

# Long-term change of species richness in a breeding bird community of a small Mediterranean archipelago

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## Abstract

*Long-term changes of species richness in a breeding bird community of a small Mediterranean archipelago.*— We analyzed the pattern of species richness changes in a bird-breeding bird community on a small western Mediterranean archipelago (Columbretes Islands) over a 40-year period (1964–2003). The aim of this study was to qualitatively account for the relative roles of local and regional factors in shaping the community. As expected, we found that regional factors (at the metapopulation spatial scale) increased diversity whereas local factors (i.e. ecological) probably prevented further increases in diversity. We found that the archipelago gained four new species (two seabirds and two falconids) during the study period, whereas no extinctions were recorded. The community seems partially or completely closed to some groups of species (e.g. small-sized birds such as passerines and storm-petrels), probably owing to predatory exclusion by Eleonora falcons (*Falco eleonora*). As newly arrived species have breeding calendars that do not fully overlap with those of resident species, competition for space in a rather saturated area is prevented. Preservation of rare species which increase gamma (regional) diversity rather than alpha diversity with common species should be the main local conservation goal.

Key words: Colonization, Extinction, Diversity, Columbretes Archipelago, Conservation, Metapopulation.

## Resumen

*Cambios a largo plazo en la riqueza de especies en una comunidad de aves nidificantes en un pequeño archipiélago mediterráneo.*— Este trabajo analiza los patrones de cambio en la riqueza de especies en una comunidad de aves nidificantes de un pequeño archipiélago mediterráneo (las islas Columbretes, Castellón) durante un periodo de 40 años (1964–2003). El estudio pretende valorar cualitativamente la influencia relativa de los factores locales y regionales. Como se esperaba, se encontró que los factores regionales (a la escala espacial de la metapoblación) aumentaron la diversidad, mientras que los factores ecológicos locales evitaron mayores incrementos. El archipiélago ganó cuatro especies durante el periodo de estudio (dos aves marinas y dos falcónidos), mientras que no se produjo ninguna extinción. La comunidad parece parcial o totalmente cerrada a ciertos grupos de especies, tales como las aves de pequeña talla (p.ej. Paseriformes y paíños) probablemente debido a la depredación excluyente por parte de los halcones de Eleonor (*Falco eleonora*). Dado que las especies que son colonizadoras recientes tienen calendarios de cría que no se solapan completamente con los de las especies residentes, se evita la competencia por el espacio de cría en un área bastante saturada. La principal meta conservacionista debe ser la protección de las especies raras, que incrementan la diversidad gamma (regional), más que la diversidad alpha de las especies comunes.

Palabras clave: Colonización, Extinción, Diversidad, Columbretes, Conservación, Metapoblación.

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## Introduction

Much debate has taken place among ecologists during the last decades about the nature of communities and the regulation of their structure. Typically, a community is now defined as an association of populations of species in a certain area, with no fixed boundaries, and whose structure is shaped by the environment, by the interactions of the populations within the community, and also by historical, regional and global processes (Ricklefs & Latham, 1993). One of the main structural properties of communities is the number and types of species in the community (see Magurran, 1988). This property is time-dependent and long-term records of species richness are thus necessary to properly characterize the diversity of a given system and to assess the role of both local and external factors in the pattern of change. The latter also involve a spatial dimension and hence demographic spatial processes of dispersal, typically emigration and immigration, which are not necessarily correlated with local factors. Examples of this are colonization of empty patches or extinction of occupied patches, in the framework of the metapopulation theory (e.g. Hanski, 1999).

We have extensively monitored the population dynamics of most avian species breeding on a small western Mediterranean archipelago but we have not studied community properties as a whole to date. The aim of this paper is to describe and discuss long-term changes in species richness in a small Mediterranean island community, to derive information of conservation interest. This goal is especially relevant from a regional perspective as many of the thousands of islands in the Mediterranean are very small and home to bird faunas which are among the most endangered in the world. (Rodríguez, 1982; Blondel & Aronson, 1999).

## Material and methods

The Columbretes Islands are a small volcanic archipelago located close to the continental slope in the north-western Mediterranean, some 50 km from the continental coast (see fig. 1). The total area of the Columbretes archipelago is 19 ha, divided in four major groups of islands. The largest island (Grossa Island, with 13 ha. or 68% of the emerged land) holds most breeding birds. This island is horseshoe-shaped, has a maximum length of about 1,200 m, a maximum width of 220 m, a minimum width of 17 m, and a maximum height of 67 m, with steep cliffs all around. As the archipelago is very small it is possible to perform reliable surveys on breeding species. Vegetation mainly consists of a number of shrubs adapted to the arid conditions and high salinity, and annual plant species. Vegetation on the main island (Grossa Island) was deeply altered by humans during the construction of the light house in the mid-19<sup>th</sup> century when it was burnt down and pigs were introduced to deal with the abundant snakes (vipers?) on the island (Serrano, 1987). The present

breeding bird community includes only eight species (see table 1). Interestingly, there are no breeding passerines on the island although they are very abundant during migration (Giménez, 1987). Local seabird populations have been monitored annually since the early 80's and annual records of breeding success have been available since 1989. Data from the 60's and 70's comes from sporadic visits to the islands by expert ornithologists. The closest seabird colonies are located 80–100 km away, at the Ebro Delta (Tarragona) and the island of Ibiza (Balearic Islands).

Information on the number and type of breeding species, as well as competitive interactions and environmental changes comes to a large extent from a literature review, including unpublished reports of the regional government (i.e. Generalitat Valenciana), over a 40-year period. Much of the recent literature on population dynamics however has been generated by our group (Martínez–Abraín et al., 2001, 2002a, 2002b, 2003a, 2003b). Following the automation of the light house in 1975 over a decade elapsed without human habitation until a permanent crew of wardens (three per 15-day shift) was established on the islands.

## Results

As seen in table 1 the "basal" community was made up of two oceanic seabirds (Cory's Shearwater *Calonectris diomedea diomedea* and the European Storm-Petrel *Hydrobates pelagicus*), a raptor commonly found in the Mediterranean islands (Eleonora's Falcon *Falco eleonora*) and the Yellow-legged Gull *Larus cachinnans*, a gull species known to breed on these islands at least since the 19<sup>th</sup> century (Salvator, 1895; Bernis & Castroviejo, 1968). The first species to join this community was Audouin's Gull *Larus audouinii*, in 1974 (Pechuán, 1974, 1975; Gómez, 1987). A second seabird species (European Shag, *Phalacrocorax aristotelis*) became established on the islands in 1991, although an isolated breeding attempt occurred in 1985 (see Martínez–Abraín et al., 2001). More recently, two new raptor species have colonized the archipelago. A pair of peregrine falcons, *Falco peregrinus*, bred successfully in 2002 and again in 2003 after several failed breeding attempts in the past, and a pair of European Kestrels *Falco tinnunculus* bred successfully during their first attempt in 2003. Hence, during a 40-year period the archipelago has experienced four colonization events, two of them by seabirds and two of them by birds of prey. Seabird species can be considered as established breeders after several decades of continuous reproduction, whereas falconids cannot, owing to their short breeding record to date. We have not included the presence in the colony of several breeding Cory's Shearwaters from the Atlantic subspecies *Calonectris diomedea borealis* (see Martínez–Abraín et al., 2002a) as a colonization event because their taxonomic identity (i.e. species or subspecies) is under discussion.

## Discussion

### Regional factors increase alpha (local) diversity

Increases in diversity at Columbretes are better explained by factors external to the archipelago than by changes in local conditions. For example, colonization by Audouin's gulls at the beginning of the 70's took place before the islands were legally protected, when they were suffering a number of human-related disturbances. In addition, fishermen and lighthouse keepers had free access to the islands which were also used as targets for military exercises at the time (Serrano, 1987). Audouin's gull dynamics is known to be very dependent on dispersal processes within metapopulations and the growth of this colony cannot be explained without attending to immigration from the outside (Oro & Pradel, 2000; Oro & Ruxton, 2001; Oro et al., 2004). The growth of the colony has recently been influenced by external factors and especially by the rescue effect of immigrant individuals from the neighbour colony of the Ebro Delta (Oro et al., 2004).

Colonization by shags coincided with a steep decline of a large colony located in Majorca, owing to sand mining close to it that probably affected local feeding grounds (Martínez-Abraín et al., 2001). Alternatively, since shag colonization occurred after island protection at the end of the eighties, it might also be related to a reduction in human disturbance.

Both Audouin's gulls and shags are good examples of the importance of emigration and immigration processes in the colonization rates at the metapopulation level (Oro, 2003). At the same time, the recent decline in Audouin's gull numbers is also a consequence of dispersal to higher quality sites, and extinction, in the absence of high immigration rates from the outside, is only buffered by the high survival of old adult philopatric breeders (Cam et al., in press).

Colonization by falconids may respond to increasing numbers of these two species on the continent and major nearby islands during the last decades (g.o.b, 1997; Martí & Del Moral, 2003), and might be supported by eventually abundant and extended migratory flows of passerines during the spring. The magnitude of these flows is also independent of local features.

### Ecological factors prevent further increases in alpha diversity

Local factors (i.e. competitive or predatory exclusion) are known to reduce diversity, either by removing species or preventing the invasion of new species. In Columbretes, predatory exclusion probably plays a role in preventing the settlement of small-sized birds (e.g. small Passeriformes adapted to arid conditions such as warblers which are present during migration periods) owing to the large density of breeding Eleonora's Falcons, that are known to prey upon all sorts of small-sized birds (Walter, 1979). In fact, during the study period falcon numbers in-

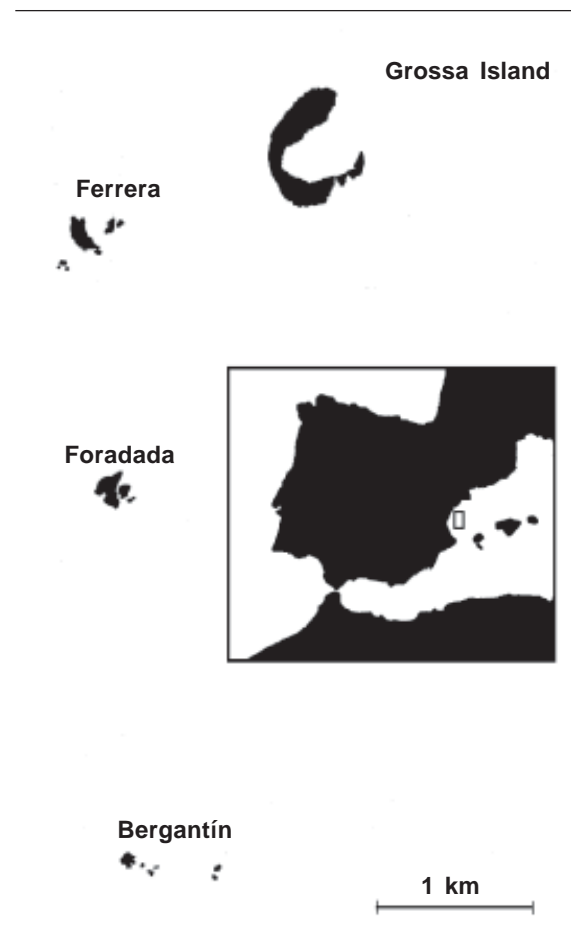


Fig. 1. Map showing the location of the Columbretes Islands within the western Mediterranean and the major groups of islands within the archipelago.

*Fig. 1. Mapa de localización de las islas Columbretes en el Mediterráneo occidental y los principales grupos de islas de dicho archipiélago.*

creased from ca. 20 pairs in 1964–1985 (Bernis & Castroviejo, 1968; Dolz & Díes, 1987) to the 40–45 present pairs (Generalitat Valenciana, unpub. data). Falcons are present on the islands between April and November, excepting June when most birds fly to the mainland to feed on insects (own unpublished observations) and hence they are present on the islands during the breeding season of passerines and storm-petrels. As early as the 19<sup>th</sup> century early visitors to the archipelago suggested that Eleonora's Falcons might have prevented colonization by small birds (see Salvator, 1895). Alternatively it could be argued that small species of long-distance migratory birds exhibit a great deal of biogeographic regionalism and are generally bad colonizers

Table 1. Historical changes in the number of all breeding species recorded on the Columbretes Islands (NW Mediterranean) between 1964–2003. A positive sign indicates that a species was present as a breeder and a negative sign indicates the opposite. The archipelago became legally protected in 1988.

Tabla 1. Cambios históricos en el número de todas las especies nidificantes observadas en las islas Columbretes (Mediterráneo nordoccidental), entre 1964 y 2003. Los signos positivos indican que la especie estaba presente como nidificante, y los negativos, la situación opuesta. El archipiélago empezó a estar bajo protección legal en 1988.

Species	1964–1973	1974–1983	1984–1993	1994–2003
<i>Calonectris diomedea</i>	+	+	+	+
<i>Hydrobates pelagicus</i>	+	+	+	+
<i>Larus cachinnans</i>	+	+	+	+
<i>Falco eleonora</i>	+	+	+	+
<i>Larus audouinii</i>	–	+	+	+
<i>Phalacrocorax aristotelis</i>	–	–	+	+
<i>Falco peregrinus</i>	–	–	–	+
<i>Falco tinnunculus</i>	–	–	–	+

(Boehning et al., 1998). It is also possible that the low vegetation cover on some of the smaller islands, together with the small total surface area and the considerable distance to the continental coast, might make Columbretes an unsuitable target for non-migrant passerines. In addition, the small populations of Passeriformes that the island could hold would be very susceptible to local extinction owing to stochastic phenomena (Legendre et al., 1999). Eleonora's Falcon might also impose some pressure on the small European Storm-Petrel, which is scarce at Columbretes despite the seemingly favourable conditions of the islands. Although storm-petrels were not found in the diet of Columbretes falcons by Dolz & Díes (1987), Columbretes wardens have found remains of storm-petrels predated by falcons in several occasions (G. Urios, pers. comm.). In addition, they have appeared as a component in the Eleonora's Falcon diet at other colonies such as the Cabrera archipelago (Balearic Islands) where foraging activity at dusk on nocturnal insects, night-dwelling arthropods such as scorpions and even on bats, has been reported (Araujo et al., 1977; Suárez, 2000). Additional support to our hypothesis comes from Bernis & Castroviejo (1968) who reported on a storm-petrel being attacked by Eleonora's falcon when it was released after ringing at Columbretes. Interestingly, the largest colonies of storm-petrel along the eastern Iberian coast (e.g. Benidorm Island) occur on islands where Eleonora's Falcons are absent, despite the presence of suitable breeding habitat.

Evidence of competitive exclusion also comes from the breeding calendar of newly arrived species. Interestingly, new species colonizing the

Columbretes Islands do not overlap in time with resident species, segregating over the breeding season. Shags coincide with Eleonora's falcons in their preference for cliffs and crevices located out of the direct influence of solar radiation (Urios, 2003; own observations) and indeed some shag nests are placed on ledges previously used by falcons. The optimal falcon nesting site is virtually occupied at the moment (op. cit.), but there is no conflict with shags regarding nesting sites because the latter start breeding in December–January, whereas falcons do so in July. Syntopic breeding of Audouin's and Yellow-legged Gulls has been possible to a large extent because the breeding calendar of the former species is delayed about one month in relation to that of the latter. Audouin's Gulls therefore occupy the space not taken by the Yellow-legged gull latter. Similarly, newly arrived Falco species (table 1) complete their reproduction well in advance of Eleonora's Falcons starting to build their nests, thus avoiding conflict even though nesting-site preferences seem to coincide.

#### Island diversity and human activities

There is no evidence in the presently available literature on bird extinctions during the profound environmental transformations associated with the construction of the light house and later human occupancy. Similarly, no extinction took place during the 40-year period considered by this study. This is at least partially explained by the life history traits of most birds breeding at the study site: high adult survival, large generation times and relatively low rates of population growth (negative or posi-

tive). However, human disturbance is an important component to understand patterns of species diversity, especially in the Mediterranean basin (Blondel & Aronson, 1999). In this region, population dynamics and distribution patterns of many species have been shaped more by human activities than by evolutionary determinants (op. cit.). Once direct human impacts were removed at Columbretes by conservation laws and especially by effectively protecting the site, only colonizations have occurred. However, human activities are changing rapidly and could drive several species to local extinction. Indeed since 1991, Audouin's Gulls have locally faced a steep decline owing to reduced food availability during the chick-rearing period when a trawling fishing moratorium was established, depriving gulls from fishing discards, their main food source in the area since colonization of the archipelago (Oro et al., 2004). The declining colony is now suffering high levels of disturbance by Yellow-legged Gulls, probably as a consequence of changed predator/prey ratios (Oro et al., in press). Additionally, Cory's Shearwaters seem to be following a decreasing trend at Columbretes because of adult mortality in long-line fishing gear (Belda & Sánchez, 2001; Cooper et al., 2003).

#### Island biodiversity and conservation goals

Increases in diversity are not good per se. Provided that our hypothesis is true, a decrease in breeding numbers of Eleonora's Falcons could lead to the colonization of the islands by small passerines and probably to larger numbers of breeding storm-petrels, increasing local diversity. However, the preservation and growth of the colony of this endemic Mediterranean raptor is a more desirable conservation goal than the gain of common species which are abundant elsewhere. Similarly, colonization by a common raptor species, such as the Common Kestrel, could result in increased predation of endemic lizards and beetles reducing the diversity of other animal taxa. Local management efforts should hence focus on promoting the persistence of rare species such as Audouin's Gulls and Eleonora's Falcons which increase gamma (regional) diversity.

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