government, and the Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*) to which the second section of this thesis is devoted.

The Andalusian Buttonquail's closest relative is the Kurrichane Buttonquail (*Turnix sylvaticus lepuranus*), with the nearest populations in Senegal, south of the Sahara Desert. These two races differ in the coloration of their back and underparts as well as on size, being the latter noticeably smaller. However, not only morphological differences have been found among them, but also among the three West Palearctic populations: Iberia, Sicily and North Africa. Although almost no biometric differences were found among them (Violani & Massa 1993), Sicilian birds tend to be slighty bigger, while Iberian ones had darker back and neck feathers (Urdiales 1993). Nevertheless, some darker individuals from North Africa have also been found in scientific collections. More detailed genetic studies are needed in order to establish the isolation grade, not only between the two races but also to reveal the phylogeography within these three former populations.

The Andalusian Buttonquail was once widespread in riverine countries, south and north of the western Mediterranean Sea. Land use intensification and human land reclamation have lead this taxon to the verge of extinction in an unnoticed vanishing process, with populations found only in Spain and Morocco at the end of the 20th century. Since 1981, when the last known Andalusian Buttonquail was shot near Doñana National Park, many initiatives have been made in Spain to determine if the species was still present. While most of the surveys failed in finding any sign of presence (Parreño 1991, Garrido 1999, Montoya et al. 2000, Garrido 2002, Gutiérrez-Expósito 2008, Gutiérrez-Expósito and Quirós 2008), some of them claimed to have positive results (Solís 1995, Urdiales 1993) but none of them could document the persistence of a population. Therefore, the Spanish Government declared it as extinct in 2018 (Resolution 11522, BOE 195). With no sightings since the sixties, it was also considered extict in Morocco. However, efforts in the late nineties lead to the rediscovery of the species in the last remnants of Mediterranean maquis near the locality of Oualidia (Garrido 2004). Further efforts resulted in coming across what is the last known Andalusian Buttonquail population, where all research effort was focused afterwards (Gutiérrez-Expósito et al. 2011).

This population has been found to occur in an intensively cultivated small coastal area. The natural habitat that once was occupied had been cleared and fragmented by wood removal and overgrazing, with just a few remnant patches still present but deserted by the species. Further efforts in finding other hidden populations should be a must, not only in Morocco, but also in Algeria where undocumented sightings have occurred in the 90's and beginning of the 21th century (Benyacoub 1993, Moussa et al. 2010). Our results show how the Andalusian Buttonquail still survives numbering in the hundreds but with a clear negative trend, with higher numbers being more than halved in the seven years' study lapse. The area still has a land organization and use system that are compatible with the presence of very rich bird communities. However, in recent years, changes towards industrial procedures, including the use of heavy machinery and an intensification in the use of agrochemicals, can compromise the persistence of this small population. To preserve this taxon a multidisciplinary approach which combines conservation biology with agronomy and social sciences is necessary to improve farmer's living standards while maintaining the biological requirements of the species with sustainable traditional farming practices. Finding the markets for high quality ecological products with a buttonquail conservation label may result in an improvement of the sustainability of the agricultural system that can benefit local farmers. Concurrently, a population genetics study is necessary to see which part of the historic genetic variability of the taxon still remains in this population and establish its current genetic variability and its degree of endogamy. At the same time, an “ex situ” conservation program is urgently needed in order to secure a captive population which can serve as a demographic source for reintroduction projects in other areas of its former distribution and to reveal many aspects of its biology which can not be studied in the field.

Ilustration by Beverley R. Morris on his work British game birds and wildfowl (1855) where noted as Andalusian Quail (*Hemipodius tachydromus*)

Findings / Conclusiones

Findings

1. A rarity index for all buttonquail species based on the information provided by the citizen science platform eBird reflected species extinction risk categories as defined by IUCN.

   Basándonos en la información proporcionada la plataforma de ciencia ciudadana eBird, hemos creado un índice de rareza que refleja con fidelidad las categorías de amenaza credas por la UICN.

2. The application of the rarity index to buttonquail subspecies highlighted the probable high extinction risk of some of them, whose conservation status has not been formaly assessed.

   La aplicación del índice de rareza a las subespecies de torillos, puso de manifiesto el probable alto riesgo de extinción de algunas de ellas, cuyo estado de conservación nunca ha sido evaluado formalmente.

3. Asymmetric heterochromia was found in 85 pallid-eye bird species, belonging to 9 families and 24 genera. This feature is present in all buttonquail species in both sexes and all age classes.

   Se encontró heterocromía asimétrica en los ojos de 85 especies de aves con iris pálido, pertenecientes a 9 familias y 24 géneros. Esta característica está presente en todas las especies de torillos en ambos sexos y en todas las clases de edad.

4. Historically, the Andalusian Buttonquail inhabited moist coastal Mediterranean-climate areas of south Europe and North Africa.

   Históricamente, el torillo andaluz habitó en zonas fértiles y costeras de clima mediterráneo del sur de Europa y el norte de África.

5. Areas of highest probability of historic presence of buttonquails in Andalusia have been subject to more intense land use changes, with decreasing rain-fed agriculture and increases in afforestation, urbanization, intensive farming and human population density.

En Andalucía, las áreas de mayor probabilidad de presencia histórica del torillo andaluz son aquellas que se han visto sometidas a cambios más intensos en el uso del suelo, con un descenso en la agricultura de secano y un aumento de las repoblaciones forestales, las zonas construidas, la agricultura intensiva y la densidad de población humana.

6. The last known extant Andalusian Buttonquail population occurs in a small, intensively cultivated area of 4,675 ha in the Doukkala Abda region (Morocco), less than 0.1% of the original extent of occurrence of this taxon.

   La última población conocida de torillo andaluz se encuentra en una pequeña área intensamente cultivada de 4.675 ha en la región de Doukkala Abda (Marruecos), y supone menos del 0.1 % del área de ocurrencia histórica.

7. Buttonquails occupy crops preferably during the flowering and fruiting growing stages, adapting its habitat choice to the crop annual rotation, although alfalfa fields and fallow land are occupied all year round.

   Los torillos ocupan preferiblemente cultivos en estado de floración y fructificación, adaptando la selección de hábitat al ciclo anual de los cultivos, si bien los campos de alfalfa y los barbechos son utilizados a lo largo de todo el año.

8. The last Andalusian Buttonquail population is subject to large seasonal fluctuations in abundance, with minimum figures at the end of the non-breeding period, increasing as the breeding season advances, a maximum in late summer, and decreasing again in autumn when the breeding period ends.

   La abundancia en esta última población de torillo andaluz está sujeta a grandes fluctuaciones estacionales, con mínimos al final del periodo no reproductor, aumentando según avanzan las estaciones, con máximos al final del verano, volviendo a disminuir en otoño a medida que el periodo reproductor llega a su fin.

9. The most updated population estimate in 2017 is below 600 individuals at the summer maximum. This population has shown a negative trend in the 7 years' study period, with being the summer 2017 estimate just one third of the figure obtained for the same period in 2011.

La estima de población más reciente corresponde a 2017 y se encuentra por debajo de los 600 individuos en el momento del máximo del verano. Esta población ha seguido una tendencia negativa a lo largo de los 7 años de estudio, siendo esta estima de verano la tercera parte de la que se obtuvo para el mismo periodo en 2011.

10. The breeding period was long, lasting between the beginning of February and the beginning of October. The juveniles born early in the season apparently incorporated to the breeding population by mid-summer.

El periodo reproductor es muy largo, desde principios de febrero hasta comienzos de octubre. Los jóvenes nacidos al principio del periodo, aparentemente se incorporan a la población reproductora a partir del verano.

11. A single predation event was found to occur in the monitored nests, so the breeding success was 91.7 %. All all complete clutches were of 4 eggs and hatching rate was of 85.7%.

De los nidos monitorizados hasta el final del periodo de incubación, sólo se perdió uno por predación, con lo que el éxito reproductor fue del 91,7 %. Todas las puestas completas tenían 4 huevos y la tasa de eclosión fue del 85,7 %.

Supplementary material

Chapter III

Supplementary Material S.3.1. Andalusian Buttonquail (*Turnix sylvaticus sylvaticus*) specimens in scientific collections and natural history museums sorted by country.

AUSTRIA

Salzburg

Haus der Natur. Museum für Natur und Technik

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
Aves-B-0264	skin	adult male	-	-	Málaga	Andalucia	Spain	Iberia

Vienna

Naturhistorisches Museum Wien

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
52.950	skin	-	1846	-	-	-	-	-
2327	clutch (2)	-	-	-	-	-	-	-
2328	clutch (2)	-	1889	-	Sevilla	Andalucia	Spain	Iberia
52.954	skin	-	1806	Gibraltar	Gibraltar	Gibraltar	United Kingdom	Iberia
31.962	skin	female	1839	-	-	-	Algeria	Maghreb
44.388	mount	-	1839	-	-	-	Algeria	Maghreb
52.946	skin	female	1904	Tunis	Tunis	Tunis	Tunisia	Maghreb
52.947	skin	male	1904	Tunis	Tunis	Tunis	Tunisia	Maghreb
52.948	skin	male	1901	Tunis	Tunis	Tunis	Tunisia	Maghreb
52.951	skin	male	1820	Gela	Siracusa	Sicily	Italy	Sicily

BELGIUM

Brussels

Royal Belgian Institute of Natural Sciences

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
279688	skin	adult male	-	-	-	-	-	-
511213	skin	-	-	-	-	-	-	-
579687	skin	adult female	-	-	-	-	-	-

FINLAND

Helsinki

Luomus Luonnontieteellinen Keskusmuseo

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
UL5538	skin	adult female	1906	Sevilla	Sevilla	Andalucia	Spain	Iberia
UL2991	mount	adult male	1879	-	-	-	Africa	Maghreb
UL2990	mount	adult male	1890	-	-	-	Morocco	Maghreb

FRANCE

Paris

Museum National d'Histoire Naturelle

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
1908.94	skin	male	1907	-	-	-	-	-
1965.3054	skin	-	-	-	-	-	-	-
1965.3055	skin	-	-	-	-	-	-	-
1943.57	skin	adult male	-	Mamora	Kenitra	Rabat-Salé-Kenitra	Morocco	Maghreb
1927.1983	skin	male	1922	Potinville	Ben Arus	Ben Arus	Tunisia	Maghreb
1927.1985	skin	adult female	1922	Potinville	Ben Arus	Ben Arus	Tunisia	Maghreb
1927.1986	skin	adult female	1922	Bizerte	Bizerte	Bizerte	Tunisia	Maghreb
1936.1784	skin	male	-	Bizerte	Bizerte	Bizerte	Tunisia	Maghreb
1936.1785	skin	adult female	-	Bizerte	Bizerte	Bizerte	Tunisia	Maghreb
1936.1786	skin	female	-	Bizerte	Bizerte	Bizerte	Tunisia	Maghreb
2006.237	skin	adult female	1894	Bizerte	Bizerte	Bizerte	Tunisia	Maghreb
1911.1805	skin	male	1908	Tathouine	Tatouine	Tatouine	Tunisia	Maghreb

Strasbourg

Musée Zoologique de Strasbourg

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
MZS Ave02294	mount	-	-	-	Algiers	Algiers	Algeria	Maghreb
MZS Ave02295	mount	-	1866	-	Algiers	Algiers	Algeria	Maghreb
MZS Ave02296	mount	-	1858	-	Algiers	Algiers	Algeria	Maghreb
MZS Ave02297	mount	-	1845	-	Algiers	Algiers	Algeria	Maghreb
MZS Ave02299	mount	juvenile	1833	-	Algiers	Algiers	Algeria	Maghreb

GERMANY

Berlin

Museum für Naturkunde

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
60531	clutch (1)	-	-	-	-	-	-	-
60532	clutch (1)	-	-	-	-	-	-	-
11444	skin	adult	1800	Setubal	Setubal	Estremadura	Portugal	Iberia
60530	clutch (1)	-	-	-	-	Andalucia	Spain	Iberia
62642	clutch (1)	-	-	-	-	Andalucia	Spain	Iberia
64992	clutch (1)	-	-	-	-	Andalucia	Spain	Iberia
65074	clutch (1)	-	1890	-	-	Andalucia	Spain	Iberia
65075	clutch (1)	-	1890	-	-	Andalucia	Spain	Iberia
11443	mount	adult	-	-	-	-	-	Maghreb
11445	mount	-	-	-	-	-	-	Maghreb
7551	skin	adult male	1901	Annaba	Annaba	Annaba	Algeria	Maghreb
7552	skin	adult female	1901	Annaba	Annaba	Annaba	Algeria	Maghreb

Bonn

Forschungs Museum Koenig

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
ZFMK:ORN:L.II.1.a.e	skin	-	1887	Tunis	Tunis	Tunis	Tunisia	Maghreb

Dresden

Staatliches Museum für Tierkunde

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
1914.10.1.2922-4	clutch (4)	-	-	-	-	Andalucia	Spain	Iberia

Frankfurt

Forschungsinstitut und Naturmuseum Senckenberg

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
19890	skin	adult male	1836	-	-	Andalucia	Spain	Iberia
19891	skin	adult female	1836	-	-	Andalucia	Spain	Iberia
11873	skin	adult female	1896	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
11874	skin	adult male	1897	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
11875	skin	adult male	1898	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
11876	skin	adult female	1898	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
19917	skin	adult	-	-	-	-	Tunisia	Maghreb

Halberstadt

Museum Heineanum Halberstadt

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
I1532A14	clutch (1)	-	1910	Antequera	Málaga	Andalucia	Spain	Iberia

IRELAND

Dublin

National Museum of Ireland

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
1902.155.01	skin	adult female	-	-	-	-	Europe	-
1902.155.02	skin	adult male	-	-	-	-	Europe	-

ITALY

Bra

Museo Civico Craveri

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
986	mount	juvenile	-	-	-	Sicily	Italy	Sicily
987	mount	adult male	-	-	-	Sicily	Italy	Sicily
987	mount	adult female	-	-	-	Sicily	Italy	Sicily

Napoli

Centro Musei delle Scienze Naturali e Fisiche

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
88	mount	-	-	-	-	Unknown	Unknown	Unknown
89	mount	-	-	-	-	Unknown	Unknown	Unknown

Florence

Museo di Storia Naturale dell'Università di Firenze

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
Coll. Gen. Ucc. N. 638	mount	adult female	1866	Aqueduct of Carthago	Tunis	Tunis	Tunisia	Maghreb
Coll. Gen. Ucc. N. 8557	skin	adult female	1878	-	-	Sicily	Italy	Sicily
Coll. Gen. Ucc. N. 8554	skin	adult male	1863	Palermo	Palermo	Sicily	Italy	Sicily
Coll. Gen. Ucc. N. 8553	skin	adult male	1881	Ispica	Ragusa	Sicily	Italy	Sicily
Coll. Gen. Ucc. N. 8552	skin	adult male	1871	Modica	Ragusa	Sicily	Italy	Sicily
Coll. Gen. Ucc. N. 8549	skin	adult male	1883	Castelvetrano	Trapani	Sicily	Italy	Sicily
Coll. Gen. Ucc. N. 8550	skin	juvenile female	1883	Mazara del Vallo	Trapani	Sicily	Italy	Sicily
Coll. Gen. Ucc. N. 8551	skin	adult male	1881	Mazara del Vallo	Trapani	Sicily	Italy	Sicily
Coll. Gen. Ucc. N. 8555	skin	adult male	1886	Mazara del Vallo	Trapani	Sicily	Italy	Sicily
Coll. Gen. Ucc. N. 8556	skin	adult male	1883	Mazara del Vallo	Trapani	Sicily	Italy	Sicily

Genoa

Museo Civico di Storia Naturale Giacomo Doria

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
MSNG 23745	mount	-	1898	Setubal	Setubal	Estremadura	Portugal	Iberia
MSNG 23743	mount	adult female	1865	Gibraltar	Gibraltar	Gibraltar	United Kingdom	Iberia
MSNG 23744	mount	-	1865	Gibraltar	Gibraltar	Gibraltar	United Kingdom	Iberia
MSNG 7808	skin	adult male	1913	-	-	-	Algeria	Maghreb
MSNG 51418	alcohol	-	1873	-	-	-	Tunisia	Maghreb

Milan

Museo Civico di Storia Naturale di Milano

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
MSNM Av27085	mount	adult female	1961	-	-	-	-	-

Rome

Museo Civico de Zoologia di Roma

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
16307	skin	adult female	1902	Gela	Caltanisetta	Sicily	Italy	Sicily
16308	skin	adult male	1902	Gela	Caltanisetta	Sicily	Italy	Sicily
16309	skin	adult male	1890	Gela	Caltanisetta	Sicily	Italy	Sicily
16306	skin	adult male	1891	Ispica	Ragusa	Sicily	Italy	Sicily
16304	mount	adult male	1890	Lentini	Siracusa	Sicily	Italy	Sicily
16305	skin	adult female	1888	Mazara del Vallo	Trapani	Sicily	Italy	Sicily

Terrasini

Museo Regionale di Storia Naturale e Mostra Permanente del Carretto

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
5533	skin	adult male	1866	Mazara del Vallo	Trapani	Sicily	Italy	Sicily

Turin

Museo e Instituto di Zoologia Sistematica dell'Universitá di Torino

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
MZUT AV12596	mount	adult female	1847	-	-	-	-	-
MZUT AV11929	mount	adult	1865	Al Marsa	Tunis	Tunis	Tunisia	Maghreb
MZUT AV5642	mount	adult female	1865	Al Marsa	Tunis	Tunis	Tunisia	Maghreb
MZUT AV12224	mount	adult male	1863	Palermo	Palermo	Sicily	Italy	Sicily
MZUT AV12225	mount	adult male	1863	Palermo	Palermo	Sicily	Italy	Sicily

Verona

Museo Civico de Storia Naturale di Verona

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
MSNVRAv 1632	mount	-	1913	Castelvetrano	Trapani	Sicily	Italy	Sicily

MOROCCO

Rabat

Université Mohammed V - Institut Scientific

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
2009-01	clutch (1)	-	2009	Ouled Ghanem	El Jadida	Doukkala-Abda	Morocco	Maghreb
NA	skin	-	2016	Ouled Ghanem	El Jadida	Doukkala-Abda	Morocco	Maghreb
2015-01	alcohol	adult	2015	Sidi Moussa	El Jadida	Doukkala-Abda	Morocco	Maghreb
227001	skin	adult female	1927	Mamora	Kenitra	Rabat-Salé-Kenitra	Morocco	Maghreb
226006	skin	adult female	1926	Ain el Aouda	Rabat	Rabat-Salé-Kenitra	Morocco	Maghreb
224007	skin	adult female	1924	Oued Akruch	Rabat	Rabat-Salé-Kenitra	Morocco	Maghreb
274002	skin	adult male	1974	Skhirat	Skhirat-Temara	Rabat-Salé-Kenitra	Morocco	Maghreb

NORWAY

Oslo

Naturhistorik Museum

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
NHMO-BI-59460	skin	juvenile	1787	Gibraltar	Gibraltar	Gibraltar	United Kingdom	Iberia

PORTUGAL

Coimbra

Museu da Ciência

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
ZOO.0002688	mount	-	-	-	-	-	Portugal	Iberia
ZOO.0002689	mount	-	1882	Montargil	Pontealegre	Alentejo	Portugal	Iberia
ZOO.0002691	mount	adult male	1913	Pereira do Campo	Coimbra	Beira Litoral	Portugal	Iberia
ZOO.0002784	mount	adult female	1917	Pereira do Campo	Coimbra	Beira Litoral	Portugal	Iberia
ZOO.0002690	mount	-	1905	San Martinho do Bispo	Coimbra	Beira Litoral	Portugal	Iberia

RUSSIA

Moskow

Зоологический музей Московского университета

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
ZMMUR37247	skin	-	1906	-	Sevilla	Andalucia	Spain	Iberia

SPAIN

Barcelona

Museu de Ciències Naturals de Barcelona

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
MZB-82-1267	mount	-	-	-	-	Andalucia	Spain	Iberia

Chiclana de la Frontera

Colegio San Juan Bosco Campano

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
NA	mount	adult female	-	-	-	Andalucia	Spain	Iberia

Seville

Estación Biológica de Doñana

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
23628A	skin	adult male	-	-	-	Andalucia	Spain	Iberia
11851A	skin	adult female	1964	Jerez de la Frontera	Cádiz	Andalucia	Spain	Iberia
11853A	skin	adult female	1978	El Acebuche, Doñana	Huelva	Andalucia	Spain	Iberia
11854A	skin	adult female	1980	El Alamillo, Doñana	Huelva	Andalucia	Spain	Iberia
11850A	skin	adult male	1981	Laguna Soriana Chica, Doñana	Huelva	Andalucia	Spain	Iberia
11849A	skin	adult female	1981	Pequeña Holanda, Doñana	Huelva	Andalucia	Spain	Iberia
11855A	skin	adult female	1981	Pequeña Holanda, Doñana	Huelva	Andalucia	Spain	Iberia
11852A	skin	adult female	1966	-	Sevilla	Andalucia	Spain	Iberia
19742A	skin	adult female	-	-	Sevilla	Andalucia	Spain	Iberia
2019.061.003	clutch (4)	-	2017	Oulad Ghanem	El Jadida	Casablanca-Settat	Morocco	Maghreb
2019.061.004	clutch (3)	-	2017	Oulad Ghanem	El Jadida	Casablanca-Settat	Morocco	Maghreb
2019.061.001	clutch (4)	-	2011	Sidi Moussa - Oulad Aissa	El Jadida	Casablanca-Settat	Morocco	Maghreb
2019.061.002	clutch (2)	-	2011	Sidi Moussa - Oulad Aissa	El Jadida	Casablanca-Settat	Morocco	Maghreb
2019.061.005	clutch (1)	-	2011	Sidi Moussa - Oulad Aissa	El Jadida	Casablanca-Settat	Morocco	Maghreb
2019.061.006	clutch (1)	-	2013	Sidi Moussa - Oulad Aissa	El Jadida	Casablanca-Settat	Morocco	Maghreb
2019.061.007	clutch (1)	-	2017	Sidi Moussa - Oulad Aissa	El Jadida	Casablanca-Settat	Morocco	Maghreb

Granada

Museo Instituto Padre Suárez

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
113	mount	adult female	-	-	Málaga	Andalucia	Spain	Iberia

Linares

Museo Mariano de la Paz

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
-	mount	-	-	-	Málaga	Andalucia	Spain	Iberia
-	mount	-	-	-	Málaga	Andalucia	Spain	Iberia

Malaga

Museo de Ciencias Naturales IES Nuestra Señora de la Victoria

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
NA	mount	-	-	-	Málaga	Andalucia	Spain	Iberia
NA	mount	-	-	-	Málaga	Andalucia	Spain	Iberia

Madrid

Museo Nacional de Ciencias Naturales

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
17804	clutch (2)	-	-	-	-	Andalucia	Spain	Iberia
1720	skin	adult male	1890	-	Sevilla	Andalucia	Spain	Iberia

Jerez de la Frontera

Private collection

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
-	mount	-	-	La Barca de la Florida	Cádiz	Andalucia	Spain	Iberia

SWITZERLAND

Geneva

Muséum d'Histoire Naturelle de Genève

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
691.095	clutch (1)	-	-	-	-	-	-	-
821.038	clutch (3)	-	1906	-	-	-	Portugal	Iberia
313.014	skin	female	-	-	-	-	Spain	Iberia
701.091	skin	male	1837	-	-	-	Spain	Iberia
3326.084	clutch (4)	-	1897	Sevilla	Sevilla	Andalucia	Spain	Iberia
484.024	skin	male	-	-	-	-	Algeria	Maghreb
1160.004	clutch (2)	-	1902	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
1605.011	mount	adult female	1925	Tunis	Tunis	Tunis	Tunisia	Maghreb

THE NETHERLANDS

Leiden

Naturalis Biodiversity Center

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
RMNH.AVES.226581	mount	male	-	-	-	-	-	-
RMNH.AVES.229116	skin	female	-	-	-	-	-	-
RMNH.AVES.229549	mount	-	-	-	-	-	-	-
RMNH.AVES.229550	mount	female	-	-	-	-	-	-
RMNH.AVES.229551	mount	-	-	-	-	-	-	-
RMNH.AVES.229121	skin	-	1904	-	Málaga	Andalucia	Spain	Iberia
RMNH.AVES.229123	skin	female	1905	-	Sevilla	Andalucia	Spain	Iberia
RMNH.AVES.78408	clutch (2)	-	1892	Algiers	Algiers	Algiers	Algeria	Maghreb
RMNH.AVES.229117	skin	male	-	Annaba	Annaba	Annaba	Algeria	Maghreb
RMNH.AVES.229118	skin	male	1902	Annaba	Annaba	Annaba	Algeria	Maghreb
RMNH.AVES.229119	skin	female	1902	Annaba	Annaba	Annaba	Algeria	Maghreb
RMNH.AVES.229120	skin	female	1903	Annaba	Annaba	Annaba	Algeria	Maghreb
RMNH.AVES.229122	skin	male	1904	Annaba	Annaba	Annaba	Algeria	Maghreb
ZMA.AVES.44558	skin	adult male	1907	-	-	-	Tunisia	Maghreb
RMNH.AVES.229507	skin	male	-	Tunis	Tunis	Tunis	Tunisia	Maghreb
RMNH.AVES.229508	skin	male	-	Tunis	Tunis	Tunis	Tunisia	Maghreb
RMNH.AVES.226579	mount	-	-	-	-	Sicily	Italy	Sicily
RMNH.AVES.226580	mount	-	-	-	-	Sicily	Italy	Sicily

UNITED KINGDOM

Belfast

National Museums North Ireland

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
Lg1739	mount	juvenile	-	-	-	-	Italy	Sicily
Lg1746	mount	adult male	-	-	-	-	Italy	Sicily
Lg1749	mount	adult male	-	-	-	-	Italy	Sicily
Lg1750	mount	adult female	-	-	-	-	Italy	Sicily

Cambridge

Museum of Zoology, University of Cambridge

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
UMZC-No15/Tur/2/i/6	skin	-	-	-	-	-	-	-
UMZC-No15/Tur/2/i/7	skin	-	1840	-	-	-	-	-

Edinburgh

National Museums of Scotland

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
NMSZ.1956.3.2750	skin	adult female	-	-	-	-	-	-
NMSZ.1956.3.2758	skin	adult female	1878	-	-	-	-	-
NMSZ.1956.3.2759	skin	adult female	-	-	-	-	-	-
NMSZ.1956.3.2762	skin	adult male	-	-	-	-	-	-
NMSZ.1956.3.2768	skin	adult female	-	-	-	-	-	-
NMSZ.1956.3.2781	skin	adult male	-	-	-	-	-	-
NMSZ.1956.3.358	skin	adult male	-	-	-	-	-	-
NMSZ1892.56.38	skin	adult female	-	-	Málaga	Andalucia	Spain	Iberia
NMSZ1925.40.55	skin	adult male	1887	Cantillana	Sevilla	Andalucia	Spain	Iberia
NMSZ.1956.3	skin	adult female	1878	Algiers	Algiers	Algiers	Algeria	Maghreb
NMSZ.1956.3.2756	skin	adult female	1878	Algiers	Algiers	Algiers	Algeria	Maghreb
NMSZ1919.2.238	skin	adult female	1866	Algiers	Algiers	Algiers	Algeria	Maghreb
NMSZ.1956.3	skin	adult female	1900	-	-	-	Tunisia	Maghreb
NMSZ.1956.3	skin	adult female	1897	Tunis	Tunis	Tunis	Tunisia	Maghreb
NMSZ.1956.3.3511	skin	adult male	1905	Tunis	Tunis	Tunis	Tunisia	Maghreb
NMSZ.1956.3.3587	skin	adult male	1902	Tunis	Tunis	Tunis	Tunisia	Maghreb
NMSZ.1956.3.959	skin	adult female	1900	Tunis	Tunis	Tunis	Tunisia	Maghreb

Leeds

Leeds Museum Discovery Centre

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
LEEDM.C.1962.369.2983	skin	adult female	-	-	-	-	-	Iberia
LEEDM.C.1962.1623.2982	skin	adult female	-	-	-	-	-	Maghreb

Liverpool

National Museums Liverpool

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
T8327	skin	adult female	1856	Algiers	Algiers	Algiers	Algeria	Maghreb
T8325	skin	juvenile male	1856	Douera	Algiers	Algiers	Algeria	Maghreb
D4576 (S)	skin	adult male	-	Tunis	Tunis	Tunis	Tunisia	Maghreb
T8326	skin	adult male	1858	Tunis	Tunis	Tunis	Tunisia	Maghreb

Manchester

The Manchester Museum

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
B.8521	skin	-	-	-	-	-	-	-
B.8549	mount	-	-	-	-	-	-	-
B.8590	mount	-	-	-	-	-	-	-
B.8519	skin	-	1869	-	Málaga	Andalucia	Spain	Iberia
B.8518	skin	-	1899	Gibraltar	Gibraltar	Gibraltar	United Kingdom	Iberia
B.8520	skin	-	1899	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb

New Castle upon Tyne

Great North Museum Hancock

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
NEWHM 2000.H1142	mount	adult female	-	-	-	-	-	-
NEWHM 2000.H1143	mount	adult male	-	-	-	-	-	-
NEWHM 2000.H1144	mount	adult	-	-	-	-	-	-
NEWHM 2016.H16	mount	adult	-	-	-	-	-	-

Norwich

Norfolk Museums

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
2000.21.4	mount	-	-	-	-	-	-	-
1923.74.593	skin	adult female	1870	-	-	-	Algeria	Maghreb
1898.26.1	mount	adult male	1898	-	-	-	Morocco	Maghreb

Tring

Natural History Museum

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
NA	alcohol	-	-	-	-	-	-	-
3811949	clutch (4)	-	-	-	-	Andalucia	Spain	Iberia
1934.1.1.1994	skin	adult female	1881	-	-	Andalucia	Spain	Iberia
1897.10.19.382	skin	adult female	-	Puerto de Santa María	Cádiz	Andalucia	Spain	Iberia
1889.5.13.131	skin	adult female	1871	-	Málaga	Andalucia	Spain	Iberia
1889.5.13.132	skin	adult female	1870	-	Málaga	Andalucia	Spain	Iberia
1907.12.20.12	skin	adult female	1872	-	Málaga	Andalucia	Spain	Iberia
1907.12.20.13	skin	adult male	1872	-	Málaga	Andalucia	Spain	Iberia
1852.10.8.1	skin	-	-	Marbella	Málaga	Andalucia	Spain	Iberia
1872.10.3.27	skin	adult male	1871	Gibraltar	Gibraltar	Gibraltar	United Kingdom	Iberia
1872.10.3.28	skin	adult female	1871	Gibraltar	Gibraltar	Gibraltar	United Kingdom	Iberia
1881.5.1.5443	skin	-	-	-	-	-	Algeria	Maghreb
1856.3.12.30	skin	chick	-	Algiers	Algiers	Algiers	Algeria	Maghreb
1881.5.1.5461	skin	adult female	-	Algiers	Algiers	Algiers	Algeria	Maghreb
1905.6.28.103	skin	-	1873	Algiers	Algiers	Algiers	Algeria	Maghreb
1891.5.1.97	skin	adult female	-	Biskra	Biskra	Biskra	Algeria	Maghreb
1891.5.1.98	skin	juvenile	-	Biskra	Biskra	Biskra	Algeria	Maghreb
1927.12.18.381	skin	adult male	1912	Hammam Meskoutine	Guelma	Guelma	Algeria	Maghreb
1939.12.9.3729	mount	adult male	1889	-	-	-	Morocco	Maghreb
1939.12.9.3730	mount	adult male	1889	-	-	-	Morocco	Maghreb
1905.6.28.904	skin	adult female	1898	Tunis	Tunis	Tunis	Tunisia	Maghreb
1905.6.28.983	skin	-	1883	Marsala	Trapani	Sicily	Italy	Sicily

UNITED STATES

Camarillo

Western Foundation of Vertebrate Zoology

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
153760	clutch (4)	-	1884	-	-	Andalucia	Spain	Iberia
28936	clutch (4)	-	1961	Utrera	Sevilla	Andalucia	Spain	Iberia
184259	clutch (1)	-	1884	-	-	-	Algeria	Maghreb

Cambridge

Museum of Comparative Zoology
University of Harvard

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
MCZ84166	skin	-	-	-	-	-	Morocco	Maghreb
MZC84165	skin	-	-	-	-	-	Morocco	Maghreb
MCZ157653	skin	adult female	1931	Mamora	Kenitra	Rabat-Salé-Kenitra	Morocco	Maghreb

Chicago

Field Museum of Natural History

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
411690	skin	adult female	1872	-	Málaga	Andalucia	Spain	Iberia
18849	clutch (3)	-	1905	Ouled Bouaziz	El Jadida	Casablanca-Settat	Morocco	Maghreb
412293	skin	adult female	1900	Tunis	Tunis	Tunis	Tunisia	Maghreb

Ithaca

Cornell University Museum of Vertebrates

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
53997	mount	-	1860	-	-	-	Algeria	Maghreb

New York

American Museum of Natural History

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
544314	skin	male	-	-	-	Andalucia	Spain	Iberia
SKIN10220	skin	-	-	-	-	Andalucia	Spain	Iberia
SKEL529	skeleton	-	-	-	-	-	-	Maghreb
SKIN10219	skin	-	-	-	-	-	Algeria	Maghreb
544321	skin	female	1874	Plain of Metidja	Algiers	Algiers	Algeria	Maghreb
544320	skin	male	1901	Ouled Salem	Casablanca-Settat	Casablanca-Settat	Morocco	Maghreb
544319	skin	male	1901	Cap Blanco	El Jadida	Casablanca-Settat	Morocco	Maghreb
544315	skin	female	1886	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
544316	skin	female	1885	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
544317	skin	female	1886	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
544318	skin	male	1886	Tangiers	Tanger-Assilah	Tanger-Tetouan-Al Hoceima	Morocco	Maghreb
544326	skin	female	1901	-	-	-	Tunisia	Maghreb
544322	skin	female	1925	Potinville	Ben Arus	Ben Arus	Tunisia	Maghreb
544323	skin	female	1925	Potinville	Ben Arus	Ben Arus	Tunisia	Maghreb
544324	skin	female	1925	Potinville	Ben Arus	Ben Arus	Tunisia	Maghreb
544325	skin	male	1925	Potinville	Ben Arus	Ben Arus	Tunisia	Maghreb

Philadelphia

Academy of Natural Sciences

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
55136	skin	adult female	1908	-	-	Andalucia	Spain	Iberia
12465	skin	-	-	-	-	Tunis	Tunisia	Maghreb
12462	skin	-	-	-	-	-	Italy	Sicily
12464	skin	-	-	-	-	-	Italy	Sicily

Washington

National Museum of Natural History
Smithsonian Institution

Ref. num.	Type	Age and Sex	Year	Locality	Province	Region	Country	Population
USNM 056852	skin	adult male	-	-	-	Andalucia	Spain	Iberia
USNM 311929	skin	adult female	1923	-	-	-	Tunisia	Maghreb

Supplementary Material S.3.2. List of localities with presence of Andalusian Buttonquail, sorted by population and country, and classified by its more recent sight as historical (before 1940), old (between 1941 and 1970), recent (between 1971 and 2000) and current (from 2001 onwards).

Population	Country	Locality	Latitude	Longitude	Year	Time
Maghreb	Morocco	Ain el Aouda	33.81	-6.79	1926	historic
		Ben Slimane	33.62	-7.13	-	historic
		Cap Bedouzza	32.62	-9.17	2010	current
		Cap Blanco	33.16	-8.62	1901	historic
		Douar el Arabet	32.92	-8.81	2018	current
		Essaouira	31.51	-9.75	-	historic
		Kasbat Ayir	32.71	-9.07	2010	current
		Kouaka	33.02	-8.71	2018	current
		Laakarta	32.68	-9.10	2010	current
		Larache	35.19	-6.14	-	historic
		Mamora	34.04	-6.70	1931	historic
		Moulay Bousselham	34.88	-6.29	-	recent
		Moulouya	35.12	-2.35	1980	recent
		Oualidia	32.73	-9.05	2010	current
		Oualidia salines	32.79	-8.96	2018	current
		Oued Akrech	33.93	-6.81	1924	historic
		Oued Rharg 1	32.63	-8.93	2001	current
		Oued Rharg 2	32.65	-8.95	2006	current
		Ouled Bouaziz	33.13	-8.55	1905	historic
		Ouled Ghanem	32.88	-8.86	2018	current
		Ouled Ghanem salines	32.84	-8.90	2018	current
		Ouled Salem	33.18	-8.50	1901	historic
		Sidi Abed	33.04	-8.69	2018	current
		Sidi Bettache	33.57	-6.89	-	historic
		Sidi Moussa	32.97	-8.76	2018	current
		Skhirat	33.85	-7.04	1974	recent
		Souk el Arba du Rharb	34.70	-6.00	-	historic
		Tangier	35.73	-5.81	1886	historic

Population	Country	Locality	Latitude	Longitude	Year	Time
Maghreb	Algeria	Ain Fezza	34.88	-1.24	1973	recent
		Algiers	36.75	3.06	1878	historic
		Annaba	36.84	7.74	1901	historic
		Biskra	34.85	5.73	-	historic
		El Kala	36.88	8.47	1994	recent
		Guerbes	36.91	7.24	2007	current
		Hammam Meskoutine	36.46	7.27	1912	historic
		L'Ouarsenis	35.67	1.80	1939	historic
		Oran	35.68	-0.61	1787	historic
		Oued Zhour	36.92	6.25	1976	recent
		Plain de Metidja	36.69	2.90	1874	historic
	Lybia	Cyrenaica	32.81	21.71	-	historic
		Garabulli	32.79	13.74	1967	old
		Suani Ben Adem	32.72	13.07	1923	historic
	Tunisia	Al Marsa	36.88	10.33	1865	historic
		Aqueduct of Carthago	36.64	10.13	1866	historic
		Bejaoua	36.84	10.01	1972	recent
		Bizerte	37.27	9.86	1922	historic
		Ichkeul	37.16	9.66	1985	recent
		Potinville	36.70	10.39	1925	historic
		Sousse	35.88	10.59	1972	recent
		Tatahouine	32.92	10.45	1908	historic
		Tunis	36.80	10.12	1905	historic
Iberia	Portugal	Abrantes	39.46	-8.20	-	historic
		Esmoriz	40.95	-8.62	-	historic
		Estarreja	40.75	-8.57	-	historic
		Evora	38.57	-7.91	-	historic
		Maiorca	40.17	-8.75	1874	historic
		Montargil	39.08	-8.17	-	historic
		Ovar	40.86	-8.63	-	historic
		Pereira do Campo	40.18	-8.59	1917	historic
		Sao Martinho do Bispo	40.21	-8.47	-	historic
		Setubal	38.53	-8.89	1800	historic
		Vagos	40.56	-8.68	-	historic

Population	Country	Locality	Latitude	Longitude	Year	Time
		Abalario	37.12	-6.69	1997	recent
		Alcalá de Guadaira	37.34	-5.84	1848	historic
		Algeciras	36.13	-5.45	-	historic
		Alhaurín de la Torre	36.66	-4.56	-	historic
		Antequera	37.03	-4.56	1910	historic
		Arcos de la Frontera	36.73	-5.80	2001	current
		Cabeza de Vaca	36.39	-6.08	1995	recent
		Campo de la Herrumbre	37.33	-6.99	1953	old
		Cantillana	37.61	-5.83	1887	historic
		Cerro de la Salineta	36.49	-6.08	1985	recent
		Chapas de Marbella	36.50	-4.82	-	historic
		Coto de Gelo	37.31	-6.39	1989	recent
		Coto del Rey	37.13	-6.45	1993	recent
		Coto del Rocio	37.10	-6.57	2002	current
		Cuartillos	36.38	-6.08	1985	recent
		Dehesa Boyal	36.39	-6.09	1985	recent
		Dehesa del Inglés	36.46	-6.08	1985	recent
Iberia	Spain	El Acebuche	37.05	-6.57	1988	recent
		El Alamillo	37.07	-6.54	1980	recent
		El Pozuelo	37.32	-3.67	-	historic
		Gibraleón	37.37	-6.97	1992	recent
		Hato Villa	37.11	-6.47	1946	old
		Hozanejos	36.37	-6.10	1985	recent
		Huelva	37.25	-6.95	1952	old
		Jerez de la Frontera	36.68	-6.13	-	historic
		La Asomada	36.41	-6.08	1985	recent
		La Barca de la Florida	36.65	-5.93	1958	old
		La Cencerra	37.06	-6.53	1993	recent
		La Janda	36.26	-5.82	1955	old
		La Linea	36.17	-5.35	1973	recent
		La Mesa	36.36	-5.90	-	historic
		La Palmosa	37.16	-6.46	1980	recent
		La Vega	36.45	-6.13	1985	recent
		Laguna del Torero	36.27	-5.93	1978	recent
		Laguna Soriana Chica	37.05	-6.54	1981	recent

Population	Country	Locality	Latitude	Longitude	Year	Time
		Las Agusaderas	36.56	-5.19	-	historic
		Llanos de Guerra	36.50	-6.07	1970	old
		Los Marines	36.90	-4.21	1996	recent
		Los Mimbrales	37.10	-6.53	-	recent
		Los Palacios	37.12	-5.83	1986	recent
		Malaga	36.72	-4.43	1901	historic
		Marbella	36.51	-4.89	1952	old
		Melilla	35.29	-2.96	1980	recent
		Nave de Pedro Perez	37.01	-6.53	1967	old
		Pequeña Holanda	37.09	-6.53	1981	recent
		Puerto de Santa Maria	36.60	-6.23	1894	historic
	Spain	Rio Oranque	37.47	-6.97	1995	recent
Iberia		Sabinar del Marqués	37.02	-6.55	1994	recent
		San Juan del Puerto	37.31	-6.84	1958	old
		San Pedro de Alcántara	36.49	-4.99	-	historic
		San Roque	36.21	-5.38	1869	historic
		Sevilla	37.39	-5.98	1906	historic
		Silla de la Reina	36.21	-5.36	-	historic
		Tierras Tiesas	37.18	-6.53	-	recent
		Utrera	37.18	-5.78	1961	old
		Vejer	36.25	-5.96	-	historic
		Velez Málaga	36.76	-4.09	-	historic
		Zalagalano	37.02	-6.48	1989	recent
	United Kingdom	Eastern Beach	36.15	-5.34	-	historic
		Gibraltar	36.14	-5.35	1899	historic

Population	Country	Locality	Latitude	Longitude	Year	Time
		Caltagirone	37.21	14.52	1857	historic
		Palermo	38.10	13.38	1863	historic
		Modica	36.87	14.76	1871	historic
		Marsala	37.80	12.46	1883	historic
		Mazara del Vallo	37.65	12.59	1888	historic
		Lentini	37.29	15.00	1890	historic
		Ispica	36.79	14.91	1891	historic
		Pachino	36.70	15.10	1892	historic
Sicily	Italy	Gela	37.07	14.25	1902	historic
		Falconara	37.11	14.05	1910	historic
		Castelvetrano	37.68	12.79	1913	historic
		Agrigento	37.31	13.58	1914	historic
		Catania	37.51	15.08	-	historic
		Licata	37.11	13.93	-	historic
		Ragusa	36.93	14.73	-	historic
		Sciacca	37.51	13.08	-	historic
		Selinunte	37.58	12.83	-	historic

Supplementary material S.3.3. Codes and description of variables used in PCA modelling.

Variable code	Description	Variable code	Description
Cont	Average temperature of warmest month - mean temperature of coldest month	PETColdQ	Mean monthly PET of coldest quarter
CT10M	Count of the number of months with mean Tª greater than 10°	PETDryQ	Mean monthly PET of dryest quarter
DIF	Diffuse Horizontal Radiation	PETSeason	Monthly variation in potential evapotranspiration
DNI	Direct Normal Radiation	PETWarmQ	Mean monthly PET of warmest quarter
Elev	Elevation over sea level	PETWetQ	Mean monthly PET of wettest quarter
Embg	Emberger's pluviometric quotient	PSeason	Precipitation seasonality
GDy0	Sum of mean monthly temperature for months with mean temperature greater than 5°C multiplied by number of days	PVOUT	Photovoltaic Electricity output
GDy5	Sum of mean monthly temperature for months with mean temperature greater than 0°C multiplied by number of days	PWarmQ	Precipitation of warmerst quarter
GHI	Global Horizontal Radiation	PWetM	Precipitation of wettest month
GTI	Global Tilted Radiation	PWetQ	Precipitation of wettest quarter
Iso	Isothermality (MeanT / TYearRange)	Rivas	Continentality compensated by elevation
MaxTColdM	Maximum Tª of the coldest month x 10	Rooting	Rooting conditions
MaxTWarmM	Maximum Tª of warmest month	Rough	Roughness
MeanP	Mean annual precipitation	SaltEx	Excess of saltas
MeanT	Annual Mean Temperature	Slope	Slope
MinTColdM	Minimum Tª of coldest month	TColdQ	Tª coldest quarter
MinTWarmM	Minimum Tª of the warmest month x10	TDryQ	Tª dryest quarter
Moist	A metric of relative wetness and aridity	Therm	Compensated thermicity index
MTDyR	Mean Diurnal range (Mean of monthly (max temp - min temp))	Thorn	Thornthwaite aridity index
NutrAv	Nutrient availability	TPI	Topographic Position Index
NutrRet	Nutrient retention capacity	TRI	Terrain Ruggedness Index
OPTA	Optimun Angle	TSeason	Temperature seasonality
OxyAv	Oxygen availability to roots	TWarmQ	Tª warmest quarter
PColdQ	Precipitation of coldest quarter	TWetQ	Tª wettest quarter
PDryM	Precipitation of dryest month	TYearR	Tª annual range (MaxTWarmM - MinTColdM)
PDryQ	Precipitation of dryest quarter	VRM	Vector Ruggedness Measure
PET	Annual potential evapotranspiration	Work	Soil workability

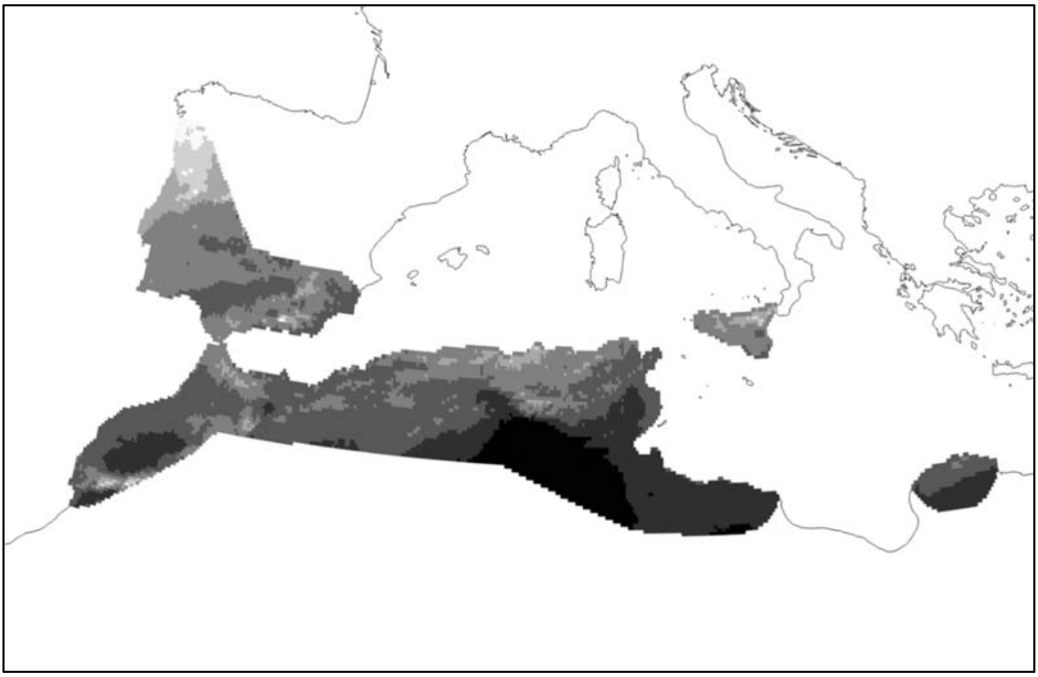
Supplementary material S.3.4. Environmental variables sorted by type, internet source and reference.

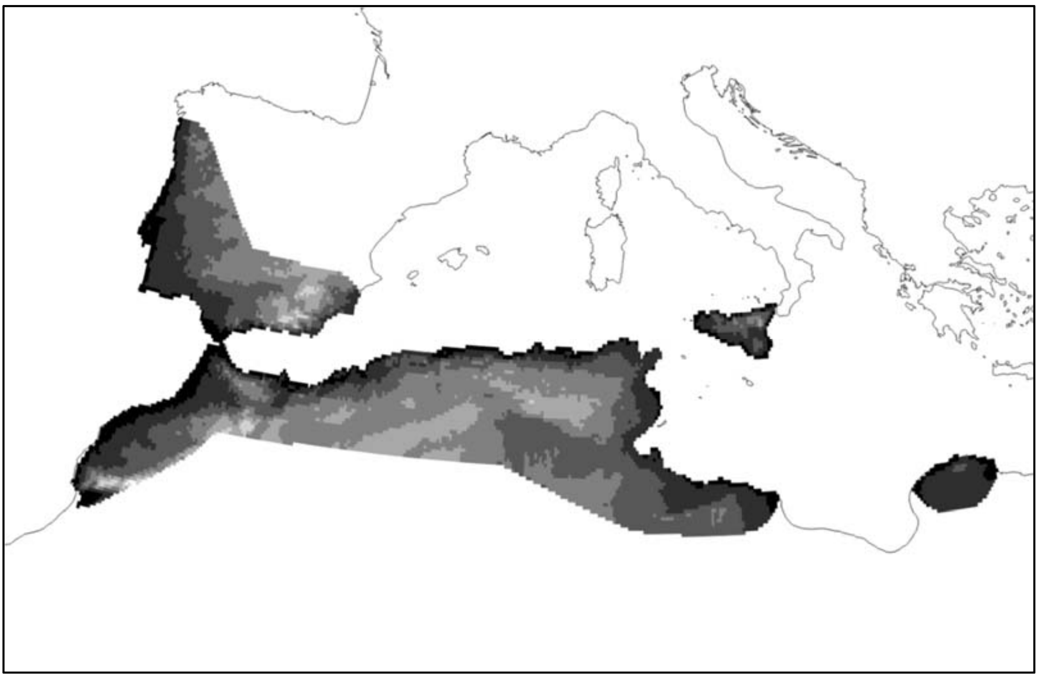
	earthenv.org	envirem.github.io	fao.org	globalsolaratlas.info	worldclim.org
Humidity	-	Moist, PET, PETColdQ, PETDryQ, PETSeason, PETWarmQ, PETWetQ	-	-	-
Precipitation	-	Embg, Thorn	-	-	PWetM, PDryM, PSeason, PWetQ, PDryQ, PWarmQ, PColdQ, MeanP
Soil	-	-	NutrAv, NutrRet, OxyAv, Rooting, SaltEx, Work	-	-
Solar radiation	-	-	-	DIF, DNI, GHI, GTI, OPTA, PVOUT	-
Temperature	-	Cont, GDy0, GDy5, MaxTColdM, MinTWarmM, CT10M, Therm	-	-	MeanT, MTDyR, Iso, TSeason, MaxTWarmM, MinTColdM, TYearR, TWetQ, TDryQ, TwarmQ, TColdQ
Topographic	Elev, Rough, Slope, TPI, TRI, VRM	-	-	-	-
Reference	Amatulli et al. 2018	Title & Bemmels 2018	Fischer et al. 2008	Worl Bank Group 2016	Fick & Hijmans 2017

Supplementary material S.3.5. Loadings of variables in both PCA factors of the whole-range PCA analysis.

FACTOR 1				FACTOR 2			
Moist	-0.91499	DNI	0.49208	Rivas	-0.90597	NutrRet	-0.12938
MeanP	-0.88545	Cont	0.50943	Elev	-0.80639	SaltEx	-0.12621
Embg	-0.86903	CT10M	0.51112	TSeason	-0.76069	OxyAv	-0.11808
PWetQ	-0.83650	TColdQ	0.51598	Cont	-0.73225	tpi	-0.10660
PWetM	-0.82539	TSeason	0.52117	TYearR	-0.71899	TDryQ	-0.08228
PColdQ	-0.82251	PETWetQ	0.54130	PETSeason	-0.62531	TWarmQ	-0.05117
PWarmQ	-0.80557	MaxTColdM	0.61815	PETWarmQ	-0.48312	Thorn	0.10746
PDryQ	-0.77302	TYearR	0.62171	MTDyR	-0.48049	MeanP	0.15394
PDryM	-0.68484	TWetQ	0.62629	PETDryQ	-0.43598	Moist	0.15416
Slope	-0.60215	Therm	0.65924	PETWetQ	-0.40553	DIF	0.18931
Rough	-0.59689	MTDyR	0.66179	OPTA	-0.40349	TWetQ	0.27641
tri	-0.59505	PETWarmQ	0.70193	DNI	-0.39243	Embg	0.28586
vrm	-0.51018	PETDryQ	0.70886	PDryM	-0.35142	PETColdQ	0.29403
OPTA	-0.41484	PVOUT	0.74648	Rooting	-0.34176	PWetQ	0.29592
Elev	-0.33154	MinTWarmM	0.75028	PDryQ	-0.34122	MinTWarmM	0.29863
tpi	-0.08124	DIF	0.75299	PVOUT	-0.31917	PColdQ	0.30149
Iso	0.00497	GDy5	0.77439	Work	-0.29843	PWetM	0.31279
PSeason	0.03169	PETColdQ	0.80872	GTI	-0.25271	MeanT	0.41674
Rooting	0.05769	GDy0	0.81160	Slope	-0.25166	GDy0	0.49185
Work	0.12095	GTI	0.81516	Rough	-0.24959	GDy5	0.52852
MinTColdM	0.20543	GHI	0.81773	tri	-0.24649	Iso	0.54537
NutrRet	0.22649	MeanT	0.85362	vrm	-0.22134	Therm	0.69968
NutrAv	0.24108	PET	0.86527	PWarmQ	-0.17623	MaxTColdM	0.71015
SaltEx	0.32729	Thorn	0.90018	PET	-0.15929	PSeason	0.73596
OxyAv	0.33609	TDryQ	0.90492	GHI	-0.15707	CT10M	0.80890
Rivas	0.34744	TWarmQ	0.90745	NutrAv	-0.14820	TColdQ	0.82932
PETSeason	0.47185	MaxTWarmM	0.92584	MaxTWarmM	-0.14048	MinTColdM	0.93398

Supplementary material S.3.6. Spatially explicit distribution of PCs values: upper PC1 gradient from oceanic wettest (white) to continental dryer (black) areas and lower PC2 gradient from cold higher (white) to warm lower (black) elevations.





Supplementary material S.3.7. Land uses and covertures used resulting from aggrupation of those defined by Moreira et al. 2007.

Forested areas
for. arbol. densa: coniferas
for. arbol. densa: coniferas+eucaliptos
for. arbol. densa: eucaliptos
for. arbol. densa: otras frondosas
for. arbol. densa: otras mezclas
for. arbol. densa: quercineas
for. arbol. densa: quercineas+coniferas
for. arbol. densa: quercineas+eucaliptos
matorral denso arbolado: coniferas densas
matorral denso arbolado: quercineas densas
matorral disp. arbolado: coniferas. denso
matorral disp. arbolado: quercineas. denso
pastizal arbolado: coniferas. denso
pastizal arbolado: quercineas. denso
rios y cauces nat.:bosque galeria
rios y cauces nat.: otras form. riparias

Rain fed woody crops
cultivos herbaceos y lenosos en regadio no regados
cultivos herbaceos y lenosos en secano
cultivos lenosos en secano: olivar
cultivos lenosos en secano: vinedo
cultivos lenosos y pastizales
cultivos lenosos y vegetacion natural lenosa
olivar abandonado
olivar-vinedo
otras asociaciones y mosaicos de cultivos lenosos en secano
otros cultivos lenosos abandonados
otros cultivos lenosos en secano
otros mosaicos de cultivos y vegetacion natural

Irrigated woody crops
cultivos herbaceos y lenosos en regadio parcialmente regados
cultivos herbaceos y lenosos regados
cultivos lenosos en regadio: parcialmente regados o no regados
cultivos lenosos regados: citricos
cultivos lenosos regados: frutales tropicales
cultivos lenosos regados: olivos
mosaico de lenosos en regadio
mosaico de secano y regadio con cultivos herbaceos y lenosos
mosaico de secano y regadio con cultivos lenosos
otros cultivos lenosos regados

Rain fed grass crops
cultivo herbaceo arbolado: quercineas. denso
cultivo herbaceo arbolado: quercineas. disperso
cultivos herbaceos en regadio: no regados
cultivos herbaceos en secano
cultivos herbaceos y pastizales
cultivos herbaceos y vegetacion natural lenosa

Irrigated grass crops
cultivos herbaceos en regadio: regados y no regados
mosaico de secano y regadio con cultivos herbaceos
otros cultivos herbaceos regados

Green house crops
cultivos forzados bajo plástico

Urbanized areas
aeropuertos
autovias, autopistas y enlaces viarios
balsas de alpechin
complejos ferroviarios
equipamiento deportivo y recreativo
escombreras y vertederos
otras infraestructuras tecnicas
tejido urbano
urbanizaciones agricola / residenciales
urbanizaciones residenciales
zonas en construccion
zonas industriales y comerciales
zonas mineras
zonas portuarias
zonas verdes urbanas

Flooded areas
arrozales
balsas de riego y ganaderas
canales artificiales
embalses: lamina de agua
estuarios y canales de marea
lagunas continentales
lagunas litorales
mares y oceanos
marisma mareal con vegetacion
marisma no mareal con vegetacion
marisma reciente sin vegetacion
rios y cauces nat.:lamina de agua
salinas indust. y parques de cultivos
salinas tradicionales

Dense scrub
matorral denso
matorral denso arbolado: coniferas dispersas
matorral denso arbolado: coniferas+eucaliptos
matorral denso arbolado: eucaliptos
matorral denso arbolado: otras frondosas
matorral denso arbolado: otras mezclas
matorral denso arbolado: quercineas dispersas
matorral denso arbolado: quercineas+coniferas
matorral denso arbolado: quercineas+eucaliptos

Open scrub
matorral disp. arbolado: coniferas. disperso
matorral disp. arbolado: coniferas+eucaliptos
matorral disp. arbolado: eucaliptos
matorral disp. arbolado: otras frondosas
matorral disp. arbolado: otras mezclas
matorral disp. arbolado: quercineas. disperso
matorral disp. arbolado: quercineas+coniferas
matorral disp. arbolado: quercineas+eucaliptos
matorral disperso con pastizal
matorral disperso con pasto y roca o suelo

Grassland
pastizal arbolado: coniferas. disperso
pastizal arbolado: coniferas+eucaliptos
pastizal arbolado: eucaliptos
pastizal arbolado: otras frondosas
pastizal arbolado: otras mezclas
pastizal arbolado: quercineas. disperso
pastizal arbolado: quercineas+coniferas
pastizal arbolado: quercineas+eucaliptos
pastizal con claros (roca, suelo)
pastizal continuo

Bare land
areas con fuertes procesos erosivos
playas, dunas y arenales
roquedos y suelo desnudo
talas y plantaciones forestales recientes
zonas incendiadas
zonas sin vegetacion por roturacion

Chapter IV

Supplementary material S.4.1. Scored AICc competitive set of seasonal model. Dark grey shade cells indicate selected covariates. Light grey shaded model is the seasonal simplest model.

season	crop type	irrigation	irrigation type	stage	height	cover	altitude	bare ground	AICc
■				■		■			347.0174
■				■		■		■	348.5049
■				■		■			348.5084
■				■		■	■		348.6259
■				■	■	■			349.0610
■				■					350.2983
■				■				■	351.6510
■				■			■		351.8465
■			■	■		■			352.1063
■				■	■				352.1198
■		■		■					352.3285
■						■			355.9635
■			■	■					355.9957
■	■			■		■			356.7585
■	■			■					358.8091
■								■	363.7681
■									367.0136
■					■				367.5889
■							■		368.9435
■		■							369.0528
■			■						373.9193
■	■								374.5023
									382.9038

Supplementary Material S.4.2. Scored AICc competitive set of year to year models. Dark grey shade cells indicate selected covariates. Light grey shaded model is the seasonal simplest model.

year	crop type	irrigation	irrigation type	stage	height	cover	altitude	AICc
■			■	■				401.0129
■		■		■				401.1003
■			■	■		■		402.0949
■	■			■	■			402.7900
■		■		■		■		402.6192
■			■	■	■			402.9657
■			■	■			■	403.0985
■	■			■				403.0360
■		■		■	■			402.9311
■		■		■			■	403.1747
■	■			■		■		403.4321
■	■			■	■	■		403.7082
■	■	■	■	■	■	■		403.8327
■	■			■	■		■	404.1717
■	■	■	■	■		■	■	404.1856
■	■	■		■	■	■		404.3793
■	■			■			■	404.7320
■	■	■		■		■	■	404.6819
■	■	■	■	■	■		■	405.0520
■	■			■		■	■	405.1933
■	■	■		■	■		■	405.0242
■				■				408.2459
■				■	■			409.0488
■				■			■	410.0763
■				■		■		410.3015
■				■	■		■	410.7787
■				■	■	■		411.0744
■				■		■	■	412.1353
■			■					425.7894
■						■		429.8462
■								432.0958
■	■							432.3193
■		■						433.4271
■					■			433.5362
■							■	433.6282
								439.7825

Supplementary material S.4.3. Variance inflation factor for the selected variables on the multi-variable models.

Model	Predictor	GVIF	Df	GVIF$^{(1/2*GVIF)}$
seasonal	season	1.242	3	1.037
	stage	1.222	3	1.034
	cover	1.110	1	1.054
year	year	1.108	2	1.026
	stage	1.353	3	1.052
	irrigation	1.254	1	1.120

Archibald Thorburn's illustration of the Andalusian Buttonquail in the authoritative Ornithology of the Straits of Gibraltar by the Lieut-Colonel Leonard Howard Lloyd Irby (1895).

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Plate of Ulrico Hoepli in the book Atlante Ornitologico. Uccelli Europei con notizie d'indole generale e particolare de Arrigoni degli Oddi (1902).

Agradecimientos

Now this is a story, all about how my life got flipped, turned upside-down and I'd like to take a minute just sit right there I'll tell you how I became the prince of a bird called Buttonquail.

Al oeste en el País Vasco, crecía y vivía sin hacer mucho caso ….. ;)

Ahora en serio. Como muchos de los aficionados a la observación de aves de mi generación, crecí y aprendí de aves con la única compañía de *El Hombre y La Tierra*. En esos tiempos de prados segados a golpe de *sega* o por el diente de las *latxas*, nadie en mi entorno, excepto mi *compañero* Felix, y algunos cazadores de malvices, eran capaces de pronunciar el nombre de un ave entendiendo su significado más profundo y mucho menos de relacionarlo con una realidad viva, emplumada y tangible. Allí me dedicaba, como cualquier chaval fascinado por la naturaleza, a atrapar ranas, lagartijas y cangrejos de río, y como no a dar plomo con la *txinbera* a los pájaros del barrio de caseríos donde se encontraba nuestra casa. Rondaría yo los 10 años cuando, un 6 de enero, los reyes magos dejaron en casa de mi tío Enrique un regalo tan inesperado como sorprendente: El Libro de las Aves de España, de la editorial Reader's Digest. En pocos días me vi deslumbrado por las magníficas ilustraciones de aquel libro y empecé a poner nombre, incluso en latinajos, a los pajarillos que muchas noches, mi abuelo y yo, nos cenábamos bien fritos.

Al poco tiempo, y también por casualidad, encontré unos prismáticos, que mi padre tenía guardados en un cajón. Por curiosidad, salí a la ventana a mirar cómo se veía con aquel chisme. Casi me caigo de espaldas cuando, sin mediar disparos de por medio, pude ver, identificar y disfrutar de las aves que en otras ocasiones colgaban inertes de mi percha. Se afanaban, en un grupo de abedules, un carbonero y varios lúganos colgando acrobáticamente de sus amentos. Un poco más lejos, un alcaudón dorsirrojo cantaba desde el cable que traía el sonido del teléfono hasta la casa. Esos Zeiss Jena pasaron de forma inmediata a ser de mi propiedad sin que su anterior dueño ni siquiera lo supiera. Así, casi de repente, las redes de suelo, la liga, la *cometa* del cuatro y medio, que me

había regalado mi abuelo, y la *nórdica* que gané en el campeonato de Guipúzcoa de tiro con carabina, fueron dando paso a la óptica y a la lectura ávida de aquél libro mágico. Poco a poco, iba aprendiendo más de las aves que había en ese libro, y para mi sorpresa, empecé a encontrarme con otras personas que también tenían prismáticos y libros de pájaros y a las que la jerga ornitológica no les resultaba ajena. Viviendo ya en Logroño, fue en la balsa de Viana, humedal geográficamente navarro, pero de alma riojana (hoy Reserva Natural de Las Cañas), donde empecé a conocer y a tomar notas de las aves que veíamos, abandonando definitivamente mis escarceos venatorios de infancia y juventud.

Poco tiempo después, quiso el destino, que empezara mis estudios de Biología en la Universidad de León, atraído por la figura de Pancho Purroy, por entonces presidente de la SEO. Allí descubrí una nueva forma de acercarse a las aves, el anillamiento científico, en el cuál se conjugaban los dos motores que modelaron mi infancia, el atavismo humano de capturar, trampear, poseer, ... y la no menos humana necesidad de estudiar y aprender. Fue gracias al grupo de anillamiento de URZ. Tenía esta asociación como sede un ático en un céntrico edificio, en la parte más alta del teatro Emperador, donde todos los jueves nos reuníamos y batallábamos fieramente por la conservación de la naturaleza, a la vez que organizábamos salidas de anillamiento los fines de semana. A los 19, certificado ya como anillador, dedicada cada vez más horas al monte, con cierto menoscabo de la Universidad, en compañía de Miguel, Justo, Bene, Josines, Benito, Guillermo, Pili, Eva, Xabi, Ordoño, Olga, Javitxu, Jacinto, Alejandro, Angelillo, César, Eloy y qué se yo cuantas personas más. Fue URZ un verdadero lugar de aprendizaje, dónde entre otros muchos amigos, aprendí mucho de biología y de conservación y pude impregnarme de la sabiduría popular de Santiago Magallón, del rigor de Luis Costa y de la honestidad y coherencia de ambos.

Con estas mimbres me licencié en Biología, y me acerqué por primera vez a Doñana en 1992, coincidiendo con la Expo de Sevilla. Dos años más tarde volví, ya invitado por amigos que empezaban el trabajo de sus tesis doctorales. Introducido en el mundo doñanero de la mano de Eloy y Javitxu, conocí a ilustres pajareros como José Luis Arroyo, Luis García y sobretodo Héctor Garrido (Chiqui) con los que acontecieron largas y avivadas conversaciones sobre pájaros en torno a unas cervezas en aquel pretérito Toruño, o recorriendo Doñana en algún destartalado todoterreno. Como no podía ser de otra manera, el torillo andaluz centró muchas de esas charlas, lo que a la postre encaminaría mis pasos hacia esta especie durante muchos años.

En aquel tiempo, el Equipo de Seguimiento de Procesos Naturales de la Estación Biológica de Doñana, tras años de esfuerzo infructuoso en la búsqueda de la especie en España, halló, en Marruecos, una perdida población de torillos en los últimos retazos de matorral mediterráneo, que aún resistían a las cortas y el sobrepastoreo, de una extensa meseta calcárea en la región de Doukkala Abda. A la par, dos magníficos ornitólogos: el francés Pierre André Crochet y el catalán José Luis Copete, encontraron también esta población, y con ellos mantuvimos durante años un fluido intercambio de información y el secreto de la ubicación del misterioso torillo. Unos años más tarde, en 2004, de la mano de Mario Sáenz de Buruaga y de Héctor Garrido, y a demanda de Juanjo Areces, entonces técnico en el Ministerio de Medio Ambiente, redacté un proyecto para iniciar, por primera vez, acciones de conservación ex situ de esta población. Acabó esta iniciativa, como otras en el futuro, en agua de borrajas. Nunca tuvo este escurridizo animal el poderío de un oso, la mirada de un lince o la majestuosidad del águila imperial, para despertar el interés de la sociedad y no caer en el olvido. Sin embargo, y gracias a la perseverancia de Chiqui, y el apoyo decidido de Fernando Hiraldo, entonces director de la Estación Biológica de Doñana, y de Juan Pérez Mercader, presidente de la Junta Rectora del Parque Natural de Doñana, comenzó en 2005 un proyecto, financiado por la Junta de Andalucía, para prospectar Doñana a fondo y confirmar o descartar definitivamente la presencia de la especie. La ejecución del proyecto recayó en manos de EGMASA (hoy Agencia de Medio Ambiente y Agua) y por fortuna la dirección facultativa del proyecto en Francisco Quirós (Curro), quien tuvo a bien llamarme por teléfono para invitarme a formar parte del mismo, liderando los trabajos de campo. No hacía ni 10 minutos que había dejado la notaría de Cazorla tras firmar una hipóteca para la compra de una casa a más de 400 kilómetros de Doñana. Esa llamada cambió de forma definitiva el rumbo de mi vida. Tras pensármelo más de dos veces, acepté y unos meses más tarde, una vez terminados mis trabajos con el alimoche en las sierras orientales de Andalucía, me trasladé a Matalascañas. Gracias Curro por esta magnífica oportunidad. El reto se adivinaba difícil y con pocas posibilidades de éxito. Muchos y buenos ornitólogos lo habían intentado antes, sin conseguir pruebas documentales de la presencia de los torillos. Para entonces la especie era más en un mito que una realidad, sólo confirmada por los últimos ejemplares abatidos en 1981 en las cercanías de El Rocío. Éstos fueron cedidos por los cazadores locales a Luis García y hoy se conservan en la colección científica de la Estación Biológica de Doñana. El propio Luis, Fernando Solís Martel, Carlos Urdiales, el Colectivo Ornitológico Cigüeña Negra, Francisco Parreño y sobre todo Héctor Garrido en Doñana, me sirvieron de inspiración y referencia para abordar la tarea: demostrar con pruebas tangibles (fotos, audios, plumas, huellas, ejemplares, …) la pervivencia en Doñana del torillo andaluz o descartarla definitivamente tras haber realizado un esfuerzo lo suficientemente intenso. Tuve la fortuna de contar en este proyecto con un comité técnico y científico formado por Isa Molina, Carlos Urdiales, Héctor Garrido, Juanjo Negro y Manuel Máñez, que siempre estuvieron ahí para asesorarme. Aun así, la ausencia de conocimiento sobre la especie era palmaria y posiblemente con más error que acierto, con la asistencia en el campo de Pedro Pablo Vázquez Limón, David Palacios y Leónidas de los Reyes, probamos muchas metodologías para su búsqueda: escuchas al amanecer y al atardecer, estaciones de trampeo y de huellas, uso de reclamos, … Gracias al apoyo de Manuela Moreno de la Red de Voluntarios Ambientales de Doñana y el concurso de los tres Carlos: Dávila, Molina y Camacho (conmigo ya éramos cuatro) de la oficina de SEO/Birdlife en Doñana pudimos realizar batidas con voluntarios. Finalmente, emulando las partidas de caza, hicimos recorridos con perros de pluma en toda la comarca de Doñana. Con la eficaz gestión de Locus Avis (gracias Bene), contamos con los setter ingleses y bracos de Ariège de Julio

Abad y los pointers y bretones de Jorge Lomas y Luis Ángel Fuentes, además de la participación puntual de los perros de Salvador Pérez Galán, Antonio Cantero, Diego Cáceres y Enrique Alés. Con ellos recorrimos más de 7.000 hectáreas de monte mediterráneo en Doñana y alrededores. Decenas de perdices, codornices, becadas, agachadizas, … fueron puestas con precisión por estos magníficos rastreadores, pero sin dar con ningún rastro del perdido torillo. Trabajaba en esos años en el Área de Conservación del Espacio Natural Doñana, donde siempre conté con la amistad y el apoyo de Laló, Teresa, Rubén, Paqui, Justo, María Elena y todo el personal técnico y los agentes de medio ambiente y celadores, que allí realizan su labor. El invierno en Matalascañas es duro, recuerda a aquel Cicely del doctor Fleischman en Alaska: frio, humedad y soledad. Por fortuna una pequeña cuadrilla de playeros, hacía que la vuelta de las infructuosas búsquedas torilleras fuera mucho más agradable: Erik, Samantha, Fernando, Felipe, Bea, Pepe y Maribel, Maria Ángeles, Anita, … A la par, un buen club de buenos amigos doñaneros se fue gestando, estos machotes me siguen hoy apoyando cuando hace falta: Javitxu, Toñe, Paco Villaespesa, Miguel Ángel Bravo, Galán, Paquito Blanco, Jordi y Sencianes. A este último le debo la generosidad del magnífico cuadro que él y muchas amistades más me regalaron por mi 50 cumpleaños, y que hoy ilustra la portada de este trabajo.

Al mismo tiempo y con la ayuda de Fernando Martínez, supimos que en el zoológico de Praga tenían un pequeño contingente de torillos batalladores, una especie asiática, pero en esencia muy cercana a la nuestra. Propusimos al Zoobotánico de Jerez que solicitara un intercambio y empezaran a ensayar con la cría en cautividad de esta especie, que sin ninguna duda sería de gran utilidad en el futuro para la conservación del torillo andaluz. José María Aguilar, Íñigo Sánchez, Luis Flores, Mariano Cuadrado, y muy especialmente Miguel Ángel Quevedo cogieron el guante sin dudarlo, recibieron tres parejas de torillos, y aunando esfuerzo e ingenio, lograron aprender y multiplicar el número de torillos hasta el punto de no saber muy bien donde ir acomodando a los nuevos torillos, ya jerezanos de nacimiento. Gracias a ellos, disponemos hoy de un protocolo de cría en cautividad de torillos detallado y preciso.

Mientras perdíamos casi toda esperanza de que aún existieran torillos en España, desde Marruecos llegaban noticias, extrañas y poco verosímiles, pero que a la postre serían el origen del hallazgo de la población que protagoniza gran parte de este trabajo. En 2004 unos observadores fineses: Hannu Huhtinen y Pasi Laaksonen vieron un ave cruzar a peón una carretera rodeada de huertas. Mientras el ave se ocultaba rápidamente en un campo de zanahorias tuvierno el tiempo suficiente para identificarlo como torillo andaluz. Ni caso hice a semejante dato que contradecía todo lo que yo creía saber sobre la especie, unos años más tarde vería lo equivocado que estaba. Desde el año 2000 ya sabíamos que había torillos en la zona, pero pocos y recluidos en los escasos palmitares existentes. Desde ese año, apenas teníamos un par de registros fiables más, gracias a nuestros torilleros asociados: Copete y Crochet. Sin embargo, para nuestra sorpresa, en 2007 un torillo apareció atropellado en esa misma carretera, rodeada de huertas, a bastante distancia de nuestros palmitos. Y aún más sorprendentemente el ornitólogo Benoît Maire fotografió por primera vez en la historia, un torillo andaluz vivo y en libertad en esa misma zona. No tuve la oportunidad de volver a Marruecos hasta 2009, tras conocer, gracias a Pierre André Crochet, que el año anterior y apenas unos días antes en ese mismo año, otros registros parecían haberse producido en esa misma comarca (Alban Guillaumet, Guillaume Lèotard, Dirk Colin y Kris de Rouck). Y allí fuimos José Luis Copete y yo, en compañía de Dave McAdams y Sandra Bañuls. Yo, aún muy excéptico de estas informaciones que se me antojaban inverosímiles, volví a centrarme en los cada vez más escasos palmitares del interior, con idea de visitar esa zona un poco más adelante. Mientras tanto, Dave y José Luis, siguieron esas pistas hasta un campo de calabazas, donde efectivamente vieron y escucharon torillos. Tras una inmediatísima llamada de teléfono, nos presentamos en la parcela lo más rápido que pudimos. Tenía el campo una empalizada de caña mediterránea, hábilmente entretejida por manos expertas, que protegía el cultivo de la constante brisa marina. Entramos andando entre la empalizada y las calabazas, que a la sazón estaban ya maduras para su recolección. De inmediato un pequeño torillo saltó de mis pies para perderse a los pocos segundos entre la espesa maraña de calabazas y plantas ruderales. Esa visita me dio, en 30 segundos, lo que llevaba buscando casi sin tregua durante tantos años. Gracias a las traducciones al dariya que, a través del móvil, Salvador Bañuls nos hacía con los trabajadores de la finca, tuvimos la oportunidad de pasar allí unos días de observación y estudio. Conocimos a Khalid el Marjani, propietario de los terrenos y excelente anfitrión que siempre nos abrió la puerta de su casa. No podemos estarle más agradecidos, a él y a toda su familia. El lugar estaba repleto de torillos. Dos hembras con sus harenes de machos se habían reproducido allí esa primavera, así que en unos pocos días aprendimos de los torillos muchísimas cosas nuevas. Cosas que jamás había leído en ninguna de las publicaciones consultadas ni oído de la experiencia de mis predecesores. Por fin, empezamos a entender a la especie y a saber cómo trabajar con ella. Supimos cómo detectarla con facilidad gracias a sus excrementos y a los rastros de su actividad en el suelo. Oímos, hasta hartarnos, el canto de las hembras que se nos antojó débil y difícil de detectar, y que además se daba una vez bien entrada la mañana. ¡Cuántos madrugones y noches perdidas en Doñana! Por fin, el mito del torillo andaluz se tornaba en realidad.

Durante el viaje de vuelta, y como tenía planeado, me detuve en el Institut Scientifique de Rabat, con la idea de visitar su colección científica, y tomar datos de las pieles de torillos que allí se encuentran. Conocí a Abdeljebbar Qninba, un científico marroquí de talante sereno y alma cooperativa. Amablemente me mostró la colección, y tras una animada charla que apañamos entre chapurreos de francés, inglés y español, le conté el hallazgo torillero de hacía unos días. Enseguida convenimos en que era necesario trabajar por la especie, y en ese momento nació una colaboración que ha durado hasta el presente. De su mano conocí a otros investigadores marroquíes, los doctores Mohamed Radi, Mohammed Znari y Mohamed Aourir de la Université Cadi Ayyad de Marrakech y a Mohamed Aziz El Agbani del propio Institut Scientifique. Ese año los viajes a Marruecos se sucedieron en compañía de Javitxu Calzada, Jacinto

Román, Isa Molina, Sandra Bañuls, José Manuel Sayago y Miguel Ángel Quevedo. Con ellos y los colegas marroquíes obtuvimos de primera mano datos inéditos sobre la especie. Encontramos nidos, vimos pollos, anillamos adultos, ensayamos la cría en cautividad, obtuvimos las primeras imágenes de video de la especie y hasta redescubrimos una especie de malófago. Aquellos apasionantes momentos sentaron las bases para abordar las tareas de monitorización de la población de torillos en los años siguientes. En este estudio preliminar fue esencial el apoyo y la asesoría técnica de Íñigo Sánchez del Zoobotánico de Jerez, Irene Zorrilla del Centro de Análisis y Diagnóstico de la Junta de Andalucía, María Paz Martín Mateo del Museo Nacional de Ciencias Naturales y de José Ramón Arrebola, Maribel Acosta y Adolfo Muñoz de las Universidades de Sevilla, Córdoba y Huelva respectivamente.

Ya de vuelta en España, y en reunión participativa en Doñana con representantes de instituciones nacionales y autonómicas, de gestión y de investigación, gubernamentales y no gubernamentales, pusimos encima de la mesa los datos que obtuvimos gracias a esta oportunidad única. Ante la pasividad generalizada, SEO BirdLife dio un paso al frente y por boca de José Javier Aransay se ofreció a costear los gastos del trabajo de campo para el año siguiente. Como hasta entonces, la dirección del Espacio Natural Doñana, de la mano de Juan Carlos Rubio, del cual yo era entonces técnico de conservación, continuó permitiéndome dedicar mi tiempo al trabajo con el torillo. Así pues, para junio de 2010, con el apoyo logístico de Tragsatec, preparamos una expedición para comprobar si aquello que el año anterior habíamos visto era un evento excepcional o si, por el contrario, éramos capaces de encontrar más torillos en la zona. De esta manera, con la coordinación de Imad Cherkaoui y Jorge Orueta de la oficina de SEO BirdLife en Marruecos y de Hamid Rguibi, que acababa de fundar la Moroccan Wildlife Association, y la participación de tres estudiantes de la Universidad de El Jadida: Fadwa Hama, Latifa Joulami y Abdellah Ichen, iniciamos una campaña de búsqueda en toda la franja costera de huertas entre Sidi Abed y Cap Bedouzza. Inesperadamente, una persona más se subió al carro en el último momento. Ruth García Gorria, riojana de nacimiento, pero bilbaína hasta los tuétanos (se dice que nacen donde quieren ¿no?), es una bióloga aficionada a la botánica y a los pájaros que, a temporadas reside con su familia en la cercana ciudad de El Jadida. La colaboración de Ruth ha resultado no sólo ser de gran valor por su ayuda en el campo, si no por su calidad humana, generando siempre buen ambiente y ofreciéndonos sin reservas su amistad y hospitalidad. El entusiasmo que ha despertado el torillo en Ruth es difícilmente igualable y eso le ha llevado a participar en prácticamente todas las campañas de muestreo que hemos realizado, y a continuar enviándome datos de aves y nidos encontrados hasta hoy mismo, mientras escribo estas líneas. A su vez a nosotros nos ha permitido compartir la bien surtida mesa por su marido Kepa y la compañía de su cada vez más numerosa familia. Gracias a todos por entender las ausencias de Ruth y la presencia de plumas, fiambres y restos de huevos en cajones y frigoríficos.

Ese mismo año nos enteramos de que una nueva autovía se había proyectado entre las ciudades de Safi y El Jadida. El trazado discurría unos kilómetros al interior de la costa y literalmente partía en dos las zonas de matorrales donde, sólo unos años antes, aparecieron los primeros torillos. Aunque ya era tarde para medidas correctoras, conseguimos que le empresa constructora: Société Nationale des Autoroutes du Maroc, aprobara unas ayudas en forma de medidas compensatorias para que SEO/BirdLife ejecutara acciones de conservación. Con esas ayudas y el apoyo decidido de Curro Quirós y del Espacio Natural Doñana realizamos dos muestreos más. En junio de 2011 en compañía de Itziar López Albacete y Abdelhak Elbanak, y en 2014 con Ernesto Gómez y Mohamed Amezian, y por supuesto siempre con Ruth, realizamos los primeros muestreos sistemáticos que nos han permitido evaluar el estado de la población y su tendencia, así como otros muchos aspectos de su biología que en esta tesis se desgranan.

Con toda la información que habíamos ido generando preparamos dos seminarios hispano-marroquíes para lanzar un plan de acción sobre la especie. Primero en Rabat (noviembre de 2010) y luego en el Zoobotánico de Jerez de la Frontera (septiembre de 2011). A pesar del entusiasmo inicial, nada de lo allí acordado pudo apenas ponerse en marcha, más por falta de voluntad política que de recursos. Lo único bueno de ser una especie tan humilde, es que los medios para afrontar acciones pueden ser también humildes, de lo que es prueba tangible esta tesis. Así pues, una vez más el torillo andaluz cayó en el olvido institucional. Afortunadamente, Gema Ruiz está ahí sin perderlo de vista, y de vez en cuando me urge con algo de información para intentar, como Pepito Grillo, recordar que algo hay que hacer desde las instituciones para promover medidas de conservación en Andalucía.

Desde 2012, había dejado el Espacio Natural Doñana para incorporarme como técnico en la Estación Biológica de Doñana, así que apenas tenía tiempo ya para dedicar al torillo. Me movía entonces entre delfines, y aves marinas. Quiso la casualidad que a través de Manuela Forero conociera a Keith Hobson, con quien compartí pasión por las aves y la migración, y profundizara en el mundo de los isótopos estables. Colaborar con Keith me permitió compaginar el trabajo con la realización de un master en la Universidad Pablo de Olavide. Durante ese curso conocí a un montón de jóvenes y brillantes mentes (olé todos esos Biocos), muchas de las cuales darán mucho que hablar en el mundo de la ciencia, y que aceptaron entre sus filas a este señor que les duplicaba la edad. Si algún día lanzamos una tesis o estudio sobre la genética de los torillos será en buena medida gracias a María Lucena.

Casualidades de la vida, viniendo de un plan de estudios universitarios anterior a Bolonia, la titulación en este master me abrió las puertas a poder solicitar alguna de las ayudas dedicadas a la formación de doctores. Al igual que con el master, ¿por qué no aparcar temporalmente el trabajo que como técnico venía realizando desde hacía 20 años, y seguir formándome? Finalmente, gracias a un contrato FPI, asociado al programa Severo Ochoa, en el Departamento de Biología de la Conservación de la Estación Biológica de Doñana, se me abría la posibilidad de realizar una tesis doctoral en un tema de mi elección enmarcado en la Biología de la Conservación. Tras valorar algunas propuestas, me lie la manta a la cabeza y lo propuse, ¿Por qué no aprovechar la ocasión para sacar a la luz esos datos que tenía sobre el torillo andaluz, y que se me antojaban tan necesarios para su conservación? Llegar a realizar una tesis con una especie tan difícil parecía una vez más un reto un tanto suicida, pero Eloy Revilla y Miguel Clavero aceptaron la propuesta, y se convirtieron por primera vez en directores de un doctorando más viejo que ellos. Con esta nueva expectativa, organizamos nuevas expediciones a Marruecos en 2017, que pude llevar a cabo gracias al director del Institut Scientifique de Rabat, Mohammed Fekhaoui, que aceptó mi solicitud para realizar una estancia en este centro, que depende de la Universidad Mohamed V. En esta ocasión, por supuesto, volvimos a contar con la colaboración de Abdeljabbar Qninba y la hospitalidad y apoyo de Ruth y Kepa, y hasta en cuatro ocasiones repetimos los muestreos de los años 2011 y 2014. Por supuesto Eloy y Miguelito participaron en el primer muestreo, pero además muchos más amigos se unieron a la causa, a cambio de un suelo duro para dormir, y sustento a base de kefta, tajine y pescado frito. Así compartí campo con Raquel y Sandra Sainz Elipe, Christian Miersch, Jacinto Román, Julio Gañán, Javitxu, Lucía y Berta Calzada, Juan Carlos Rivilla y Javi Esquivias quien, además, tomó imágenes para dar visibilidad a la especie y su problemática ante la sociedad. Ese año tuvimos la suerte también de conocer y disfrutar de la hospitalidad de Chusa de Lope. En esos viajes, y gracias a las cámaras prestadas por Julio Rabadán, Sonia Sánchez-Navarro y Tomás Redondo, conseguimos grabaciones inéditas de la vida íntima de los torillos.

Cuatro años he estado en la Estación Biológica de Doñana, rodeado de viejos y nuevos amigos en el Departamento de Biología de la Conservación, siempre bajo la atenta mirada y eficiencia de Sofía. Sería aquí casi imposible nombrar a tanta gente que ha soportado mis chapas torilleras (Rosa, Alfredo, Fran, Isa, …) y sobretodo mis ingenuas dudas metodológicas, estadísticas e informáticas. He compartido despacho con Laura, Antonio, Carlos, Bego y un montón de estudiantes de master, que nos traen aire fresco por temporadas. En el grupo de carnívoros: Miguel, Alberto, Marcello, Paco, Javi, Alejandro, Carlos, Juan Carlos y Jacinto, durante segundos e incluso minutos llegaron a dejar de lado linces, osos, lobos y otras fieras para charlar sobre estos animalillos durante el café de las 11. A ellos y al resto de compañeros del Departamento de Biología de la Conservación, muchas gracias. Para la realización de esta tesis, por requerimiento del programa Severo Ochoa, también conté con un comité asesor. Figuras de la talla de Beatriz Arroyo, Phil McGowan y Pedro Jordano sacaron tiempo para aportar ideas a este proyecto. Muchas gracias a mi hermana Marta por la traducción al francés de estas líneas.

Estoy seguro que en un cuento tan largo ¡enhorabuena por haber llegado hasta aquí! me he dejado a mucha gente en el tintero, mil disculpas por los olvidos.

Yo, creo que, como todo el mundo, soy producto de mis aptitudes y actitudes, pero también de las gentes que me he ido encontrando a lo largo de la vida y que de alguna manera son responsables de lo que hoy soy. En lo que al torillo se refiere casi todo se lo debo a Chiqui y a Curro que pusieron su confianza en este pajarero vasco y a Abdeljebbar que nos facilitó tanto el trabajo en Marruecos. En lo personal se lo debo todo a mi padre y a mi madre, que siempre entendieron con benevolencia que este mal estudiante dedicara más tiempo al campo que a las aulas, y a Raquel quien me ha aguantado estos últimos años, casi desde que empecé a escribir este libro que ahora tienes en las manos.

Plate 158 by Henry Leonard Meÿer in the 4th volume of his "Coloured ilustrations of british birds and their eggs", published in 1847 as Andalusian Hemipode or Gibraltar Quail.

Possibly one of the best ever paintings of an Andalusian Buttonquail was made in 1944 by William Hutton (Bill) Riddell.

Remercemients

Now this is a story, all about how my life got flipped, turned upside-down and I'd like to take a minute just sit right there I'll tell you how I became the prince of a bird called Buttonquail.

In West Philadelphia born and raised….. ;)

Non, plus sérieusement. Comme grand nombre d'observateurs d'oiseaux parmis tous ceux de ma géneration, j'ai grandi et appris à les connaitre avec, comme seule compagnie, l'emision télévisée “El Hombre y La Tierra”. Dans ces temps de prés taillés à coups de faux et de faucille, personne dans mon entourage, à l'exception de mon ami Félix et autres chasseurs de grives, était capable d'évoquer le nom d'un oiseau, en saisisant sa signification profonde et, encore moins, de le comprendre comme une réalité vivante, emplumée et tangible. Là bas, à la campagne, je consacrais mon temps, comme tous les enfants fascinés par la nature, à la capture de grenouilles, de lézards et autres crabes de rivière et, bien entendu, à cibler les oiseaux, au beau milieu des fermes parmis lesquelles se trouvait notre maison. Je devais friser la dizaine lorsqu'un 6 janvier, fête de l'Epiphanie, les Rois Mages déposaient un cadeau chez l'oncle Enrique, aussi surprenant qu'inattendu, Le livre des Oiseaux d'Espagne, publié par Reader’s Digest. En quelques jours, emerveillé par les magnifiques illustrations, je me suis mis à attribuer des noms, y compris en latin, à tous ces petits oiseaux que mon grand père et moi avions l'habitude de dîner en friture lors de nombreuses soirées.

Peu de temps après, tout aussi par hasard, je suis tombé sur une paire de jumelles, que mon père conservait dans un tiroir. Poussé par la curiosité j'ouvris la fenetre et me mis à observer la realité à travers ce machin. Et là! je faillis tomber à la renverse, en réalisant que, sans besoin des coups de fusil, on pouvait parfaitement observer et idéntifier, les mêmes oiseaux qui, souvent, pendaient inertes dans mon cintre. Au milieu des bouleaux, se bouscoulaient, un Mésange Charbonnière et quelques Tarins des Aulnes, suspendus de façon acrobatique de ses chatons. Un peu plus loin, une Pie-grièche Échorcheur chantait perchée sur le fil du téléphone qui amenait le jus jusqu'à chez nous. Des cet instant, les Zeiss jena sont passés à faire partie de ma proprieté sans que, même son ancien propriétaire, soit au courant. C'est ainsi, d'un seul coup, que filets pour oiseaux, et carabines (une un cadeau de mon grand père et l'autre gagnée dans un concours de tir du departement), ont laissé place aux exercices d'optique et à la lecture avide du livre magique. Petit à petit, j'aprennais d'avantage sur les oiseaux répresentés et, à ma grande surprise, j'ai commencé à rencontrer d'autres gens, équipés, eux aussi des jumelles et des livres d'oiseaux et habitués au langage ornitologique. Une fois ma famille installée à Logroño, c'est à l'étang de Viana, en Navarre, dont l'âme appartient tout de mème à la Rioja (aujourd'hui Réserve Naturelle de Las Cañas), que j'ai commencé à étudier et prendre des notes sur les oiseaux observés, abandonant definitivement les diversions vénatoires d'enfance et de jeunesse.

Peu de temps après, le destin m'a amené à initier des études en biologie à l'Université de León fortement attiré par la figure de Pancho Purroy, alors président de la SEO. J'ai decouvert ainsi une nouvelle façon d'approcher les oiseaux, plus scientifique, à travers la pose de bagues, reliant ainsi les deux moteurs qui on faconné mon enfance, d'une part, l'habitude atavique propre à l'homme, de capturer, pièger et s'appropier... de l'autre, le besoin, tout aussi humain, d'étudier et d'apprendre. C'était par le biais du groupe de baguage URZ. L'association, dont le siège se trouvait sur les combles du Théâtre Emperador en plein centre ville, se reunissait tous les jeudis pour défendre avec ardeur la conservation de l'environement, au même temps qu'organisait des sorties le week end pour baguer les oiseaux. A 19 ans, certificat de anneleur en poche, je delaissais quelque peu mes cours à l'Université en consacrant de plus en plus de temps aux sorties de campagne, en compagnie de Miguel, Justo, Bene, Josines, Benito, Guillermo, Pili, Eva, Xabi, Ordoño, Olga, Javitxu, Jacinto, Alejandro, Angelillo, César, Eloy et je ne sais pas combien d'autres. URZ a été un veritable lieu de rencontres, où, parmis des nombreux amis, j'ai beaucoup appris sur la biologie et la conservation et pu m'impregner de la sagesse populaire de Santiago Magallón, la rigueur de Luis Costa et l'honneteté et cohérence des deux.

C'est ainsi que j'ai obtenu ma maitrisse en Biologie, me rendant pour la première fois a Doñana en 1992, à l'occasion de l'Exposition Universelle de Sevilla. Invité à nouveau, deux ans plus tard, par des amis qui démarraient leur Doctorat, j'ai été introduit dans le monde du Parc de la main de Eloy et Javitxu, et rencontré ainsi des célébres ornitos, comme José Luis Arroyo, Luis García et bien sur, Héctor Garrido (Chiqui), avec lesquels on entamait des longues et vives discusions sur les oiseaux autour de quelques bières dans le vieux Toruño, et on parcourait le parc de Doñana dans quelque vieux tout terrain. Bien évidement, le Turnix mougissant était au centre de nombreuses conversations, ce que finirait, à terme, par acheminer mes recherches pendant des longues années vers l'étude de cette espèce.

A cette époque, après des années des recherches infructueuses sur l'espèce en Espagne, l'Equipe de Suivi de Procesus Naturels du Station Biologique de Doñana, a fini par trouver, au Maroc, une population ds Turnix, nichée dans quelques restes du buisson mediterranéen, dernier survivant aux coupes et à la surabondance des troupeaux, dans le plateau de la région de Doukkala Abda. En même temps, deux ornitologues, le francais Pierre André Crochet et le catalan José Luis Copete, découvraient aussi, cette même population d'oiseaux. Pendant des années on a pu établir avec eux un fluide interchange d'informations et le secret de l'ubication du misterieux Turnix. Quelques années plus tard, en 2004, aidé par Mario Sáenz de Buruaga et Héctor Garrido, à la demande de Juanjo Areces, à l'epoque au Ministère de l'Environnement, j'ai redigé un projet, afin de mettre en place, pour la prémiere fois, des actions pour la conservation ex situ de l'espèce en question. Cette iniciative, comme tant d'autres après, se soldera par un échec. Ce discret et évasif animal n'a jamais été doté de la puissance d'un ours, le regard d'un lynx ou la majesté d'un aigle impérial pour attirer l'attention de la société et éviter de tomber dans l'oubli. Cependant, grace a la perseverance de Chiqui, du soutien indéfectible de Fernando Hiraldo, alors directeur du Station Biologique de Doñana, et de Juan Pérez Mercader, Président de la Junta Rectora du Parc Naturel de Doñana, un nouveau projet a pu voir le jour en 2005, financé par la Junta de Andalucia, dont le but était d'explorer Doñana de fond en comble pour confirmer ou écarter definitivament la présence de l'espèce. Le suivi du projet est tombé entre les mains de EGMASA (aujourd'hui Agence pour l'Environement et l'Eau) et fort heureusement, sous la direction de Francisco Quirós (Curro), qui, a estimé pertinent de m'inviter à faire partie de l'équipe en tant que leader du travail de campagne.

Ca faisait à peine dix minutes que je venais de quitter le notaire, à Cazorla pour signer l'achat d'un appartement...à 400 kilomètres de Doñana!!!. Cet appel a été un tournant definitif dans ma vie. Après longue réflexion, j'ai décidé d`'accepter et, quelques mois plus tard, finalisés mes travaux sur l'alimoche dans les montaignes orientales d'Andalousie, j'ai demenagé à Matalascañas. Un grand merci Curro pour cette magnifique opportunité. Le défi me semblait difficile et avec peu de chances de réussite car, des nombreux et excellents ornitologues, s'étaient essayé avant moi sans trouver la moindre preuve tangible de la présence du turnix. A cette époque, l'espèce était devenue plus un mythe qu'une réalité, uniquement confirmée par les derniers exemplaires abattus en 1981 à proximité de El Rocío. Ceux ci furent offerts par les chasseurs locaux à Luis García, et se trouvent aujourd'hui dans la collection scientifique de la Station Biologique de Doñana.

Fernando Solís Martel, Carlos Urdiales, le Colectif Ornitologique Cigüeña Negra, Francisco Parreño et surtout Héctor Garrido de Doñana, m'ont inspiré et servi de reférence à l'heure d'aborder la tache: demontrer par des preuves tangibles (photographies, audios, plumes, empreintes, individus, …) l'existence du Turnix mougissant en Doñana, bien, exclure definitivament son existence, suite à des recherches suffisement exhaustives. J'ai eu l'inmense chance de compter pour ce projet, avec l'aide d'un comité technique et scientifique composé par Isa Molina, Carlos Urdiales, Hector Garrido, Juanjo Negro et Manuel Mañez, qui ont toujours été là pour me porter conseil. Pourtant, l'absence de connaissances sur l'espèce était un fait, et, aidé dans le travail de campagne, probablement, avec plus d'erreurs que de succès, par

Pedro Pablo Vázquez Limón, David Palacios et Leónidas de los Reyes, on a testé des nombreuses métodologies pour sa recherche, telles des écoutes à l'aube et au coucher du soleil, bases de pièges et d'empreintes, utilisation d'appels, … Grace au soutien de Manuela Moreno du Réseau de Volontaires de l'Environnement de Doñana et le concours des trois Carlos: Dávila, Molina et Camacho (avec moi on était quatre) du bureau de la SEO/Birdlife de Doñana, on a pu battre la campagne à l'aide de benévoles. Finalement, émulant des parties de chasse, on a organisé des parcours avec des chiens de plume à travers le territoire de Doñana. Grace à la gestion de Locus Avis (merci Bene), on comptait sur les setter anglais et les bracos de l'Ariège de Julio Abad et les pointers et bretons de Jorge Lomas et Luis Ángel Fuentes, en plus de la participation ponctuelle des chiens de Salvador Pérez Galán, Antonio Cantero, Diego Cáceres et Enrique Alés. Avec eux, on a parcouru plus de 7.000 héctares de mont méditerranéen de la région de Doñana et des alentours. Des dizaines de perdrix, cailles, becasses, becassines… ont été réperées avec précision par ces magnifiques traceurs, sans pour autant trouver la moindre trace du disparu turnix. Pendant ces années, je travaillais au Centre de Conservación de l'Environement de Doñana, où j'ai toujours pu compter avec l'amitié et le soutien de Laló, Teresa, Rubén, Paqui, Justo, María Elena et tout le personnel technique, les agents de l'environement et les surveillants qu'y travaillent. L'hiver de Matalascañas est très dur, ca me rappelle le Cicely du Docteur Fleischman en Alaska: froid, humidité et solitude. Par chance, une petite group d’amis, rendait le retour des recherches infructuoses, beaucoup plus agréable: Erik, Samantha, Fernando, Felipe, Bea, Pepe et Maribel, Maria Ángeles, Anita, … Au meme temps, s'est formé progresivement, un joli petit club de bons amis de Doñana, des braves gens qui continuent aujourd'hui de me soutenir des que j'en ai besoin: Javitxu, Toñe, Paco Villaespesa, Miguel Angel Bravo, Galán, Paquito Blanco, Jordi et Sencianes. A ce dernier, je dois un génereux cadeau, la réalisation d'un magnifique tableau que lui et des nombreux amis m'ont offert lors de mon 50ème anniversaire, et qu'aujourd'hui, illustre la prémière de couverture de ce travail.

Au même temps, par le biais de Fernando Martínez, on a appris l'existence, au zoo de Prague, d'un petit nombre de Turnix combattant, une espèce asiatique, au fond très proche de la notre. On a proposé au Zoobotanique de Jerez de soliciter un échange, afin de démarrer quelques tentatives d'élévage en cautivité de l'espèce, ce qui, sans doute, pourrait être dans un futur, d'une grande utilité pour la conservation du Turnix mougissant. José María Aguilar, Íñigo Sánchez, Luis Flores, Mariano Cuadrado, et tout particulièrement, Miguel Angel Quevedo se sont lancés dans l'aventure, sans hésitation. Après réception des trois couples de turnix et grace à une bonne dose d´effort et d'ingeniosité, ils ont réussi à multiplier leur nombre, au point de ne plus savoir où installer les nouveux nés, ceux-ci andalous par naissance. Grace à eux, on dispose aujourd'hui d'un protocole detaillé et precis des turnix élevés en cautivité.

Alors qu'on avait perdu presque tout espoir de prouver l'existence du Turnix en Espagne, des nouvelles arrivaient du Maroc, des nouvelles bizarres et invraisemblables mais qui, finalement allaient deboucher sur la découverte de la population qui est, en grande partie, la protagoniste de ce travail. En 2004, des amateurs finois, Hannu Huhtinen et Pasi Laaksonen ont observé un oiseau traverser a peón une route entourée de potagers, pour aller se cacher dans un champs de carottes, qu'ils ont identifié comme étant un Turnix mougissant. Je n'ai preté aucune attention à une pareille donnée, car elle mettait en branle tout ce que je croyais savoir sur l'espèce. Ce n'est que des années plus tard que j'ai fini par comprendre combien j'avais eu tort. Depuis l'année 2000, on connaissait l'existence des turnix dans le secteur, mais ils n'étaient pas nombreux et vivaient reclus dans quelques palmiers existants. Des lors, on comptait à peine sur deux registres fiables grace à nos amis: Copete et Crochet. Cependant, en 2007, à notre grande surprise, un Turnix a été decouvert écrassé sur la même route de potagers, assez distante de nos palmiers. Et, plus surprenant encore, l'ornitologue Benoît Maire, a pu photographier pour la première fois dans l'histoire, un Turnix mougissant vivant et en liberté, dans cette même région. Je n'ai pas eu l'occasion de retourner au Maroc avant 2009, apres avoir appris par Pierre André Crochet, que l'année précedente et tout au long de cette année, d'autres registres s'etaient produit dans la région (Alban Guillaumet, Guillaume Leotard, Dirk Colin et Kris de Rouck). On s'est alors rendu là bas, José Luis Copete et moi même, accompagnés par Dave McAdams et Sandra Bañuls. Moi, très esceptique, tant les informations me semblaient peu fiables, me suis centré plutot sur l'ensemble de palmiers de l'interieur, de plus en plus rares, dans l'idèe de visiter le dit secteur un peu plus tard. Pendant ce temps là, Dave et José Luis, suivaient des traces jusqu'a un champ de citrouilles, où, en effet, ils ont réperé et entendu les turnix. Suite à leur appel téléphonique immédiat, j'ai debarqué sur le champ. Le terrain était encerclé par une cloture de jonc mediterranéen, tissé habilement par des mains expertes, afin de protéger les cultures de la persistente brise de la mer. On s'est frayé un chemin entre la palissade et les citrouilles, par ailleurs, bonnes et mures pour la récolte. Soudain, un petit turnix a sauté entre mes pieds pour aller disparaitre, quelques secondes après, parmis l'épais enchévétrement des citrouilles et des plantes. En à peine 30 secondes, j'ai eu devant les yeux ce que je m'attelais à chercher sans trève depuis des années. Grace à Salvador Bañuls, qui nous a traduit via son portable, le dariya parlé par les travailleurs du champ, on a eu l'occasion de rester la bas quelques jours d'observation et d'étude. On a rencontré Khalid el Marjani, le proprietaire du terrain, et excellent hote qui nous a ouvert les portes de sa maison. Nous ne pourrons jamais assez le remercier, lui et toute sa famille. Ce lieu était rempli de turnix. Deux femelles, et leur harem de males, avaient réussi à se reproduire sur place pendant le printemps, ce qui nous a permis d'aprendre en seulement quelques jours, beaucoup de choses que l'on ignorait sur le turnix. Des choses que je n'avais jamais lu dans des publications, ni entendu des experiences directes de mes predeceseurs. On a enfin commencé à comprendre l'espèce et à savoir comme travailler avec elle. On a appris à la répérer facilement, grace aux excréments et aux traces d'activité sur le terrain. On a ecouté, jusqu'à la saciété, le chant des femelles qui nous semblait faible et difficile à répérer, émis, par ailleurs, tard dans la matinée. Combien des nuits et des levers à l'aube inutiles à Doñana! En fin, le mythe du turnix devenait une réalité.

Lors du voyage de retour, je me suis arreté, comme prévu, à l'Institut Scientifique de Rabat, afin de voir la collection scientifique et saisir des données sur la peau des turnix qui s'y trouvent. J'ai ainsi rencontré Abdeljebbar Qninba, un scientifique marrocain d'humeur sereine et esprit coopératif. Il m'a montré la collection avec beaucoup d'amabilité, et après une conversation fort animée, composée d'un bafouillage de français, anglais et espagnol, je lui ai fait part de notre récente trouvaille quelques jours plutot. On a rapidement conclu qu'il était necessaire de travailler sur l'espèce, et ce jour là est né une étroite collaboration qui se poursuit encore de nos jours. Grace à lui j'ai pu rencontrer d'autres chercheurs marrocains, les docteurs Mohamed Radi, Mohammed Znari et Mohamed Aourir de l'Université Cadi Ayyad de Marrakech ainsi que Mohamed Aziz El Agbani du même Institut Scientifique. Cette année là les voyages au Maroc se sont succedé, en compagnie de Javitxu Calzada, Jacinto Román, Isa Molina, Sandra Bañuls, José Manuel Sayago et Miguel Angel Quevedo. Avec eux et nos colègues marocains on a réussi à obtenir de prémière main des données inédites sur l'espèce. On a trouvé des nids, reperé des poussins, bagué des adultes, on s'est essayé à l'élévage en cautivité, capté les premieres images video de l'espèce et on est allés jusqu'à decouvrir une espèce de malophage. Ces moments passionants allaient servir de base aux futurs travaux de saisie informatique de la population de turnix qui ont été menés tout au long des années suivantes. Pour réaliser cette étude preliminaire fut essentiel le soutien et conseil technique de Íñigo Sánchez du Zoobotanique de Jerez, Irene Zorrilla du Centre d'Analyses et Diagnostiques de la Junta de Andalucía, María Paz Martín Mateo du Musée National de Sciences Naturelles et José Ramón Arrébola, Maribel Acosta et Adolfo Muñoz des Universités de Seville, Cordoue et Huelva respectivement.

De retour en Espagne, lors d'une réunion participative à Doñana, avec des representants des institutions nationales et fédérales, de gestion et de recherche, gouvernamentales et non gouvernamentales, on a mis sur la table toutes les données obtenues grace a cette decouverte inouie. Devant la passivité générale, SEO/BirdLife a fait un pas en avant avec son porteparole, José Javier Aransay, et proposé le financement du travail sur le terrain pendant les années à venir. Comme auparavant, le directeur de l'Espace Natural de Doñana, Juan Carlos Rubio, où je travaillais en tant que technicien de conservation, m'a permis de continuer à dedier le temps de travail à l'étude du turnix. C'est ainsi que, en juin 2010, avec le soutien logistique de Tragsatec, on a organisé une nouvelle expédition, afin de constater si, ce qu'on avait vu l'année précedente, était une chose d'exceptionnelle ou si, au contraire, on réussisait à retrouver plus de turnix dans la région.

C'est sous la coordination de Imad Cherkaoui et Jorge Orueta du bureau de SEO BirdLife du Marroc, de Hamid Rguibi, fondateur de la récente Moroccan Wildlife Association, et la participation de trois étudiants de l'Université de El Jadida: Fadwa Hama, Latifa Joulami et Abdellah Ichen, qu'on a démarré une campagne de recherche dans toute la frange cotière de potagers entre Sidi Abed et Cap Bedouzza. De façon tout à fait inattendue, un nouveau membre est venu intégrer l'équipe à la toute dernière minute. Ruth García Gorria, née à La Rioja, mais de Bilbao jusqu'à la moelle (c'est bien connu que ceux de Bilbao naissent ou ils veulent non?). Il s'agit d'une biologiste, amateur de botanique et des oiseaux qui, habite par périodes, avec sa famille, dans la proche ville de El Jadida. La collaboration de Ruth s'est averé d'une grande valeur, non seulement par son aide de travail de campagne, mais aussi par ses grandes qualités humaines, générant de la bonne ambiance en permanence et nous offrant, sans réserves, son amitié et son hospitalité. L'enthousiasme reveillé par le turnix chez Ruth n'est en rien comparable, à celui qui l'a amené, par la suite, à participer dans presque toutes les campagnes d'échantillonage, et continuer d'envoyer les données des oiseaux et des nids decouverts jusqu'à l'instant oú j'écris ces lignes. Ce qui nous a permis, par ailleurs, de partager sa table, bien remplie par les soins de son mari, Kepa, et la compagnie de sa chaque fois plus nombreuse famille. Merci à tous d'excuser Ruth pour ses quelques absences, ainsi que pour la présence de plumes, cadavres et restes d'oeufs dans les tiroirs et le frigo.

Cette même année on a appris l'existence d'un nouveau projet de construccion d'Autoroute entre les villes de Safi et El Jadida. Le tracé se déroulait quelques kilomètres à l'interieur de la côte et coupait litteralement en deux la zone des buissons où, quelque années auparavant avaient été découverts les premiers turnix. Si bien il était trop tard pour entreprendre des mesures de modification, on a quand même reussi à obtenir une aide de compensation de la part de l'entreprise, la Société Nationale des Autoroutes du Maroc, destinée à SEO BirdLife afin de finacer des actions en faveur de la conservation. Grace à ces aides et, au ferme soutien de Curro Quirós et de l'Espace Naturel de Doñana, on a pu réaliser quelques échatillonages supplementaires. En juin 2011, assisté par Itziar López Albacete et Abdelhak Elbanak, et en 2014 par Ernesto Gómez et Mohamed Amezian, et bien entendu toujours avec la collaboration de Ruth, on a réalisé les premiers échatillonages systématiques, ce qui nous a permis d'évaluer l'état et les tendences de la population, ainsi que d'autres aspects de sabiologie qu'on décortique dans cette thèse.

Avec toute l'information recoltée, on a organisé deux seminaires hispano-marrocains dont le but était de demarrer un plan d'action pour l'espèce. D'abord à Rabat (novembre 2010), ensuite au Zoobotanique de Jerez de la Frontera (septembre 2011). Malgré l'enthousiasme du début, rien de ce qui avait été prévu n'a pu voir le jour, plus par manque de volonté politique que de ressources. La seule chose positive d'ètre une espèce aussi humble, est que les moyens, pour afronter les actions, sont aussi d'une grande simplicité dont cette thèse est la preuve. Ainsi, une fois de plus, le Turnix mouggisant est tombé dans l'oubli des institutions mais fort heureusement, Gema Ruiz est toujours là et ne le perd pas de vue. De temps à autre elle m'appelle avec quelque information, afin de tenter, tel Jimmy le Criquet, de promovoir quelques actions pour sa conservation en Andalousie.

En 2012, j'avais quitté l'Espace Naturel de Doñana afin d'intègrer, en tant que technicien a la Station Biologique de Doñana, ce qui ne me laissait guère le temps de me consacrer au turnix. Pendant cette période, j'evoluais plutôt entre dauphins et oiseaux marins et le hasard a voulu, que par le biais de Manuela Forero, je rencontre Keith Hobson, avec qui je partage ma pasion pour les oiseaux et la migration, me permettant une immersion dans le monde des isotopes stables. La collaboration avec Keith me permit d'alterner travail et études avec la réalisation d'un master à l'Université Pablo de Olavide. Cet année là, j'ai rencontré tout un tas de jeunes et brillants cerveaux (olé! tous ces Biocos), dont beaucoup feront parler le monde de la science, qui ont accepté entre ses rangs et sans réserves, ce monsieur qui les doublait en âge. Si un jour on lance une thèse ou une étude sur la génetique du turnix ca sera en grande partie grace a María Lucena.

Hasard du destin, venant d'un plan d'études universitaires anterieur au plan Bolonia, ce diplôme m'ouvrait les portes pour l'obtention des aides de formation en doctorat. Après le Master, pour quoi ne pas arreter pendant un temps mon travail de technicien, que je réalisais depuis 20 ans, et continuer ma formation? En fin, grace à un contrat FPI, lié au programme Severo Ochoa, au sein du Département de Biologíe de la Conservation de la Station Biologique de Doñana, s'ouvrait devant moi la possibilité de réaliser une thèse de doctorat, sur le sujet de mon choix, toujours dans le cadre de la Biologíe de Conservation. Après un temps de réflexion, j'e me suis lancé et proposant le sujet. Pour quoi ne pas profiter de l'occasion et faire lumière sur toutes les données dont je disposais sur le Turnix mougissant et, qui me semblaient si nécésaires pour sa conservation? Réussir á écrire une thèse sur une espèce aussi complèxe me semblait un défi quelque peu suicidaire, mais Eloy Revilla et Miguel Clavero ont accepté ma proposition, devenant ainsi, pour la première fois, directeurs de thèse d'un éléve doctorand plus vieux qu'eux. Avec ces expectatives, on a organisé des nouvelles expéditions au Maroc au cours de l'année 2017, que j'ai pu mener à but grace au directeur de l'Institut Scientifique de Rabat, Mohammed Fekhaoui, qui a accepté ma demande de séjour dans ce centre rataché à l'Université Mohamed V. Une fois de plus, on a pu compter avec la collaboration d'Abdeljabbar Qninba et l'hospitalité et soutien

de Ruth et Kepa, et on a refait, jusqu'à quatre fois, les échantillonages des années 2011 et 2014. Bien sur, Eloy et Miguelito ont participé au premier échantillonage, mais beaucoup d'autres amis ont rejoint la cause, en échange d'un sol dur en guise de matelas, et des répas a base de kefta, tajine et friture de poisson comme répas. C'est ainsi que j'ai partagé la mission avec Raquel et Sandra Sainz Elipe, Christian Miersch, Jacinto Román, Julio Gañán, Javitxu, Lucía et Berta Calzada, Juan Carlos Rivilla et Javi Esquivias qui, par ailleurs, prennait des images pour donner une visibilité à l'espèce et sa problématique dans la société. Cette année là on a eu la chance de rencontrer et profiter de l'hospitalité de Chusa de Lope. Lors de tous ces voyages et grace aux caméras pretées par Julio Rabadan, Sonia Sanchez-Navarro et Tomás Redondo, on a reussi à obtenir des images inédites de la vie intime du turnix.

J'ai passé quatre ans dans la Station Biologique de Doñana, entouré de vieux et des nouveaux amis, au sein du Departement de Biologie de la Conservación, toujours sous le regard attentif et competent de Sofía. Il me serait impossible de citer ici tous les personnes qui ont du supporter mes discours lourdingues sur le turnix (Rosa, Alfredo, Fran, Isa, …) en plus de l'ingenuité de mes doutes sur la métodologie, l'estatistique et l'informatique. J'ai partagé bureau avec Laura, Antonio, Carlos, Bego et un tas d'étudiants en master, qui nous ont apporté de l'air frais à chaque saison. Dans le groupe des carnivores: Miguel, Alberto, Marcello, Paco, Javi, Alejandro, Carlos, Juan Carlos et Jacinto, qui ont reussi pendant quelques secondes, voir quelques minutes à laisser de coté lynx, ours, loups et autres fauves, pour papoter sur ce petit animal, pendant la pause café de 11h. A eux, et à tous les colégues du Départament de Biologie de la Conservation, un grand merci. Pour la réalisation de cette thèse, à la demande du programme Severo Ochoa, j'ai pu compter également avec l'appui d'un comité de soutien. Des figures de rélévance comme Beatriz Arroyo, Phil McGowan et Pedro Jordano ont reussi à consacrer un peu de leur temps pour apporter des idées à ce projet. Un grand merci à ma sœur Marta pour la traduction française de ces lignes.

Je suis certain que dans un si long récit, (toutes mes félicitation d'être arrivé jusque là!) j'ai du laisser pas mal de monde dans l'encrier et vous demande toutes mes excuses pour ces oublis.

Je pense que, comme nous tous, je suis le produit de mes propres capacités et d'une actitude face à la vie, mais aussi de toutes ces personnes rencontrées pendant le parcours de vie, et qui sont, en quelque sorte, responsables de ce que je suis devenu aujourd'hui. En ce qui concerne le turnix je dois presque tout à Chiqui et Curro, qui ont misé toute leur confiance sur cet amateur d'oiseaux basque, et aussi à Abdeljebbar, qui nous a tellement facilité le travail au Maroc. D'un point de vue personnel je dois tout à mon père et à ma mère, qui ont toujours accepté, avec bienveillance, que ce mauvais étudiant consacrasse plus de temps aux sorties à la campagne qu'aux bancs de l'Université et à ses cours, et aussi à Raquel qui a du me supporter pendant ces dernières années, depuis que j'ai commencé à écrire ce livre que tu tiens en ce moment entre tes mains.

"Almost throughout the higher sections of the animal kingdom you have males fighting for the females, the females caring for the young; here, in one insignificant little group of tiny birds, you have the ladies fighting duels to preserve the chastity of their husbands, and these latter sitting meekly in the nursery and tending the young.

It is, to our ideas, a very odd arrangement, because we have become so thoroughly imbued with the spirit of the opposite one; but it answers apparently just as well, so far as the interests of the race are concerned, as that one with which we are so familiar, and on which we pin our faith; and in this and many similar cases it has often seemed to me that nature mutely warned mankind against dogmatism and against the foolish, though all too prevalent, belief that only what we know and are used to can be good, and that neither government nor society can get along equally well under any laws and forms but just those which we are become accustomed."

Allan O. Hume & Charles H.T. Marshall
1879
The Game Birds of India,
Burmah, and Ceylon

EXCELENCIA SEVERO OCHOA

UNIVERSIDAD PABLO DE OLAVIDE SEVILLA AÑO 1997

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