

## **PhD-Dissertation Reviews in Ornithology(2014–2015 Academic Year)**

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## PHD-DISSERTATION REVIEWS IN ORNITHOLOGY (2014-2015 academic year)

Edited by Francisco VALERA

This section includes the abstracts of some of the PhD-Dissertations submitted in Spain during the 2014-2015 academic year as well as some others not published in earlier volumes of *Ardeola*. They are in alphabetical order by University where they were presented and, then, by year and alphabetical order of the author's surname.

*Esta sección incluye los resúmenes de algunas de las Tesis Doctorales en Ornitología defendidas en España en el curso 2014-2015 junto con otras no recogidas en reseñas anteriores. Se ha seguido una ordenación alfabética por universidades y, dentro de ellas, por año y autor.*

### **Informative note:**

In its section PhD-Dissertations Reviews in Ornithology, *Ardeola* reports any studies on ornithological issues presented in our country. The section is intended as an updated overview of the latest ornithological research performed mainly in Spain. In spite of the efforts of the editor to compile all the theses, we are aware that the collaboration of researchers (supervisors and doctorates) is needed to give a full view of ornithological research in Spain. We therefore invite the scientific community to report on their results (address: [ardeola@seo.org](mailto:ardeola@seo.org)). The Scientific Committee of SEO/BirdLife grants a biannual prize to the best Ph Dissertation included in this section. The prize is awarded in the corresponding Spanish Ornithological Conference. We are looking forward to hearing from you, also as proof of the relevance and quality of ornithological research in Spain.

### ***Nota informativa:***

*Ardeola* recoge en su sección Reseña de Tesis Doctorales en Ornitología aquellas tesis leídas en nuestro país que estudien temas ornitológicos con el fin de informar sobre las más recientes investigaciones desarrolladas, fundamentalmente en España, en este campo científico. A pesar de los esfuerzos que realizamos para reseñar todas las tesis concluidas, somos conscientes de que un registro completo y actual de las mismas requiere de la colaboración de los investigadores (directores y doctorandos). Por ello invitamos a todos aquellos implicados en la realización de tesis en ornitología a que nos informen de sus resultados (dirección: [ardeola@seo.org](mailto:ardeola@seo.org)). El Comité Científico de SEO/BirdLife otorga con carácter bianual un premio a la mejor tesis doctoral reseñada en esta sección, que es entregado en el Congreso Español de Ornitología correspondiente. Esperamos vuestras noticias como buena señal de la pujanza de la investigación ornitológica en nuestro país.

## Universidad de Alcalá de Henares

Teixeira Assunção de Albuquerque, Maria José  
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Supervisors: Rey Benayas, J. M. and Rodríguez Fernández, M. A.

Distribution and relevant areas of terrestrial vertebrate diversity in Europe and America.  
[*Distribución y áreas relevantes de diversidad de vertebrados terrestres en Europa y América.*]

### Abstract:

Assessing broad biogeographical patterns of species distribution is crucial to identify high-value biodiversity areas (HVBA) -areas featuring high species richness, rarity and vulnerability. Identifying HVBA and assessing whether such areas are included in protected areas (PAs) networks is a primary goal for biological conservation. Although PAs networks are important to preserve species and ecosystems, a number of studies have shown that PAs do not necessarily ensure the conservation of biodiversity. In this sense, the ability of PAs in representing biodiversity is doubtful. The main goal of this study was to identify HVBA for amphibians, reptiles, birds and mammals at broad and regional scales and also to investigate whether the actual PAs network represents these areas. We also identified (i) the geographic pattern of terrestrial vertebrate in Europe by assessing species richness, rarity, vulnerability, and a combined index of the three former, assessed (ii) whether HVBA of terrestrial European vertebrates are included in the current protected area network, and (iii) if European bird diversity is well represented by special protected areas for bird species. We finally identified (iv) key conservation areas for mammal species across American Terrestrial Biomes. Our results showed a clear geographic gradient of vertebrate diversity across Europe. The HVBA were mostly located in the Mediterranean basin and the highest vulnerability was found in the Iberian Peninsula for most vertebrate taxa. However, it should be noted that even

though the actual PAs network covers most HVBA areas, we observed a large number of cells without PA coverage in areas of high diversity of vertebrates in Europe. Considering a more detailed assessment of European bird species, our results showed little association between bird richness patterns and the cover of PAs. In America, the overall geographic distribution patterns of mammal species diversity, HVBA, and gaps of HVBA occurs at Mesoamerica, the Andean region and the Brazilian Atlantic Forest Biosphere Reserve, indicating that the representation of mammal species distribution and richness by actual PAs network are far from complete. We conclude that there are still a great number of conservation gaps to be filled in. Therefore, a higher number of PAs must be established to fill in these gaps, especially for threatened species.

Academic year: 2013-2014.

## Universidad Autónoma de Madrid

Bravo Párraga, Carolina

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Supervisor: Bautista, L. M. and Alonso, J. C.  
Trophic ecology of the great bustard *Otis tarda*: influence of habitat and sexual size dimorphism.

[*Ecología trófica de la avutarda común Otis tarda: influencia del dimorfismo sexual y del hábitat.*]

### Abstract:

Knowledge of the feeding behavior of a species is key for understanding both biological requirements and the factors that influence such behavior. What, when and where do they eat? How does their diet composition change according to environmental factors, such as food availability? Are body size and/or sex key factors in the intra-specific variability of diet? These questions arise when studying the feeding ecology of a species. I focused on the foraging behavior and niche partitioning in

sexually sized dimorphic birds within a context of evolutionary behavioral ecology. In sexually sized dimorphic species, physiological constraints derived from differences in body size might determine different nutritional requirements and thus a trophic niche divergence between males and females. However, the relationships between sexual dimorphism and dietary overlap are not well understood in birds. The great bustard, which shows the highest sexual size dimorphism (SSD) among birds (males weighing 2.44 times more than females), was used as a model species. Adult birds live in sexually segregated flocks, which suggests a possible role of niche specialization in the evolution of their SSD. Under this framework, the objectives of my thesis were to review the relationship between the trophic niche divergence and the SSD (chapter 1); and to assess the sexual differences in feeding behavior of great bustards by analysis of: i) diet composition of young and adult birds (chapter 2 and 3), ii) dietary responses according to food availability (chapter 4), iii) characteristics of the wintering feeding area and home range of birds during winter (chapter 5), and iv) consumption of toxic beetles (chapter 6). I highlighted the role of sexual dimorphism in the feeding behavior and its consequences for the management of the species as well as for the evolutionary theory of feeding behavior in dimorphic birds.

Academic year: 2014-2015.

## Universidad de Barcelona

García Tarrasón, Manuel

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Trophic ecology, habitat use and ecophysiology of Audouin's gull *Larus audouinii* in the Ebro Delta.

[*Ecología trófica, uso del hábitat y ecofisiología de la gaviota de Audouin Larus audouinii en el delta del Ebro.*]

## Abstract:

This thesis revolves around two main interrelated sections using Audouin's gull *Larus audouinii* in the Ebro Delta as model organism. In the first section we study the trophic ecology and habitat use in this near threatened species, with special emphasis on the relationship with fisheries. In the second section we investigate ecophysiological aspects such as the allocation of resources and nutrients to egg production, and its relationship with diet. The results presented in the first section of the thesis show the strong dependence of Audouin's gulls from the Ebro Delta on fisheries. Foraging movements of breeding birds revealed a strong association with fishing activities during work days (specially trawling during daylight and purse-seine during the night). However, at sea activity was more important during the day than during the night. An increase in the use of rice field habitats was also detected in absence of fishing activities (during weekends) due to opportunistic feeding on American crayfish *Procambarus clarkii*. However, a key aspect presented in this thesis was the significant sex-related differences in the foraging behaviour in relation to fishing working cycles. Female Audouin's gulls tended to perform longer at-sea foraging trips on weekends compared to males. This is probably a consequence of the need to feed on high quality resources (like marine fish) after laying the eggs to meet their nutritional requirements, instead of the easily available but lower quality American crayfish from the nearby rice fields. The very high mercury levels found in the feathers of Audouin's gull chicks from the Ebro Delta are a consequence of the great consumption of fishing discards (since mercury levels are higher in mesopelagic environments), together with the accumulation of toxic sediments at Flix reservoir (90 Km upstream from the Ebro Delta) carried down by the river. In the second section of the thesis, the great dependence on fishing activities was also reflected in the re-

source allocation into the clutch. An isotopic  $\delta^{15}\text{N}$  enrichment in the albumen of eggs synthesized during the weekends was observed, which is probably attributed to an increase in the consumption of resources from the rice fields (with enriched nitrogen signatures compared to marine resources) as well as to the mobilization of female reserves. The stable isotopes of the eggs showed that during trawling moratorium periods, laying females dramatically switched to rice field diets (unlike exposed above during the incubation period) probably because of the strong link to the nest during laying. However, although American crayfishes have high levels of carotenoids (especially astaxanthin), rice field diets were associated to lower antioxidant capacity in the eggs. Also, rice field diets were related to smaller egg size. Finally, the limiting nature of calcium circulating levels (constraining egg synthesis) and antioxidant molecules (decreasing their concentration especially in the last eggs of the clutch) were also revealed for females.

Academic year: 2014-2015.

Pagani-Núñez, Emilio

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Diet and plumage colouration in the great tit *Parus major*. Are birds what they eat?

[*Alimentación y color del plumaje en el carbonero común Parus major ¿Son las aves lo que comen?*]

Abstract:

Animals display different foraging strategies when they look for food for their offspring, showing great variability among species, populations and individuals. This pattern is especially marked in Mediterranean forests due to their great biodiversity. There are three key factors that characterize these strategies: the kind of prey that parents prefer, the degree of behavioural consistency in the short term and along the annual cycle, and the trophic structure of the population in which this be-

haviour is recorded. In relation to these factors, an important question is to determine how these trophic preferences relate with the degree of ornamentation showed by the individuals. According to the “good parent hypothesis”, females should rely on male ornaments as indicative of their parental quality. In consequence, it is expected that the most ornamented individuals show the most efficient foraging strategies. This is especially relevant in the case of carotenoid-based colouration, which can only be acquired through the food. Our objective was to characterize parental foraging strategies in our study population, and to study the relationships of these foraging strategies with the carotenoid-based ornaments of parents and offspring. Our model species was the Mediterranean great tit *Parus major*. First, we found that, as usual, caterpillars were the main prey, although in our area parents fed a high quantity of spiders to their offspring. We also recorded great variability among pairs (the proportion of spiders ranged from 0 to 50%). We showed that great tits had a highly consistent foraging behaviour in the short-term, and that they preferred spiders not only during the breeding season, but throughout the annual cycle. We stressed that although the population could be characterized as trophic generalist, some individuals showed a tendency towards specialization. The most specialist pairs fed fewer caterpillars and raised more nestlings. We analysed the relationship between diet and plumage colouration, and found that more ornamented parents (with higher hue in the yellow breast) delivered more spiders to their nestlings, which showed better body condition. Moreover, those nestlings that were fed with more spiders displayed brighter colours than those that were fed with fewer spiders. We may conclude that in the Mediterranean context and in relation to avian diet, parental investment is a matter of quality and spiders have a great importance as alternative prey.

Academic year: 2014-2015.

Sánchez-Donoso, Inés

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Supervisors: Rodríguez Teijeiro, J. D., Puigcerver Oliván, M. and Vilà Arbonés, C. Impact of game restocking on common quail *Coturnix coturnix* populations.

[*Impacto de las sueltas cinegéticas en las poblaciones de codorniz común Coturnix coturnix.*]

#### Abstract:

The common quail is a popular game bird in Europe. Massive restocking of farm-reared individuals for hunting purposes is a common practice in several European countries. Although restocking of common quail is legally allowed, some suspicion has been aroused about the possible hybrid origin of farm-reared quails, which would be descendants from crosses with domestic Japanese quail *C. japonica*. Crosses in the wild between restocked farm-reared and native common quails pose an important threat for the common quail since they may result in the introgression of non-adaptive alleles into native populations. For example, hybrids do not show the migratory instinct observed in common quails that allows overcoming the annual depletion of the habitat (due to the harvest of winter cereal crops). The goal of this thesis is to understand the effects that game restocking has over common quail populations and to gain knowledge to improve common quail conservation and management. By using genetic methods, results from this thesis show that the vast majority of quails reared in Spanish farms for restocking are not common quails but domestic Japanese quails and hybrids. Restocked individuals show higher mortality and nest predation in the wild than common quails, but they successfully reproduce with the same or even higher probability than native quails. Results show that genetic introgression has already occurred in common quail populations in Catalonia and genetic data support a slow ongoing introgression

of domestic Japanese quail alleles into the common quail gene pool. Simulations predict this could result in extensive admixture in the near future if releases are maintained. Intensive control and genetic monitoring of individuals for restocking is needed as the massive release of farm-reared hybrids represents a severe threat for the long term survival of the common quail.

Academic year: 2014-2015.

#### Universidad de Castilla-La Mancha

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Ecology and conservation of Iberian sandgrouse: a multiscale approach.

[*Ecología y conservación de Pteróclidos ibéricos: una aproximación multiescalar.*]

#### Abstract:

Identifying the ecological requirements and the habitat features that allow species persistence is critical for developing conservation strategies, especially for species inhabiting environments subjected to rapid anthropogenic change, such as European agro-systems. European farmland birds have suffered a 52% decline in their populations in the last 30 years due to agriculture intensification. This dissertation deals with the spatial ecology, distribution, niche segregation and multi-scale habitat selection of two closely-related bird species associated (but not restricted) to agricultural areas: the pin-tailed sandgrouse (*Pterocles alchata*, Linnaeus 1766) and the black-bellied sandgrouse (*Pterocles orientalis*, Linnaeus 1758). I employed a multiscale top-down approach to study the abiotic, biotic and anthropogenic factors that determine the geographic distribution, ecological niche and abundance of both species, and their habitat

requirements at local and microhabitat scale. Lastly I identified conservation problems influencing sandgrouse survival at different locations, including temporal (season) and individual (behavioural decisions regarding movement) variations. The central question in my thesis was how species whose origin is located in isolated undisturbed environments (deserts) thrive in humanized dynamic environments (farmlands) subject to varying conditions as a result of human activities. Although both sandgrouse species are closely-related, they occupy distinct niches in sympatry and in allopatry. Abiotic and anthropogenic factors explained most of the variation in sandgrouse distributions at large scale. Among abiotic factors, temperature seems to mediate niche partitioning between both species. Hence, the pin-tailed sandgrouse preferably distributes over the thermo- and meso-Mediterranean levels whereas the black-bellied sandgrouse is more common over the meso- and supra-Mediterranean levels, and both species usually co-occur in the intermediate level (meso-Mediterranean). Both species were associated with arid flatlands, and arable land cover was the most important anthropogenic variable determining their large-scale distribution. However, the black-bellied sandgrouse exploits a broader range of environmental conditions (wider niche breadth), and has thus a wider global distribution than the pin-tailed sandgrouse (niche-breadth hypothesis). In this sense, at large scale the latter species is mostly associated with agrarian homogeneous landscapes, whereas the black-bellied sandgrouse selects heterogeneous landscapes with a broader variety of land uses (arable lands, pastures, shrublands), and both co-occur in intermediate positions between the two extremes along the gradient of habitats. Environmental conditions determine regional densities of pin-tailed sandgrouse whereas biotic interactions explain the density of the black-bellied sandgrouse in areas with abiotic conditions simi-

larly conducive for both species. The pin-tailed sandgrouse reaches high densities and wide distribution at regional level where conditions seem to match its optimum (high mean annual temperature, high temperature in July and greater cover of arable lands), in the Spanish South Central Plateau, which is its core area of distribution in Europe. This suggests that the niche-position hypothesis may operate at regional scale for this species. Changes in agrarian management during the last century may have affected the pin-tailed sandgrouse more negatively than the black-bellied sandgrouse. The former species has disappeared from areas where irrigation agriculture has expanded the most (Northern Central Plateau and Guadalquivir Valley), resulting in a network of core and marginal populations less interconnected than in the case of the black-bellied sandgrouse. At local scale, both sandgrouse tend to avoid high cereal crops (pre-harvest, April-June), and select ploughs and fallows, that are used for nesting, feeding and as refuge. Therefore reduction of fallow surface results in net habitat loss for both species during the breeding period. Actually, most of the outward pre-breeding and breeding seasonal movements from the Special Protection Area SPA Campo de Calatrava (used mostly as wintering grounds) may be triggered by local adaptations to spatio-temporal variations induced by agrarian practices. Although the underlying mechanism behind these movements deserves further investigation, these individual behavioural decisions seem to increase survival and can thus be regarded as an advantageous strategy. In general, survival rate of the pin-tailed sandgrouse tended to be lower towards the northern margin of the European distribution. In the core distribution area (central Spain) mortality was more frequent during the non-breeding season due to higher predation rates. Illegal hunting was also recorded indicating a need for stricter law enforcement and regulation plans within protected areas. Besides agricultural manage-

ment, land use change due to human population growth, urbanization and infrastructure development are negatively affecting sandgrouse distribution and abundance. At local scale, both species avoid farms, recreational houses and tracks, and select fields distant from infrastructure, being the black-bellied sandgrouse relatively more sensitive to human disturbance than the pin-tailed sandgrouse, a pattern also observed at larger scales. Given that at national and regional scale both species are linked to human-modified agricultural areas, anthropogenic management at landscape (i.e. urbanization, infrastructure construction, hunting management) and land use levels (agrarian practices at field scale) may be exerting deleterious effects on both sandgrouse, thus decoupling large-scale model predictions and the actual situation at local scale. Local scale factors may indeed explain why highly suitable areas are currently unoccupied. Agriculture expansion during the Neolithic created open landscapes that allowed sandgrouse (and other farmland birds) to expand over Europe, however, paradoxically, the same activity may be driving them out from the European continent due to the intensification of agrarian practices. Additive negative effects of human encroachment, urbanization, and infrastructure development may be exacerbating the impact of agriculture intensification, further degrading otherwise suitable areas. Reverting the current situation for sandgrouse and other farmland birds depends on the effective application and enforcement of biodiversity conservation policies at European and national level.

Academic year: 2014-2015.

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Ecology and management of generalist predators: the case of the red fox *Vulpes vulpes* and the black-billed magpie *Pica pica*.

[*Ecología y gestión de depredadores generalistas: el caso del zorro Vulpes vulpes y la urraca Pica pica.*]

#### Abstract:

In today's society the perception of, and attitudes towards, predators vary frequently between social groups interested in conservation of biodiversity and productive activities such as livestock raising or hunting. Some members of the latter groups consider certain predators as harmful to certain prey of economic interest (i.e. livestock and game species) because of their predatory habits, which often leads to lethal control of these predators. Predator control is also used as a management tool for the conservation of some endangered species and to reduce the risk associated with zoonoses caused by predators. Whatever the purpose, lethal predator control is often a source of social conflicts. Predator control is usually focused on generalist species, which can become abundant under certain circumstances because of their ecological flexibility. The black-billed magpie *Pica pica* and the red fox *Vulpes vulpes* represent the paradigm of generalist species and in turn are considered detrimental for different human interests, such as agriculture, hunting or livestock raising, in most of their distribution range. The legal control of these species is a common and widely applied management measure in many hunting areas within Europe. Despite this, there is little scientific knowledge about different issues related to this management, particularly in complex ecosystems, such as most found in the Iberian Peninsula. The main aim of this PhD thesis was therefore to improve the scientific knowledge about the ecology and management of the black-billed magpie and the red fox. To achieve this goal, different aspects related to the trophic ecology of these predators, the suitability and improvement of the methods used to control their populations and the ecological implica-

tions of such management were studied. The main findings of this thesis confirm that both the black-billed magpie and the red fox are generalist predators. The black-billed magpie presents a generalist diet (including a wide range of foods) in agricultural environments within central Spain. During its breeding season (and that of other bird species), arthropods and cereal seeds are the most frequent food groups (percent of occurrence, PO > 60%). Eggs and birds are consumed only occasionally (PO < 6% and 17% respectively; percentage of volume, VOL < 4%), and more frequently during the magpie incubation stage, so that its impact on this type of prey does not seem important. Nevertheless, more complex studies in different scenarios (i.e. different densities of magpies and prey), and over longer temporal scales, are still necessary to clarify this controversial issue. Cage-traps with a magpie as decoy are the legal method most commonly used for controlling this bird in Spain. It has been shown in this thesis that these cage-traps used to capture magpies are highly efficient and selective when used during their breeding season in agricultural environments within central Spain. Highest capture rates are obtained in the first days after cage-trap setting, and neither the gender nor the origin (local or foreign) of the decoy seems to affect the capture rate. The results of this study also suggest that magpies' control could reduce locally their population abundances, at least with certain intensity of extraction and with a capture effort sustained over time. Although magpie extractions reduce the density of this corvid in the short term, population responses after trapping may vary, for example, as a consequence of different breeding stages when trapping takes place. On the other hand, Iberian red foxes prey mainly on European wild rabbits *Oryctolagus cuniculus* in places where this prey is abundant, whereas they mostly consume small mammals, fruits and seeds where rabbits are

scarce. Changes in Iberian red foxes diet are related to geographical variables, types of habitat and seasonality, which determine the availability of their main food items. The combined use of baits and scent attractants can improve the efficiency of cage-traps to capture red foxes in addition to reducing captures of non-target species. However, the selectivity of cage-traps to control red foxes is still very low and far from the standards established in the Spanish legislation. By contrast, the Collarum capture system (a new coil-spring-powered neck cable restraint trap) is highly selective for capturing foxes, constituting an advisable alternative to cage-traps. In the case of red foxes, this thesis suggests that under certain intensity of control their abundance may decline. However, in these circumstances the likelihood of spatial occupation of other sympatric mesocarnivores, such as the stone marten *Martes foina*, can increase as result of competitor release processes. On the other hand, fox control reduces diurnal activity of this carnivore. This PhD thesis provides valuable information on the ecology and management of generalist predators in complex ecosystems, where scientific knowledge is still limited and the scarce information available is often inconclusive. In any case, more research effort is needed to make the conservation of predators, and thus of ecosystems, compatible with the sustainable use of natural resources.

Academic year: 2014-2015.

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Supervisors: Alonso-Álvarez, C. and Mateo Soria, R.  
Metabolism of carotenoid pigments and expression of associated colored traits: the case of red-legged partridge *Alectoris rufa*.  
[Metabolismo de pigmentos carotenoides y expresión de caracteres coloreados asociados: el caso de la perdiz roja *Alectoris rufa*.]

**Abstract:**

Avian coloration plays an important role in sexual selection. Many colored traits are produced by carotenoid pigments (many yellow, orange or red colors). Ornaments colored by carotenoids are often used as signals of individual quality in part due to the fact that the organism of animals is unable to synthesize these pigments *de novo*. These compounds can be scarce in the field. Thus, obtaining carotenoid with food could be costly. Moreover, they are organic compounds with relevant physiological functions acting as antioxidants, detoxifying agents or immune boosters. Hence, carotenoid allocation to colored ornaments could impair health or, instead, being constrained by individual condition. All these potential costs would promote the reliability of carotenoid-based signals under a handicap scenario: only the best individuals would be able to express the ornaments at its optimal level, obtaining the highest fitness returns. In spite of all these ideas, many questions related to the mechanisms involved in the expression of carotenoid-based sexual signals still remain open. The aim of this thesis was to deepen these questions by studying the coloration of the red-legged partridge *Alectoris rufa*. We have identified the carotenoid molecules giving color to the red teguments (eye rings, bill and legs) of this species. The main pigments were two keto-carotenoids, i.e. astaxanthin and papilioeritrinone, in order of abundance. They are quite similar in chemical structure and color characteristics, and are present in the ornaments both as free compounds or esterified with fatty acids. Among the fatty acids combined with these carotenoids, the most abundant ones were palmitic, stearic, oleic and linoleic acids. Wild red-legged partridges were redder than animals born in captivity (birds reared in commercial or experimental farms). The loss of carotenoid-based coloration under captivity is an old issue in ornithological litera-

ture. In order to understand the potential mechanisms constraining carotenoid production, carotenoid composition in bare parts of wild and captive animals was compared. We did not detect any difference in carotenoid composition (qualitative differences), but quantitative differences, wild birds showing higher concentrations of both astaxanthin and papilioeritrinone. These carotenoids are probably the result of metabolic transformation of the two main carotenoids present in the diet of granivorous birds (lutein and zeaxanthin). These hydroxyl-carotenoids were also the most abundant pigments in the blood, liver and subcutaneous fat of red-legged partridges. We propose that zeaxanthin should lead to astaxanthin by means of two consecutive oxidations, whereas lutein would produce papilioeritrinone by one oxidation and one dehydrogenation reactions. Since astaxanthin, papilioeritrone or their intermediate molecules were not detected in internal tissues, the most probable biotransformation site in this avian species is the tegument. In addition to lutein and zeaxanthin in internal tissues, vitamin A and E were also detected. We speculate that the function of these antioxidant vitamins was probably protecting carotenoids from oxidation. In this line, we found that partridges showing the reddest ornaments also had the highest values of liver hydroxyl-carotenoids and vitamin E, and the lowest values of vitamin A in the same organ. We propose that keto-carotenoid-based ornaments may, at least partially, signal the capability of the liver to endure the cost derived from storing high quantities of pigments, and particularly, high zeaxanthin levels. In addition, we suggest that red ornaments in red-legged partridges should be involved in sexual selection because females increased their investment in egg production when housed with males whose red color was artificially intensified by means of paint. These females tended to start the laying period earlier and produced

more eggs than females mated with control males. We also experimentally demonstrated that a diet with the ratio between lutein and zeaxanthin levels biased to the last compound increased both astaxanthin deposition in bare parts and red coloration when compared to a less biased diet. This is an interesting finding considering that lutein was the most abundant carotenoid in internal tissues. In fact, it suggests that red ornaments of red-legged partridges may also reveal the individual capacity to obtain a higher proportion of zeaxanthin with the diet or to absorb this compound from food. Lastly, we experimentally found that a certain level of exposure to reactive oxygen species may favor absorption mechanisms or metabolic biotransformation of substrate carotenoids, though depending on the level of other antioxidants in the bare part tissue, particularly vitamin E. We found that birds exposed to low levels of diquat dibromide in the drinking water (a free radical generator) showed redder traits and also higher levels of astaxanthin, but not papilioeritrinone, in the bare parts. This effect was clearer in birds with high vitamin E levels in tissues. The results of this experiment suggest that red colors produced by ketocarotenoids requiring biotransformation from carotenoid substrates (lutein or zeaxanthin) may also transmit information about the quality of birds to correctly manage oxidative stress. A certain level of oxidative stress would be required to obtain the reddest traits. In summary, in the case of red-legged partridges, several mechanisms could simultaneously be acting assuring signal reliability: the necessity of attaining higher zeaxanthin absorption or obtaining higher proportion of zeaxanthin in the diet, the capability of the liver to store high zeaxanthin levels by managing antioxidant vitamin levels and, finally, the capacity to endure certain level of oxidative stress in bare parts to favor biotransformation.

Academic year: 2014-2015.

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Structure and genetic diversity in fragmented populations of blue tit *Cyanistes caeruleus*. [*Estructura y diversidad genética en poblaciones fragmentadas de herrerillo común* *Cyanistes caeruleus*.]

#### Abstract:

The study of factors determining structure and genetic diversity of natural populations is critical to understand their demographic and evolutionary trajectories and thus to predict their responses to future environmental changes. In this thesis we studied genetic structure and relationship between genetic diversity and fitness in terms of parasite prevalence, survival and development of ornaments in Mediterranean populations of blue tits *Cyanistes caeruleus*. We used microsatellite markers classified as neutral and functional depending on whether they are or not located in genome regions that are actively transcribed to RNA. The results of the genetic analysis showed there was limitation to gene flow among populations. Females showed higher dispersion distances than males, a pattern that was reflected in the presence of genetic structure in males but not in females. Landscape genetic analyses also revealed there was genetic structure in the study area, although it was subtle, possibly because habitat fragmentation could force individuals to disperse greater distances through unfavorable habitats to find new breeding places. Furthermore, the genetic structure was detected primarily with neutral markers, what could be because functional markers were subject to stabilizing selection. Spatial heterogeneity and fragmentation of populations could also have generated strong inter-population variability in avian malaria prevalence patterns (12-41% for lineage SGS1) suggesting important differences in parasite transmission rates among geographically close populations. Moreover, we showed

that host genetic diversity estimated with neutral markers was associated with the probability of infection by avian malaria parasites. However this relationship was non-linear, so that individuals with intermediate levels of heterozygosity had higher probability of being parasitized. A combination of subtle positive and negative local effects and/or a saturation threshold in the association between probability of infection and host genetic diversity in combination with increased resistance to parasites in highly homozygous individuals may explain the observed negative quadratic relationship. This relationship was not significant for the subset of functional markers and did not differ between study areas with different degrees of parasitic pressure. Nevertheless, the environmental context influenced the direction and the intensity of the relationship between genetic diversity and annual probability of survival. In particular, we observed that the accumulated precipitation was positively correlated with the intensity of selection on heterozygosity. In addition, the selection of heterozygous individuals and moderate heritability of heterozygosity could have generated a gradual increase of genetic diversity in the population, suggesting a micro-evolutionary response to selection. Finally, we observed a positive relationship between the expression of secondary sexual characters and heterozygosity estimated with functional markers on males. Males with a higher level of carotenoid chroma on the yellow breast, a brighter blue crown, longer song bouts, and higher body condition were more heterozygous, indicating that genetic diversity can be reflected across multiple traits that are likely to be used by females during mate choice decisions. This indicates that the mechanism by which females select their partners might be mediated by the increased capacity of males with high genetic diversity to develop ornaments, which could facilitate female election of a couple with higher genetic quality. Overall, the results

from this thesis highlights the importance of integrating different types of molecular markers and ecological data obtained at different space-time scales to improve the knowledge of factors that determine the genetic structure of natural populations, as well as the consequences that genetic diversity has on different components of fitness.

Academic year: 2014-2015.

## Universidad de Córdoba

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Behavioural adaptations of cavity nesting birds.  
[*Adaptaciones comportamentales de aves que anidan en cavidades.*]

### Abstract:

Nesting cavities offer conditions of relatively constant temperature and humidity as well as protection from rain, solar radiation and predators. Availability of nesting cavities, thermal properties of the nests and ectoparasites loads are among the main factors implicated in the evolution of cavity nesting behaviour. The main goal of this thesis is to increase our understanding from an evolutionary perspective of the behavioural strategies arising during several stages of the reproductive cycle of various small altricial cavity-nesting birds: the pied flycatcher *Ficedula hypoleuca*, the Eurasian nuthatch *Sitta europaea* and the blue tit *Cyanistes caeruleus*. This PhD thesis involves descriptive studies and field experiments aimed at understanding the mechanisms underlying adaptations for nest site selection and defense, for determining nest structure and composition, for defense against ectoparasites and for female nutrition during the incubation stage. Given that nesting cavities are a scarce resource, there may be strong

competition over them. We found that levels of testosterone differ between populations of the same species, being higher in populations where the likelihood of nest-site usurpation by intruders is greater. We also found that the level of female aggressiveness against intruders decreases with higher testosterone levels in high density areas. These females may not consider the presence of female intruders as risky and may therefore tend to ignore potential competitors. Similarly to other species, dominant individuals are not necessarily the most aggressive ones. After obtaining a nest cavity or nest-box, nest building begins. Some species such as nuthatches show clear preferences for certain nesting materials and cavities for breeding. The selection of nesting material and the amount of mud in nuthatches' nest-boxes can be explained as a trade-off between requirements for nest construction and availability (as a function of distance to the nest). Nesting cavities constitute micro-environments very likely to be colonized by ectoparasites and certain nesting materials may be used due to their insecticidal properties. Additionally, nests without any structure such as those built by nuthatches may offer fewer opportunities for hiding to ectoparasites and nest composition may affect ectoparasite development through the effects of microclimatic conditions associated with different nest materials. Here we show that the replacement of unstructured nests (nests made of loose heaps of material without any structure or nest cup to contain eggs and nestlings) by structured nests did not result in changes in ectoparasite loads for nuthatches, which suggests that the preferences for nest materials in this bird species are unrelated to ectoparasitism. We suggest that nuthatches' nests contribute to reduce the thermal loss for nestlings and possibly eggs during female absences by remaining buried into loose and heat-producing bark flakes. Generalist ectoparasites infest nests of avian

cavity-nesting passerines as a response to different factors exhibited by the host species. Differences in nest composition among host species are not the main factor explaining ectoparasite prevalences and abundances, while nest size, breeding phenology, brood size and nest-cavity microclimate may all affect levels of infestation in different ways for each host-parasite association. Given the negative impact of ectoparasites on nestlings there will be selection on hosts to reduce parasite infestations through behavioural means. We found that frequency and intensity of female anti-parasite behaviours during the incubation and nestling periods decreased as a consequence of the experimental reduction of ectoparasite infestation and these behaviours were more intense in the host species with highest infestation levels. As a response of higher nutritional needs arising from higher ectoparasite loads we showed that nestlings begged more intensely. While begging by nestlings has received much attention as an honest system of communication, begging between mates has been less studied. We tested whether female begging during incubation is an honest signal of energetic need and found that experimentally handicapping female pied flycatchers intensified begging displays arising from condition impairment and that males were able to respond by increasing their feeding rates to females.

Academic year: 2014-2015.

## Universidad de Extremadura

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Malaria parasites and its consequences in the behaviour and fitness of Passerine birds.

[*Parásitos maláricos y sus consecuencias en el comportamiento y eficacia biológica de Paseriformes.*]

### Abstract:

Similarly to the rest of vertebrates, birds coexist with a great number of parasites that may exert a strong selection pressure in birds, determining life histories of their avian hosts. Avian malaria and related haemosporidian are one of the most studied bird parasites. They may provoke detrimental effects on their avian hosts affecting survival, diminishing host body condition, and decreasing reproductive success. Despite much research focused on haemosporidian parasites in recent years, there is still limited knowledge on many different issues concerning host-parasite interactions. i) For example, several studies have shown a relationship between parasite infection and the behaviour of their hosts, but the link between haemosporidian parasites and the escape behaviour of their avian hosts remains unknown. ii) Moreover, no study has previously experimentally tested the effect that malaria parasite may provoke in the escape behaviour of their avian host. iii) Furthermore, despite the ability of *Plasmodium relictum* lineages to be present in almost all continents and their invasiveness in many island avifauna, no study has shown the presence of the malaria lineage *P. relictum* SGS1 infecting birds in mainland America. Another issue needing a deeper analysis is the identification and detection of essential genes involved in the life cycle of avian malaria. Although some of these essential genes have been analyzed, there are still a significant number of crucial genes that have not been detected. iv) For instance, the chitinase gene, a critical gene allowing the malaria parasite trespassing the midgut of the mosquito, has not been identified in one of the most widespread and harmful avian malaria parasite, *P. relictum*. v) Similarly, the MSP1 gene, required for allowing the entrance of the malaria parasite to the red blood cell has been scarcely used for epidemiological studies of birds. vi) Finally, the

number of studies that have correlated the effects of haemosporidian infection on feather growth rate are still limited, and they are mainly focused on one single species. In the first chapter of this thesis we found that intense escape behavior was positively related to prevalence of infection with *Haemoproteus* and *Leucocytozoon*, whereas that was not the case for *Plasmodium*. Species emitting more frequently fear screams and struggling more when held in a hand showed higher prevalence of *Haemoproteus* and *Leucocytozoon*. These results suggest that species with a higher intensity of escape behaviour have higher prevalence of blood parasites. Following this idea, in the second chapter, we also found that the prevalence of malaria infection was reduced in infected sparrows treated with primaquine and chloroquine. Once the infection was cleared, the biting rate of these medicated individuals significantly decreased. Additionally, these birds also spent more time in tonic immobility before flying away. These outcomes imply that the experimental reduction of malaria parasites provoked a decrease in the intensity of escape behaviour, suggesting that malaria parasites may manipulate the escape behaviour of their avian hosts. Therefore, malaria parasites could increase the likelihood of individuals escaping from predators, but also would benefit the parasite by increasing its transmission opportunities. In the third chapter we found that the overall prevalence of avian malaria and related haemosporidian found in Neotropical birds was 32.4%. Twelve out of 18 native bird species were infected with haemosporidian parasites. The pathogen pSGS1 was widespread and was the most prevalent parasite found (39 % of the total infections), infecting eight host species in both localities. As far as we know, this is the first report of this invasive pathogen in mainland America, thus representing a possible menace to over one-third of all bird species in the world. In the

fourth chapter, we identified the chitinase gene in two mitochondrial lineages of *P. relictum* (SGS1 and GRW4) which showed both the long (*Pr*CHT1) and the short (*Pr*CHT2) copy of the chitinase gene. Because of the high variability of this gene, it can be used for epidemiological studies of malaria parasites. Moreover, the identification of both copies in *P. relictum* sheds light on the phylogenetic relationship of the chitinase gene in the genus *Plasmodium*, supporting the hypothesis that avian malaria parasites are the ancestors of mammal malaria parasites. In the fifth chapter, we found that only three juvenile house martins *Delichon urbicum* were infected by pSGS1. All these juveniles were infected with MSP1 allele Pr2, thus showing that this allele is actively transmitted in Europe. This is the first report showing an active transmission of avian malaria parasites in house martins in Europe. Moreover, most of the adult house martins infected with pSGS1 also showed the same MSP1 allele than juveniles. Additionally, two adult house martins were infected with MSP1 alleles Pr1 (pSGS1) and Pr4 (pGRW4), but these alleles were not found infecting juvenile house martins. These findings suggest that most of the house martin population may get the infection by pSGS1 in Europe, although we cannot discard that pSGS1 Pr2 could also be transmitted in Africa. All these results show that house martins are exposed to two different parasite fauna of *P. relictum*. Finally, in the sixth chapter, we found that malaria parasite was identified as a factor provoking a decrease in feather growth rate in both natural-infected and experimental-infected individuals. These outcomes demonstrate the negative effects of malaria parasites on the feather growth rate of house sparrows under natural and experimental conditions.

Academic year: 2014-2015.

## Universidad de Granada

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Bacterial biodiversity of uropygial secretion and eggshells of hoopoes *Upupa epops*: stability and acquisition.

[*Biodiversidad bacteriana de la secreción uropigial y la cáscara de los huevos de abubillas Upupa epops: estabilidad y adquisición.*]

### Abstract:

Survivorship, reproduction and, therefore, fitness of a large number of organisms depend on their relationship with microorganisms. Some bacteria live in symbiotic mutualistic associations with macro-organisms, which may even evolve specialized structures, dwellings, etc. to host and enhance growth of mutualistic symbionts. The symbiotic relationship between hoopoes *Upupa epops* and the bacteria of their uropygial gland is an example of these mutualisms between animals and microorganisms. Symbionts of hoopoes are antibiotic producing-bacteria that reduce probability of pathogenic infection in the nest environment. The effects of these symbionts on feather-degrading bacteria or embryo pathogens can be seen as the results of an interaction between the community of bacteria hosted in the gland and those present in the nests of hoopoes (eggs, feathers, skin of females and nestlings, etc.). The symbiosis with bacteria is only apparent in incubating females and nestlings, but not in males. The hoopoe is the only bird species for which it has been described that females collect secretion with the beak and spread it, not only on feathers, but also on eggshells. Thus, by mean of preening, the bacterial symbionts of the uropygial gland and/or their antimicrobials will reach the body surface of hoopoes and their eggshells, and influence the bacterial

communities of these locations by, for instance, preventing the invasion of microorganisms that are host pathogens. The vast majority of bacteria produce antimicrobials against other microorganisms with which they are in competition for resources and space. In the case of mutualistic bacteria these antimicrobials would help hosts fighting against pathogenic infections. This is likely the case for hoopoes and their bacteria growing in their uropygial gland that are effective against feather-degrading microorganisms and some potential pathogens of embryos. Thus, investigating the connection between the symbiotic bacterial community of the uropygial secretion of hoopoes and those of other locations within the nests, including nest materials, would help to understand mechanisms of symbiotic bacterial acquisition by hoopoe females and nestlings, including the possibility of vertical transmission from mothers to offspring. This meta-community approach would also serve to extend our knowledge on mechanisms of bacterial protection of hosts from pathogenic microorganisms. This thesis deals with the study of bacterial communities of the nests environment of hoopoes, including those of their uropygial gland, and the relationships among them. By mean of molecular analyses, we characterized bacterial communities of the uropygial gland, beak and brood patch of incubating females and eggshells at the end of the incubation period, and explored similarities among them. In terms of number of Operational Taxonomic Units (OTUs), the bacterial community of the uropygial secretion was the richest (124 OTUs) followed by that of the beak (106 OTUs), eggshells (98 OTUs) and brood patch (97 OTUs). However, most of these OTUs appeared only sporadically, and the average number of bacterial strains per individual, gives a better representation of these communities: uropygial secretion (22 OTUs), beak (9 OTUs), brood patch (9 OTUs) and eggshells (8 OTUs). Bacterial

communities of the beak and brood patch were quite similar to each other in composition, and significantly different from those of the secretion and eggshells, which also differed from each other. Several of the detected OTUs did appear in all studied communities, and some of the most prevalent in secretion samples also appeared in samples of the beak, brood patch and eggshells at relatively high frequencies. This suggests that the bacteria of the uropygial secretion play a role determining the bacterial community of the eggshells. In accordance with this possibility, we detected a nested pattern among explored bacterial communities. All these results suggest that preening behaviour of female hoopoes with uropygial secretion containing bacterial symbionts is used to transmit them to eggshells to prevent embryo pathogenic infections. To explore the role of bacterial communities within the nests of hoopoes as sources of symbiotic bacteria for females and for developing nestlings, we performed two experiments. On the one hand, we manipulated bacterial communities of nests of hoopoes, characterized the bacterial community of the cloaca of females, and explored their associations with those of the secretion of females and of the eggshells. Results showed that the bacterial community of the secretion of females did not depend on that of the nest material or of the cloaca. However, the experimental modification of the bacterial community of nest materials did affect the bacterial community of the eggshells and, then, the probability of embryo infection. On the other hand, we performed cross-fostering experiments moving nestling hoopoes between pairs of nests for which we had previously characterized the bacterial communities of brooding females. The results pointed out a significant genetic component determining the bacterial community of the uropygial gland of nestlings given that the nest of origin explained larger amount of

variance than the nest of rearing. Bacterial communities of cross-fostered nestlings were more similar to those of their siblings and mothers than to the bacterial communities of stepsiblings and stepmother. These results may be explained by vertical transmission of symbionts from mother to offspring before the experiment, or by particularities of the uropygial gland of offspring that were inherited from mothers that enhance probability of acquiring particular bacterial symbionts from the nest environment. The meta-population approach adopted here has allowed the detection of patterns of interactions among communities of the nests of hoopoes that are essential for the understanding of the symbiotic association between hoopoes and bacteria.

Academic year: 2014-2015.

## Universidad de La Laguna

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Patterns and processes of incipient differentiation in the spectacled warbler *Sylvia conspicillata* in Macaronesia.

[*Patrones y procesos de diferenciación incipiente en las poblaciones macaronésicas de curruca tomillera Sylvia conspicillata.*]

### Abstract:

The aim of the present Ph Dissertation is to understand the factors promoting divergence in songbirds with recently (i.e. early Holocene) founded populations, using a multidisciplinary approach including song, morphology and genetic information. To achieve this objective the spectacled warbler, *Sylvia conspicillata* was selected as study model. This species shows a patchy distribution around the Mediterranean basin, but also inhabits three oceanic North Atlantic archipelagos (Madeira, Canary

Islands and Cape Verde). The distribution of this species through discrete geographical entities such as oceanic islands, together with the diversity of environmental characteristics found on each island, do of this species an ideal system to investigate incipient differentiation in non-model populations. This thesis is organized in four chapters. The first chapter studies the song characterization in Fuerteventura's population. Results showed that the song of this bird has a large repertoire (43-126 syllables), is poorly stereotyped inter- and intra-individually, and it is characterized by adding new syllables during a song bout. The second chapter analysed the song internal organization and its relation with song bout duration, using principles of the information theory. Results showed that the high syntactical complexity is kept regardless song bout duration. Such a result suggests that there are not limitations among duration and complexity characteristics. Males seem to sing complex song bouts with high level of variation and uniqueness due to few syllables are shared among individuals. Furthermore, these results would confirm that this species has an open communication system, that is, males do not have a delimited repertoire but an innovative capacity of adding new syllables during a song bout. At the third chapter we studied the process of early differentiation in the spectacled warbler in 14 populations separated by sea barriers from three Macaronesian archipelagos and from the neighbour continental areas. The approach involved the study of sexual acoustic signals, morphology and genetic data. Mitochondrial DNA did not provide a clear picture about its genetic structure. However, microsatellites analyses consistently identified two genetic groups, albeit without correspondence to subspecies classification and little correspondence to geography. Coalescent analyses showed significant evidence for gene flow between the two

genetic groups identified. Discriminant analyses could not correctly assign morphological or acoustic traits to source populations. Therefore, although theory predicting that on isolated populations, genetic, morphological and, especially, acoustic traits can lead to radiation, we have strikingly failed to document differentiation on these attributes in a resident passerine throughout three oceanic archipelagos. Causes explaining such unexpected result are discussed there. Finally, in the last chapter the number of acoustic variables measured was increased in order to scrutinize on a fine-grained level the acoustic variation among populations. The final aim was to assess the association of the acoustic variation with environmental cues (climate), neutral genetic variation (drift) and biological constraints (morphology). Results showed that song divergence did not follow a geographic pattern, but certain correspondence with genetics suggests that the species is going through an incipient differentiation process. Some song characteristics were also correlated with beak morphology, body size and climatic variations between populations, so it seems that part of song variation could be related to adaptations to the environment. However, relationships among morphology and acoustics appear to be contrary to the expected pattern highlighted by previous studies, and could be explained by the insectivorous trophic ecology of this species. The association between climatic conditions and song characteristics does seem to support the theory of acoustic adaptation, since song variation is more related to vegetal cover than to air rarefactions. Thus, the frequencies uttered in the wettest areas (with denser vegetation), appear to be lower, probably to favour the sound transmission. Overall, observing the results obtained during this thesis, it seems clear that it is necessary to scrutinize the birdsong internal structure and not only the repertoire size to characterize properly the

song of any species. In addition, this thesis has revealed that spectacled warbler's song has not suffered significant diversification in Macaronesia, despite its complexity and capacity to innovate. However, some morphological and climatic characteristics seem to be conditioning the incipient acoustic structure detected. In summary, results obtained with this thesis emphasise the intrinsic complexity of acoustic differentiation processes between populations.

Academic year: 2013-2014.

### Universidad de Málaga

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Ecomorphology and evolution of the avian flying system: aerodynamic implications for the flight of stem birds.

*[Ecomorfología y evolución del aparato volador aviano: implicaciones aerodinámicas en el vuelo de las aves basales.]*

#### Abstract:

The number of the fossils of Mesozoic Aves unearthed has increased considerably in the last decade. All these birds are stem taxa because they are phylogenetically closer to the root of avian clade than all modern birds (Neognathae). Numerous paleontological studies dealing with different questions relative to taxonomy, phylogeny and morphological evolution of these birds have been published. However, considerably less abundant are those works focused on explaining the way of flying of stem birds, and they are overwhelmingly centered on the aerial behavior of the most basal bird *Archaeopteryx*. This thesis is a comparative study between stem and flying modern birds where the main objectives are to characterize the flight mode of the studied stem taxa; to explore the

morphological variation in the avian apparatus of flight by identifying the effects of the corporal size, phylogeny and adaptation; and to identify macroevolutionary patterns related to early phases of the avian flight. The scarcity of this type of studies can greatly be due to the difficulty of obtaining reliable estimates of the basic aerodynamic variables (i.e. body mass, wing span and wing area) for non-neognath birds. In the first part of the thesis, a methodology based on multivariate models is developed for obtaining estimates of body mass, wingspan and wing area as reliable as possible for stem avian fossils. Then, a fine aerodynamic characterization of plenty of Mesozoic extinct birds could be performed through the calculation of several key aerodynamic parameters as wing loading (i.e., body mass/wing area), aspect ratio (i.e., squared wing span/wing area) and “natural” wingbeat frequency. Additionally, up to date works focused on the study of the wing bone morphology of stem birds, only have used longitudinal measures. Such analyses do not take into account the information given by the width of epiphyses and diaphyses, as well as by the size of the regions of muscle origin and insertion, which are functionally very important. In the second part of this thesis, morphofunctional analyses over 25 measurements from the skeletal elements (including epiphyses, diaphysis and muscles regions) that compose the flight apparatus are performed for identifying specific adaptations and the shape transition of the flight apparatus. Joining the different standpoints of the first and the second part of the work, the results allow concluding several statements about macroevolutionary patterns in the avian lineage. Firstly, concerning evolution of body size: (i) the ancestral trend to miniaturization was continued in Aves as far as the clade Pygostylia is concerned, which could be related to selective pressures associated to flight requirements. Meanwhile, size varia-

tion within Pigostylia could be a diffusive phenomenon, associated with an adaptive radiation in the base of Pygostylia and with the acquisition of some traits that improve flight ability. From the Pygostylia node onwards, when basic flight skills were achieved, the selective pressures associated to flight requirements were reduced while other ones might have appeared. On the other hand, conclusions concerning morphological evolution of the wing bones are: (ii) robustness reduction of humerus, ulna and major metacarpal as body size increases is observed among modern birds. This negative allometry allowed flying birds to increase their body size reducing the energetic disadvantages derived from an increase in the inertial moment of the wing. This pattern was gradually acquired through the evolutionary history of the clade Aves. This seems to indicate an adaptation for withstanding the stresses generated during flight; (iii) the combined decrease of robustness of the humerus and ulna could have allowed the diffusive variation of the body size of flying birds at the base of Pygostylia, as such pattern reduces the energetic disadvantages that result from a size increase; (iv) compared to the plesiomorphic condition, *Archaeopteryx* and *Confuciusornis* tend to increase the length of the deltopectoral crest, the robustness of the radius, the length of the alular digit and its distance to the wrist. In contrast, there is a trend to reducing these traits from the node that groups Sapeornithidae and Ornithothoraces onwards, in order to improve the mechanical advantage for flapping and the aerodynamic benefit provided by the alular digit; (v) on the contrary, the joint variation of the bicipital crest and the length of the distal region of the hand, which are related to the advantage in the maneuverability and in the flight length, seems to show a morphological “explosion” from the most basal condition onwards, which is followed by a potential decrease in the evolutionary

rates of the crown (Neognathae). Finally, concerning the origin and diversity of bird's flight, (vi) the conclusion for the most basal bird, *Archaeopteryx*, is that it probably was not able of developing a continued flight, although it did obtain benefit of flapping the wings on earth. In addition, the ability of performing a flapping flight has been inferred for another long-tailed bird *Jeholornis*. Given these aerodynamic inferences for both fossils, it is reasonable to conceive that the plesiomorphic flight type of birds is by continuous flapping; (vii) all stem birds that belong to Pygostylia have been identified as flyers by continuous flapping (except *Sapeornis*). In addition, the two taxa analyzed that are more related to modern birds, *Gansus* and *Ichthyornis*, have been hypothesized as potential dynamic soarers. All this seems to indicate that the exploitation of the different types of flight that are known among modern birds took place in the crown group or, at least, from very derived non-neognath ornithuromorphs onwards.

Academic year: 2014-2015.

## Universidad de Murcia

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Waterbird community of Mar Menor lagoon (Murcia, SE Spain): responses to functional processes, structural gradients and management applications.

[*La comunidad de aves acuáticas del Mar Menor (Murcia, SE España): respuestas a procesos funcionales, gradientes estructurales y aplicación a la gestión.*]

### Abstract:

Mediterranean wetlands have historically been essential to human development because of the multiple, direct and indirect services that they offer. They are ecosystems

of high biodiversity, harboring many species of high ecological and conservation value. But despite these values and services, wetlands are among the most threatened ecosystems in the world. This is particularly the case of coastal wetlands, mainly due to their natural fragility and because they represent input sinks and transitional environments, and to the intensive use that man has generally made of many of their resources (both biotic and abiotic). This thesis deals with the study of Mediterranean coastal wetlands and their associated biodiversity. Specifically, the set of studies described below were developed in the complex Mar Menor coastal lagoon-associated wetlands. We analyzed the response or the bioindicator role of the waterbird community to different functional processes and to several natural or artificial structural gradients present in the lagoon, at different spatial and temporal scales. Among these processes we highlight on the one hand, the trophic change in the water due to the discharge, in recent decades, of agricultural and urban effluents, causing a change in primary production and driving the system towards a state of eutrophication. On the other hand we also study the effect of the intense urban development that has dramatically changed the structure of the shoreline and adjacent inland landscapes. The analyses were carried out using data sets recorded through different census methodologies, always depending on the scale of study and preset specific objectives. Usually, two distinct communities have been studied: winter and summer. Both the overall community response (studied through biological indices) and the indicator role of particular "focal" species or guilds, with respect to selected factors and gradients, have been studied, following this structure: (i) long term studies analyzing the relationship between trophic changes in the whole lagoon and certain representative species, as well as testing their bioindicator

role; (ii) studies about the structure and distribution of waterbird community in the main water mass and its dependence of internal gradients, processes and elements; (iii) comparative studies of the patterns of change in waterbird communities at two spatial scales (local and small wetlands vs the whole lagoon as a wetland complex); (iv) modeling the response, at different spatial scales, of certain indices and selected species to internal gradients and elements and to the adjacent terrestrial landscape structure. Our results highlight how the waterbird community is modified when the trophic conditions of the system change, usually resulting in a trivialization and loss of global conservation value of the community. This is observed at different spatial scales from small marginal wetlands to the whole lagoon. However, this change occurs sequentially through recognizable stages with well-defined abiotic conditions. In addition, the response of species to local processes (such as eutrophication) is mediated by their more general preferences for the structure of the immediate landscape, their tolerance to human presence and their foraging strategies and trophic requirements. The importance of natural terrestrial landscapes and the first strip of shallow water for the richness and diversity of the bird community and for waterbird use are stressed. These studies can provide further insights into the implications of certain human factors and landscape features on the lagoon systems and their various components, and contribute significantly to develop more efficient models of assessment and management (i.e. Two-scale Management System proposed in chapter 3). Thus it seems necessary to standardize and implement monitoring programs of specific biological groups (such as waterbirds), coupled with land and water management systems at different scales (local, landscape scale). This joint approach should result in the development of comprehensive management plans and wetland sys-

tems (either restored or created), capable to harmonize the objectives of biodiversity conservation (e.g. Birds and Habitats Directive) with those of water quality preservation (Framework Water Directive).

Academic year: 2014-2015.

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Territorial occupancy models in forest raptor populations.

[*Modelos de ocupación territorial en poblaciones de rapaces forestales.*]

Abstract:

One of the most studied stages of the life cycle of organisms is the reproductive period, since it provides direct information on the dynamics of populations. Breeding site selection is an important component of breeding behaviour and may have implications for an individual's reproductive effort and success. Studies on this topic are important for understanding the evolution of nest-site selection, the dynamics of populations and the conservation of species. Individuals establishing new territories probably use inadvertent social information, such as cues concerning the past reproductive success of conspecifics (public information), cues based on location of the information producers (location cues), which may be social cues such as the presence of conspecifics or heterospecifics, and even non-social cues or direct components such as nests (old nest hypothesis) or habitat characteristics. The selection of breeding sites is widely regarded as a hierarchical process, whereby individuals make choices at varying spatial scales, ranging from the regional, down to habitat type, and finally nest site. In this thesis we studied some topics of population ecology related to reproductive settlement of raptors populations (territorial persistence and

replacement, site fidelity, nest reuse and building patterns, nest longevity and their effects on reproductive output). The study is focused on a forest raptor community (the booted eagle *Aquila pennata*, the common buzzard *Buteo buteo* and the northern goshawk *Accipiter gentilis*) located in a protected Mediterranean forest ecosystem in Southeastern Spain “Sierras de Burete, Lavia y Cambrón” (Murcia). The general aim of this thesis was to analyze the breeding settlement process of forest raptors considering different factors that influence this process, namely those related to individual quality and location cues (presence of heterospecifics and presence of nests). The forest raptor community was monitored to obtain information about: (i) the territorial occupancy and breeding success of birds during the breeding period over several years (1997-2013), (ii) individual identification of some eagles, and (iii) habitat structure at territorial scale. These long term data were analysed using Markov transition models, generalised linear mixed models and survival analyses. This thesis contains four chapters: (i) territorial occupancy dynamics in a forest raptor community; (ii) factors determining territory fidelity in a migratory forest raptor, the booted eagle; (iii) patterns of nest reuse in forest raptors and their effects on reproductive output; and (iv) lifespan analyses of forest raptor nests: patterns of creation, persistence and reuse. The objectives of the first chapter were to construct a Markovian occupancy state model in order to examine the patterns of interspecific interactions among the three species. The results show that the territorial occupancy dynamic of the forest raptor community is stable across the study period, the main characteristic being the high territorial persistence of the three studied species. The most abundant species in the community was the booted eagle and interspecific territorial interactions among species were uncommon. The objec-

tives of the second chapter were to evaluate territory fidelity of the booted eagle in relation to the previous breeding success of the individuals, other individual-related factors (sex, years of consecutive experience in the same territory and mate change), and territory quality, measured as the average productivity of each territory during the study period. About 70% of the booted eagles studied showed territory fidelity after breeding success in the previous year, following the “win-stay:lose-switch” rule. In the third chapter we described and compared the territorial settlement pattern (territory formation, new establishments in old territories and reoccupancy events) of booted eagles and common buzzards, to examine and compare the pattern of nest building and nest reuse in old territories by both species and to test whether nest building is costly to pairs in terms of current reproductive output. The results showed that although the reproductive output was significantly higher when newly established booted eagles constructed new nests, most breeding pairs preferred to reuse these structures instead of building new ones. These findings provide an interesting view on how forest raptors use old nests as important resources, probably taking them as location cues for nesting site selection. Finally, the aims of the fourth chapter were to estimate nest persistence using two types of lifespan analysis, describing the pattern of nest reuse and alternation by different forest raptor species and assessing the effects of nest use on breeding success. This study shows that the average life expectancy of nest structures was sufficiently high (17.9 to 19.7 years) to permit the studied bird community to reuse and alternate nests in multiple breeding attempts. Breeding success did not increase with the frequency of nest use in any of the studied species. The main conclusion of this thesis is that the breeding site establishment of the studied forest raptors is a complex process

determined by different factors, such as individual quality and the presence of old nests. Moreover, forest nesting-platforms should be kept as a management measure in order to preserve an adequate supply of breeding sites for the raptors in the study area.

Academic year: 2014-2015.

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Morphological changes associated with digestive parasites of Pygoscelid penguins.

[*Alteraciones morfológicas asociadas a macroparásitos digestivos en los pingüinos pigoscélidos.*]

#### Abstract:

In order to take the appropriate decisions to conserve the Antarctica we need first to investigate the different diseases and parasites present in the wild, crucial factors to understand the Antarctica ecosystem health. This thesis aims to contribute to the knowledge of the pathogenesis associated with helminths within the digestive tract of three species of penguins: chinstrap penguin *Pygoscelis antarctica*, gentoo penguin *Pygoscelis papua* and Adélie penguin *Pygoscelis adeliae* collected in locations throughout the Antarctic Peninsula. In order to accurately interpret the changes produced by digestive parasites on their hosts it is necessary to have detailed knowledge of this organ in its normal state. However, the gastrointestinal tract in penguins has been poorly investigated. We therefore carried out a detailed morphological description of the digestive system of the chinstrap penguin. The macroscopic description of the different segments was done based on the observations of the necropsies performed either on the entire animal, or on intestinal parts previously thawed. To prevent tissue changes due to freeze-thaw process, the necropsy of a

clinically healthy adult specimen was performed in situ in the Antarctic base, during the campaign 2012-2013. Small tissue samples from each part of the digestive system were selected for histopathological studies. Most of the studies conducted on gastrointestinal worms of Antarctic penguins only address taxonomy. As a general objective of this research we aimed to contribute to the knowledge of the morphological alterations produced by the different species of parasites and their mechanisms of action. Gastrointestinal tracts from 80 recently death individuals were collected in different locations along the Antarctic Peninsula. All individuals were subjected to parasitological studies and lesions containing parasites, nodules or scares were taken for histology. Samples were prepared for analysis under the light microscopy. Some parasites of *Corynosoma* sp. and *Parorchites zederi* were removed for examination by Scanning Electron Microscope (SEM). The anatomy of the gastrointestinal system in chinstrap penguin coincides with that described for birds in general and specifically with reference to Adélie penguin, sharing the characteristics of carnivorous birds. Among the different species of helminth that infect Pygoscelids, the cestode *Parorchites zederi* is proving to have a greater capacity to generate gross and microscopic lesions. We found that gentoo penguins were the most sensitive ones to these parasites showing the most serious lesions. *Corynosoma* sp. follows in term of lesions severity although the low intensity, the poor penetration, and the lack of severe lesions indicate that the effects are not very harmful. The results of our investigation lead us to catalog the cestode *Tetrabothrius pauliani* and the nematode *Stegophorus macronectes* as practically non-pathogenic agents.

Academic year: 2014-2015.

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Parasite fauna in *Pygoscelis* penguins: morphology, infection, molecular characterization and applications.

[*Parasitofauna de pingüinos pigoscélidos: morfología, infección, caracterización molecular y aplicaciones.*]

#### Abstract:

In spite of its geographic isolation, the Antarctic ecosystem is not free from the presence of infectious agents. This thesis aims to contribute to the knowledge of gastrointestinal parasites from three species of Antarctic penguins: chinstrap penguin *Pygoscelis antarctica*, gentoo penguin *Pygoscelis papua* and Adélie penguin *Pygoscelis adeliae*. Thus, necropsies were carried out on individuals who had died due to natural causes. An amount of 79 penguins were collected from different islands of the South Shetland Archipelago and from islands located southwards, close to the Antarctic Peninsula. The vast majority of penguins analyzed were parasitized, showing an overall prevalence of 89%. However, the number of parasites species found was very low, only six (*Tetrabothrius pauliani*, *Parorchites zederi*, *Stegophorus macronectes*, *Pseudoterranova* sp., *Corynosoma* sp.1 and *Corynosoma* sp.2). Only *T. pauliani*, *P. zederi* and *S. macronectes* could be considered genuine parasites from *Pygoscelis* penguins, the remaining should be considered accidental parasites. This small variety in parasite species may be due to the high trophic specialization (stenophagia) of penguins, as they mainly feed on krill. The challenge to identify fractionated adult parasites, in bad condition or in various developmental stages such as eggs or larvae, led us to carry out alternative techniques for diagnosis and identification such as molecular methods.

We performed the molecular characterization of the two most prevalent parasite species: *S. macronectes* and *P. zederi*, obtaining the sequence of rDNA (18S, ITS1, 5.8S, ITS2 and 28S) from *S. macronectes* and the 18S rDNA sequence from *P. zederi*. Both sequences have been deposited in the GenBank database. Due to null molecular phylogenetic information of these species, new studies were performed. Hence, 18S rDNA of *S. macronectes* and *P. zederi* were used in order to classify them molecularly within their orders. Finally, for obtaining new diagnostic methods, molecular probes of the most prevalent parasite, *S. macronectes*, were developed from the ITS regions and tested on individuals of the same species, closely-related species, eggs and feces.

Academic year: 2014-2015.

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Ecology of fragmented natural systems under semiarid conditions.

[*Ecología de sistemas naturales fragmentados en condiciones semiáridas.*]

#### Abstract:

Biodiversity has evolved in the Mediterranean basin throughout geological history and along the different stages of human colonization. In recent decades, urban development processes have been promoted continuously throughout all this area. The interaction between these two types of development, natural and urban, is the origin of one of the main problems currently faced by Mediterranean biodiversity. In this regard, the southeast of the Iberian Peninsula has been no exception. Many profitable habitats for biodiversity have been occupied directly by human constructions totally incompatible with the persistence of the former. In other cases, urban development has resulted in fragmentation of natural areas

modifying local species composition and promoting variations in their regional distribution areas. On this basis, the current thesis studies: (i) the biological communities that inhabit these fragmented areas, showing the effects of the fragmentation types on the biodiversity of natural patches depending on the dominant ecosystem type; (ii) the performance of some biological interactions in these systems, and (iii) management measures for the natural development and recovery of these areas. Birds and woody vegetation have been chosen as bioindicators of the communities in these forest fragments. The studies that compose this thesis have been developed in forest patches of diverse nature that are distributed throughout the municipality of Murcia, located in the south east of the Iberian Peninsula (West Mediterranean). The dominant climate is semiarid Mediterranean. In this area, the reforestation policies implemented in the middle XXth century plagued the mountain with aggressive techniques like monospecific plantations of Aleppo pine *Pinus halepensis*. Semi-arid climatic conditions may limit the development of this species, so the result is often underdeveloped forested areas with little representation of other plant species. The current thesis is structured in 5 chapters that address the problem of fragmentation at different scales. The results of chapter 1 demonstrate that there is no correlation between the legal status of a patch and its conservation value. In this way, greater values of conservation indexes were obtained in patches without or with a lower protection category than in other patches with regional or higher protection. Chapter 2 works at the same scale, and its main results show effects of urban fragmentation in birds. Changes in community composition and diversity occur as a result of the edge effect created by urbanization, whose influence depends on the intrinsic characteristics of each patch. For that reason, at a landscape level it is

necessary to identify management measures that buffer or mitigate urban effects. Also, these guidelines should be considered in the creation of new urban areas that will increase fragmentation of Mediterranean landscapes. At a territorial scale, chapter 3 shows that the results are different depending on the geographical or administrative scale of the index involved. For example, patches with steppe physiognomy or scrublands have greater conservation values for European indexes due to the scarcity of such landscapes in the Community territory and the consequent value of species associated to them. The opposite happens with national conservation indexes where steppe landscapes are more common, and forest species have greater value. On the basis of all this, management measures applicable to Mediterranean forest patches have been proposed. It is recommended to reduce the number of pine trees in those patches with high density. Besides, protection of non forested areas should be implemented to complete the landscape diversity protected under local and regional regulations. Chapters 4 and 5 focus on the dispersal of seeds of shrubs by birds in forest patches. Chapter 4 analyses dispersal at the patch level and the role of *P. halepensis* trees as perches and later nurse plants of Mediterranean fleshy-fruited shrubs (*Rhamnus lycioides*, *Pistacia lentiscus*, *Asparagus albus*). Finally, chapter 5 studies frugivory during the periods when seed production is limited. Higher production and seed consumption were observed in the interior of the studied patch, and preferential dispersal to specific places within it was found. Two alternative dispersal models in fragmented Mediterranean forest patches were proposed. The first model proposes important within-patch consumption by adult and territorial individuals who have no need to move significantly (either outside the patch or within its limits). In this way, consumption and dispersal are concentrated

in the interior of the patch. Only less dominant individuals who would be displaced to the peripheral areas could contribute to seed transport at larger distances. The second model proposes a similar behavior in the patch, but in this case with higher influence of urban areas as attractors (i.e. sources of water and food resources). Directed dispersal of seeds of patch shrubs towards garden areas (that would act as sinks) seems in this case ecologically irrelevant, while the risk of propagules of exotic species being transported into the patch is greatly increased. Again, a reduction of pine density in the patch is proposed as a way to contribute to a more homogeneous dispersal within it.

Academic year: 2014-2015.

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On the road: the different impacts of motorized traffic on animal populations.

[*"On the road": los distintos impactos del tráfico motorizado sobre poblaciones animales.*]

### Abstract:

Road ecology is a recent branch of Conservation biology that studies the effects of road-networks and motorized traffic on biodiversity and ecosystems. The most investigated impacts are road-kills and barrier effects, but most studies are descriptive approximations. Contrarily, the primary purpose of Road ecology should be to determine the mechanisms producing road-related impacts, with the aim to plan the most suitable mitigation measures. The main objective of this thesis was to produce a relevant contribution to Road ecology, suggesting how to investigate the mechanisms potentially determining road-kills, barrier effects and the effectiveness of mitigation measures, but also

increasing the knowledge about little-known road-related impacts such as changes in behavior and biological invasions. The first chapter of this thesis aimed to determine the life history, temporal and spatial factors affecting road-kill probability for vertebrate species in a Mediterranean landscape (Doñana Natural Park, southwestern Spain). Abundant species were more road-killed than rare species, but also ectotherms had higher road-kill probability than endotherms (including birds). Species abundance was also the most relevant factor determining road-kill probability (both temporally and spatially) for different functional groups of species (for example resident, breeding, wintering and migrant birds in the temporal analysis and small passerines in the spatial analysis). The second chapter was the first study investigating the factors determining barrier effect along a heterogeneous road-network (i.e. paved and unpaved roads with different traffic intensity). Our study area was Doñana (both National and Natural Parks) and the mere presence of a linear infrastructure (in most cases unpaved roads virtually without traffic) was the main factor determining road avoidance in red deer *Cervus elaphus* and wild boar *Sus scrofa*. The possible mechanism may be the association between linear infrastructures and individuals' memory (and related possibilities) of vehicles transiting along them, and therefore this finding might be applied to other long-lived vertebrates with high cognitive capacities. Nevertheless, different species can be differently affected by barrier effect. In fact, habitat generalist species are more prone to use road proximities than habitat specialist species. We showed this difference into the third chapter of this thesis, in which the model species were the small mammals (the generalist deer mouse *Peromyscus maniculatus* and two specialist voles, *Myodes gapperi* and *Microtus pennsylvanicus*) of Banff National Park (Canadian Rocky

Mountains). The main consequence was that habitat generalists were the only species using the wildlife road-crossing structures, and for this reason the actual effectiveness of these mitigation measures could not be correctly estimated by traditional general surveys without species identification. The fourth chapter concerned a little-known road effect: the road-related changes in behavior. More specifically, we focused on the effects of vehicle disturbance on the breeding behavior of the European bee-eaters *Merops apiaster* nesting along the roadsides of Doñana National Park. We found that the bee-eaters perceived a circulating vehicle just as a natural predator, producing the same behavioral responses (*i.e.* massive stampedes and alarm calls), apparently without habituation. On the other hand, the nestling feeding rates were higher along highly travelled roads compared with less travelled roads, and increased during high-traffic days and rush-hours. We suggested different hypotheses to explain this behavioral change, and we also discussed the potential trade-off between negative and positive effects to breed along the roads. The fifth chapter focused on another little-known road impact: the road-related biological invasions. This chapter represents one of the first studies of vertebrate invasions mediated by roads, focusing on the synanthropic birds introduced in New Zealand (blackbirds *Turdus merula*, sparrows *Passer domesticus*, starlings *Sturnus vulgaris* and mynas *Acridotheres tristis*). We found that these species used the intercity roads to forage on the abundant and easily accessible food directly and indirectly related to human activity. The thesis finishes with a general discussion focusing on the emerging issues and the future challenges of Road ecology.

Academic year: 2014-2015.

## Universidad de Santiago de Compostela

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Kentish plover *Charadrius alexandrinus* in north-western Iberia before and after the Prestige oil spill.

[*El chorlito patinegro Charadrius alexandrinus en el noroeste Ibérico antes y después del accidente del Prestige.*]

### Abstract:

Until the 1990s there were major gaps in our knowledge about reproductive biology, conservation status, distribution and population trend of NW Iberia kentish plover. The main goal of this work is to study and evaluate these parameters in relation to the *Prestige* oil spill (November, 2012). In chapter 1, we performed an experimental study to evaluate the effect of the observer on nest fate. The results showed no negative effects of our presence in the vicinity of the nest. Daily survival rate during the incubation period was higher in disturbed nests, which could be a positive effect of the monitoring activity explained by the nest predators' avoidance of research activities. However, the high rate of nest losses in both visited and non-visited nests, the increased human presence and the difficulty of identifying causes of mortality, could mask the effect of the observer on nest success. In chapter 3 we assessed the Galician kentish plover population trend aiming to elucidate potential *Prestige* effects on abundance and distribution. Data showed a population decline up to 2004 followed by a moderate increase. The variation before and after the oil spill was obvious both with regard to population size and habitat use, with an increase in the number of birds and breeding locations after the spill and changes in distribution along the Galician Coast. Redistribution of plovers seems related to the level of exposure of the

beaches to the *Prestige* pollution. Birds from heavily impacted areas displaced seeking better conditions. At present, the impact is persisting since the distribution of birds did not recover to the pre-spill conditions. Increasing bird numbers from 2005 agree with results observed in the analysis of the genetic structure of the species in the Iberian Peninsula (chapter 2). With regard to the Spanish and Portuguese population trends, our results do not support the recent decline hypothesis because there is evidence of population expansion for the Atlantic coast population. At a regional level, population growth was attributed to the combination of three main factors: successful management strategies undertaken after the oil spill, changes in the spatial distribution of the breeding pairs and immigration of birds. Re-sighting data confirmed the dispersal of individuals between the Galician and Portuguese coasts. This dispersal seems responsible for the high gene flow observed at Iberian level (chapter 2). However, accounting for the extremely low hatching success and high site fidelity of the Galician population, dispersal would be asymmetric. We hypothesise that the Galician population represents a sink that would decline in the absence of immigration. Moreover, this sink hypothesis could explain the extinction of the Cantabrian population. In chapter 4 we evaluated plumage oiling considering the characteristics of the nesting beaches and season progress. The affected parts were primarily the abdomen and, to a lesser extent, the breast. Heavily oiled birds were observed on non-estuarine beaches, the most exposed ones to the arrival of the fuel. However, the distance from the beach to the initial oil spill did not explain the distribution of affected adults. Oiled birds were highly dispersed throughout the Galician coast probably due to the great extent of the spill and the strategy for managing the *Prestige* until its sinking. The advance of the breeding season resulted in a decrease in the

degree of plumage oiling, probably as a result of a partial moulting as well as the oiling clean-up due to the action of water and preening. Nevertheless, slight inter-monthly variation evidenced persisting oil on the substrate. In chapter 5 we analyzed the levels of Polycyclic Aromatic Hydrocarbons (PAHs) in Kentish plover eggs from NW Iberia trying to elucidate spatial or temporal patterns. There were no spatial differences in total PAH levels, probably due to the high dispersal of fuel. However, the PAH levels showed a significant influence of the year with a decline in the first years and a substantial increase in 2007. In this year an important change was observed, not only in total PAH concentration, but also in the pattern of PAH accumulation. We related this fact with the extensive forest fires occurred in Galicia during summer 2006, with high incidence in coastal areas. In chapter 6 we analyzed long-term data on NW Iberian Kentish plover breeding success, egg structure, female condition and breeding effort to ascertain the existence of sublethal effects of *Prestige* oil on reproductive performance. Combined pre- and post-spill data showed that egg structure and breeding performance changed over time. Eggshell thickness and first laid egg volume showed variations after the spill. We found females with worse condition and nest abandonment was registered. Data showed a change in the pattern of intracatch egg-size with a homogenization trend after the spill. Our results showed no pre- post-*Prestige* differences in hatching success and a high fledging success in the years following the spill event. The latter observation can be explained by the wardening efforts of nests and chicks made from 2003 to 2006 at the main breeding beaches. We found differences on egg fertility, with lower values just after the oil spill. Lastly, nest desertion occurred at low levels only in the post-*Prestige* periods. Thus, we hypothesize that desertion was related to poor female condition, without pre-

cluding the influence of other factors. We show that contamination has long-term complex consequences that may not be evident in terms of productivity in populations under high levels of early predation and may even lead to misleading interpretations.

Academic year: 2014-2015.

## Universidad de Sevilla

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Unmanned Aerial Systems in Conservation Biology.

*[Utilización de sistemas aéreos no tripulados en biología de la conservación.]*

### Abstract:

Unmanned Aerial Systems (UAS) have been used for decades in the military field, mainly in dangerous or tedious missions where it is preferable to send a vehicle equipped with sensors than to use human piloted conventional aircrafts for information gathering. Recent technological advances, exponential growth of the market, price breakdown and more user-friendly systems have led to the incorporation of the UAS to the civilian world. UAS have proven useful in ecological studies, such as animals monitoring and habitats characterization, and their potential for spatial ecology has been pointed out, but to date there are just a few studies addressing their specific use in conservation biology. This Ph Dissertation attempts to fill the gap of knowledge in practical functions of small UAS in conservation biology. It describes for the first time the use of these systems in an immediately applicable way for impact assessment of infrastructures and protection of endangered species. It also presents UAS as a tool for obtaining high-resolution spatiotemporal information, which helps to understand habitat use in

rapidly changing landscapes. Furthermore, it demonstrates that these systems can provide information as valid as the one obtained by conventional techniques on the spatial distribution of species in protected areas. This thesis contains four chapters that explore the stated questions examining four representative case studies. To accomplish the objectives, we conducted several field campaigns using low-cost small UAS along 2009-2015. The first chapter addressed the environmental impact assessment of infrastructures. Accidents on power lines are one of the most important causes of man-induced mortality for raptors and soaring birds. In this chapter we describe the use of low cost small UAS equipped with onboard cameras for power line surveillance. We characterized four power lines, geo-referenced every pylon in selected portions and assessed their hazard for birds. We compared the effectiveness of two variants of the UAS method for data acquisition and two ways of plane control. In the second chapter we studied the suitability of UAS for the management of endangered species. Rhinoceros poaching is an urgent conservation issue that requires immediate solutions. In this chapter, we describe the use of a small low cost UAS equipped with three different types of cameras to test their ability to support rhinoceros anti-poaching tasks in the KwaZulu-Natal province of South Africa. We performed several flights in order to test the technical capabilities of the system to detect rhinoceros, to reveal simulated poachers and to conduct fence surveillance. We evaluated the influence of flight altitude, time and habitat type in the effectiveness of the system. Considering the most common modus operandi of poachers, we also analyzed the aspects that affect remotely piloted aircraft's integration in anti-poaching operations. The third chapter addressed the topic of conservation in a human dominated landscape. Here we describe the combined use of GPS data loggers and environmental infor-

mation recorded by UAS to study habitat selection of a small bird species, the lesser kestrel *Falco naumanni*, living in a human dominated, highly dynamic landscape. After downloading the spatio-temporal information from the kestrels, we programmed the UAS to fly and document with pictures the paths of those same birds shortly after their flight, extracting environmental information at quasi-real time that we used to study the availability of different habitat types along the bird flight path. The last chapter dealt with conservation in protected areas. In this chapter we assess the usefulness of UAS overflights to: (i) get data to model the distribution of free-ranging cattle by comparing that information with the results obtained from GPS-GSM collared cattle, and (ii) predict species densities by comparing with actual density in Doñana Biological Reserve (south of Spain). The experiments performed in the frame of this thesis show that low cost small UAS equipped with embarked cameras that provide high-resolution images enable monitoring the environment at the researcher's desired frequency and revisiting sites to perform systematic studies, which is valuable for ecological research. The results also reveal that UAS use in conservation biology has some constraints, mainly related with the scope of the missions, the limiting costs of the systems, operating restrictions associated with weather, legal limitations and the need of specialized personnel for operating the systems, as well as some difficulties for data analysis related with image processing. Overall, given the novelty of the subject and its likely relevance in the near future, I consider that providing information on the capabilities and limitations of UAS, based on practical experiments in conservation biology, is not only of scientific interest but combines environmental and industry interests, which brings added value and usefulness of this thesis to society.

Academic year: 2014-2015.

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Maternal effects during early development of yellow-legged gull *Larus michahellis*.

[*Efectos maternos en el desarrollo de la gaviota patiamarilla* *Larus michahellis*.]

### Abstract:

Environmental variations experienced by the offspring during development is mainly influenced by parental (more often, maternal) phenotype (i.e. maternal effects). It has been recently suggested that maternal effects are not only a simple conduit by which environmental variation passes passively through the maternal phenotype into the offspring ("transmissive maternal effects"). Indeed, if mothers have reliable information about the future environment, then they can also actively adjust the phenotype of their offspring for the environment they are likely to encounter ("anticipatory maternal effects"). Thus, under heterogeneous and predictable environmental conditions at short term, mothers can induce an adjustment in the phenotype of their offspring to match local environment conditions. The aim of this thesis was to study the role of maternal effects during early development of yellow-legged gull *Larus michahellis* chicks, under free-living conditions. Specifically, we examine whether: (i) the presence of predators during egg formation influences the morphology and behaviour of the offspring; (ii) the differences in laying date, egg size and embryonic development rate determine sibling competition and, ultimately, chick survival, within the brood; (iii) maternal-derived egg antioxidant levels can adjust offspring phenotype for the post-hatching environment conditions ("environmental matching hypothesis") or, by contrast, if maternal-

derived antioxidants effects are always positive (“silver spoon hypothesis”); and (iv) two carotenoids with different molecular structure (lutein and  $\beta$ -carotene) play an antioxidant and immunostimulatory role during early life. All studies were carried out in a large colony of yellow-legged gulls on Sálvora Island, Parque Nacional das Ilas Atlánticas, Galicia, Spain, during the reproductive seasons of 2010-2013. The main results were: (i) offspring morphology and behaviour were affected by the presence of predators (i.e. models of American mink *Neovison vison*) during egg formation, possibly through maternal-derived components transferred to the eggs; (ii) morphology and behaviour differences among siblings were accentuated in broods whose mothers were exposed to predators during egg formation; (iii) embryos from third-laid eggs developed faster than embryos from second-laid eggs, possibly to reduce hatching asynchrony; (iv) differences in body mass and tarsus length between siblings were determined at the time of egg formation; (v) chick body mass at 30 days of age (i.e. close to the end of the growth period) was determined by the vitamin E availability during egg formation, independently of vitamin E availability during post-hatching period (“silver spoon hypothesis”) and thus, the results did not support the “environmental matching hypothesis”; (vi) tarsus size at 30 days of age was affected by vitamin E supplementation during egg formation or post-hatching period, but it was not affected when vitamin E was supplemented in both periods; (vii) only after facing an oxidative challenge did lutein, but not  $\beta$ -carotene, supplementation enhance antioxidant capacity and reduce protein oxidative damage during early life; and (viii) the immunostimulatory effect of carotenoids depended on chick oxidative status. Overall, these results highlight the role of maternal effects on the offspring phenotype in response to different environmental conditions.

Academic year: 2013-2014.

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Seabird conservation at the rear edge: the case study of European shag (*Phalacrocorax aristotelis* Linnaeus, 1761) at the north-west Iberian Peninsula.

[*La conservación de poblaciones periféricas en aves marinas: el caso del cormorán moñudo (Phalacrocorax aristotelis Linnaeus, 1761) en el noroeste de la Península Ibérica.*]

#### Abstract:

Because of their isolation and small size, rear edge populations (i.e. populations placed in the southernmost limit of species range) are especially prone to extinction. Here, we investigated some of the main threats affecting an endangered population of a coastal seabird, the European shag *Phalacrocorax aristotelis*, in the southern limit of the species distribution, the north-west Iberian Peninsula. Attending to environmental causes, we studied the influence of climate (North Atlantic Oscillation, NAO, and Sea Surface Temperature, SST) on two sex-related population parameters: fledgling sex ratio and sex-specific dispersal. Later on, we searched for possible long-term effects of the *Prestige* oil spill on reproduction, and we investigated the direct and indirect effects of an alien predator, the American mink *Neovison vison*, on the population dynamics and the reproductive success. Finally, we evaluated the presence of inbreeding depression after a severe decline in population size by nearly 70% as a consequence of the *Prestige* oil spill. The main results and conclusions of this thesis are as follows: (i) fledgling sex ratio was female skewed in NAO-positive years and male skewed in NAO-negative years. Accordingly, females dispersed a longer distance in NAO-positive years when females were overproduced, and on the contrary, males dispersed more in NAO-nega-

tive years. Our findings provide rare evidence on vertebrates with genetic sex determination that climate conditions may govern population dynamics by affecting sex-specific density and dispersal; (ii) our study revealed long-term reproductive impairment during at least the first ten years since the *Prestige* oil spill. Annual reproductive success did not differ before the impact, but after the impact it was reduced by 45% in oiled colonies compared to unoiled ones; this effect was yet active ten years after the spillage. This is a rare documentation of long-term effects after a major oil spill, highlighting the need for long-term monitoring in order to assess the real impact of this type of disturbance on marine organisms; (iii) we found that, after the arrival of mink, shags nested on sites where the risk of predation by mink was low. This shift entailed a cost in terms of reduced drainage in sites with lower levels of predation risk. Our simulation model suggested the preference for safer nest-sites is likely to reduce the reproductive success of the population, especially at medium-high densities. Our study highlights that there is a risk of underesti-

imating the impacts of invasive predators by overlooking the indirect effects of predator presence on population dynamics of potential preys; (iv) we found a strong effect of multilocus heterozygosity on female reproductive performance, and a significant, although weaker, effect on breeder survival. However, matrix population model suggests that this relatively small effect of genetic diversity on breeder survival had a profound effect on fitness. This highlights the importance of integrate life-history consequences in heterozygosity-fitness correlations (HFC) studies. Importantly, heterozygosity was correlated across loci, suggesting that genome-wide effects, rather than single loci, are responsible for the observed HFCs. Overall, the HFCs are a worrying symptom of genetic erosion in this declining population. We argue that HFCs may still be useful as genetic signs of conservation concern in endangered populations. Many long-lived species are prone to extinction, and future studies should evaluate the magnitude of fitness impact of genetic deterioration on key population parameters, such as survival of breeders.

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