

The Behavioural Ecology, Local Population Dynamics and Conservation of the Bearded Reedling *Panurus Biarmicus* in “El Hondo Natural Park” (SE Spain)

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Abstract: The behavioural ecology of the Bearded Reedling *Panurus biarmicus* in wild using data available from mist-netting has received little attention. One of such aspects is to evaluate if flock composition and structure vary among reed successional stages and facilitates dispersal among near wetlands in small and semi-isolated populations by analysing mist-netting capture events. This study shows that mist-netting events comprised catches of solitary birds or small groups in samples from small to moderate size. Overall mean frequency of each flock result in a population of low aggregation at low densities and being lower than reported from bigger central Spanish populations. A majority of birds of these flocks are "transients", characterized by have shorter wing lengths and smaller body masses compared to "residents", which attain higher body masses and longer wing lengths. Residents have the ability to settle in unmanaged sparse habitats in the periphery of the wetlands and the possibility to undertake longer flights outside wetlands is greater due to a higher condition and performance. Since a high overnight mass loss of birds has been verified in this study, I hypothesize that Bearded Reedlings move in short-times elapsed from sunset (before arriving at the roosts) to sunrise, so earlier surveys carried out in wetlands might give inadequate results to monitoring Bearded Reedling's populations, demanding alternative methods to survey them properly. Due to the occurrence of such residents, the importance of saltmarshes with reed sparse-patches in the periphery of wetlands results in a key factor for the dispersal of this species.

Keywords: Bearded Reedling, Dispersal, Reed Succession, SE Spain, Social Structure

1. Introduction

It is broadly assumed that social status may be determined by sex, age [1] body size and body condition [2]. In social birds matching a group-system in some part of the year it has been proved that some species have a double diet: seed-based [3-5] and invertebrate-based [6]. Some birds are termed "resident", staying at the site for long-periods and being recaptured on some occasions. By contrast, the majority of social birds are "transients", staying for short periods and often only being caught once. Transients are more mobile than residents which make only short-range [3, 6]. Residents are consistently heavier than transients in absence of predators [7] and preys reduce its abundance in the proximity of predators [8].

Is generally probed that social behaviour strongly depends on the environment where birds can develop its vital cycles

[9]. Since body mass is affected by age and moult and decreases to improve manoeuvrability (see review in [10]) and further flight is traditionally related to longer wings [11, 12] is generally assumed that birds that have good manoeuvrability are agile in clumped habitats, such as reeds, and abilities dispersal [13]. Also is found that birds in better condition and size (expressed as body mass and wing-length) stay for short periods at given site than those that habits sparse habitats [11, 14], probably due to the variability in the food availability [15] or due to changes in the microclimatic conditions of the habitat [16].

The Bearded Reedling *Panurus biarmicus* is a socially monogamous reed-dwelling passerine with a strong sexual dimorphism and a fragmented distribution across reed patches of Western Palearctic [17, 18]. In the breeding season, they often breed in groups [19]. These groups usually consist of several breeding pairs and group size is usually

determined by available nest sites. In these groups, females pursue extra-pair fertilizations on which some morphological traits, as body size and condition are enhanced [19]. Pairs are formed in juvenile flocks and usually remain stable for life [20]. Studies in wild based in observations show that its behaviour is nomadic-named eruptive- after breeding which reflects large high flying multi-age flocks of different size related to its complete moult [4, 21-22]. Habitat preferences differ on breeding and on wintering [23, 24]. These are based in tail length which influences how Bearded Reedlings move and make use of their habitat [25]. The social behaviour indicates that the level of influence that males exert on social cohesion is not related to ornamental traits so Bearded Reedlings are likely to have a consistent social position within their flocks. Pioneer works on the behavioural ecology of the Bearded Reedling are based primarily in observations [21, 24, 26-27]. However, few studies in wild using data inferred from mist-netting have been performed [28-30]. Its social system inferred from mist-net captures indicates a basic unity of two [28] or more individuals [29] however observations give higher sizes [21]. This is due mainly to biases in the captures since part of the Bearded Reedling's flock stay near from mist nets once that some individuals have been already trapped.

Some internationally protected habitats such as reed-marsh habitats immerse in fragmented, semi-isolated wetlands, support important populations of endangered birds [31-33, 24]. They are adequate to the management of these habitats that play a key role in the success and survival of these birds (see [34] for a review). The behaviour of these endangered or uncommon marshland small birds might aid to define strategies to the conservation of their habitats [24] or mechanisms for the conservation of this species [35-37].

In this paper, I analyse some capture data from this social bird which conform flocks of different size and composition in a so-called eruptive behaviour [21] as part of its vital cycle. I use a dataset of measures and events of mist-nets in Bearded Reedlings captured and after ringed at “El Hondo” Natural Park (SE Spain). On doing so I try to analyse the flock structure and dynamics is related with successional stages of the reed where the effect of management actions remains nowadays unclear. In view of this, we aim to hypothesize that habitat structure influences flock variability and not intra-specific factors such as age and sex composition, often assumed in social structure studies [7]. Since wing length is related with wing shape [38] is understable that transient birds have greater wing shapes than residents [39] so larger measures of body size, highly related to wing length [40] and weight, highly related to condition [41, 42]. We should be expect that birds in poorer condition and size, behave as transients, behave in worse ability for movement and dispersal in managed dense reed patches in the core of wetlands, than birds often retrapped in better condition and size, termed as residents, which stay at the earlier stages of succession at totally or partly unmanaged

habitats acting as corridors that abilities its dispersal and survival.

2. Material and Methods

2.1. Study Area

The subspecific status and distribution in Eurasia of the Bearded Reedling remained controversial on early [43, 44] but today is currently assumed as polytypic species in the Western Palearctic [17] and corresponding to the *Paradoxornithidae* Family. Since late 1960's [45] the species expanded in some European countries (England and the Netherlands: [44, 46], France: [47]; Sweden: [48]; Switzerland: [49]. Apparently, its expansion in Europa is followed to the expansion of the Groundsel *Senecio spp.*, a pioneer saltmarsh seed plant strongly linked to the first successional steps of reed *Phragmites australis* invasion [50]. The species is of not conservation concern in Europe [51] but its status in Spain passed from Near Threatened [52] to Critically Endangered [53] so population studies linked to conservation management are of highly priority in Spain.

Breeding population in Spain is spread in three nucleus of centre (Castilla-La Mancha), North (Navarra and Ebro Valley) and East (Comunidad Valenciana and Cataluña) and it has been estimated in almost 1000 pairs (1998-2002: [54]) and with similar estimates in winter (2007-2010: [55]). The south Comunidad Valenciana lies in the south westernmost limits of its European distribution range, at the southern of Alicante wetlands complex [17, 18]. The southern Alicante population comprises two main internationally protected wetlands [56, 57]: El Hondo Natural Park, Elche-Crevillente, 38°10'N 00°44'W monitored from 1980's [58-60] and Santa Pola's salt pans Natural Park, 38°12'N 00°37'W, surveyed recently [61] and distant among them 10.9 km as remnants of a great saltmarsh swamp in the past centuries [59]. They kept the most important populations of the Spanish Levant in 2005-2006 (70 and 25 pairs respectively [62]) and with absence of recaptures of ringing birds among them [63] although is not discarded movements among near wetlands [58, 64, 65] so both populations appear to have a semi-isolated status.

Inside El Hondo Natural Park, a trapping site was chosen from 1991 so-called Bearded Reedling's edge line [59]. Reedbed edge lines are probed to be the sites of wetlands concentrating the most densities of marshland passerine birds [66, 101] and these sites are usually preferred as roosting sites because they receive much more sun radiation [67]. This line conform three units of reed succession from the outermost (cleared-reed) towards the innermost of one of the two reservoirs (dense reed) (Table 1). Sites are distant 100 meters among them. Some areas of reed were submitted to management actions from 1992 onwards (Table 1) and measures of density of reed stems [68] and height of reed (cm) after each management action were taken for research purposes [22, 69].

Table 1. Vegetation characteristics of the reedbed plots and mist-netting results. Means, standard errors and sample sizes in brackets.

	CLEARED	SALTMARSH	DENSE REED
	CR	SR	DR
Description	Dense bush of Shrubby Seablite <i>Suaeda vera</i> and <i>Sarcocornia fruticosa</i> with scarce reed stems <i>Phragmites australis</i>	Dense bush of Glasswort <i>Halocnemum strobilaceum</i> with abundant reed stems <i>Phragmites australis</i>	Dense reed stems <i>Phragmites australis</i> in association with Bindweed <i>Calistegia soldanella</i> .
Reed height (cm)	101.1 ± 6.2 (14)	133.7 ± 5.7 (7)	221.3 ± 14.7 (16)
Density (stems/m ²)	31.5 ± 4.6. (4)	47.9 ± 2.9 (7)	32.6 ± 10.7 (7)
Year of samples	1992-1993	1998-2002	1992-2007
Mist-nets home range	5.18 Ha	1.72 Ha	0.864 Ha
Bush cover	60%	80%	0%
Water regime	Shallow water	Shallow/Deep water	Deep water
Main management actions	control (never managed)	medium managed	heavily managed.
Study years	1992-1993	1998-2002	1992-2007
Mist-Netting effort (m ² x hour)	4793	25367	2042
Mean flock size	2,2 ± 0,6 (11)	1,8 ± 0,5 (84)	1,6 ± 2,0 (49)
Bearded Reedling's abundance	0,0050	0,0057	0,0039
Bearded Reedling's body mass (gr)	13,2 ± 0,2 (24)	12,7 ± 0,1 (133)	13,2 ± 0,1 (76)
Bearded Reedling's wing-length (mm)	58,4 ± 0,4 (24)	57,3 ± 0,2 (135)	59,9 ± 0,2 (77)

2.2. Local Population Dynamics

Populations of Southern Alicante are currently of about 40 pairs (2005-2006,2013: [62]) shorter size than estimated in earlier years (75 pp; 1998-2002:[54]) and showing a decreasing trend of about 90% [62] higher than decreasing trend of 10% estimated by ringing schemes (1992-1999: [70]). Population models [62] prevent a short term quasi-extinction process of this populations in these areas. By contrast, population models based in ringing abundances covering a broader time scale (1991-2007:[60]) offer a population trend model at El Hondo for this species as bottleneck, as occur in another endangered species in Iberia (see for example, [71]), with a heavy decreasing trend (1991-2001) and afterwards heavy increases (2002-2007). Methodologies offered in current surveys [62] don't assume that the data used in the analysis represent an unstructured population with possible alle effect [22] and with deviations from larger models that might underestimate of the effective population size (see for example: [72-74] for criticisms inside bottlenecks sampling).

2.3. Mist-Netting Protocols

Between 1991- 2007, a variable number of units of mist-nets (each unit 12 m length, 2,5 m high, 30 mm mesh size) placed in groups varying between one and ten and during variable hours and days were used in the Bearded Reedling's edge line. Birds were captured between sunrise and sunset. Mist-netting has found to provide reliable data on the sex and age structure of flocks in a minimum radius of more than 10 km in passerines [74]. In order to minimize effects of weather and predator disturbance on mist-netting efficiency [75-78], mist-nets groups were placed at the same height from the ground in sunny days and checked every 10 minutes. Particularly mesh size diameter used in this study (15-20 mm) was adequate to capture birds of less than 16 gr [79] and hence to assure

that the most number Bearded Reedlings present in a given flock was trapped. Some authors find that mist-netting show differences in spacing system, flight distance, and flight frequency of birds that exert strong effects on capture rates but mist-netting that assumes similar frequency of captures of adult and juvenile birds, is shown to be a reliable estimator of ages and sexes [80] although mist-netting can offer some biases in productivity [81]. I also calculated the home range of mist nets (Table 1) as the imaginary surface of a T-polygon of 5 mist nets in the central line (12 meters each standard length) and 1-3 mist nets of diameter at each one of the separation line, depending on the habitat surveyed. The home ranges resulted on average similar those of other marshland passerines [82, 83].

2.4. Capture Data Recording

Individual Bearded Reedlings were ringed with adequate numbered aluminium rings (Spanish Ministry of Environment-MMA remit) and checked for date and hour of capture. According [2] intra-specific factors usually is considered to determine the social status are tarsus length, body mass, age and sex. For this reason birds were also noted for wing length (left, maximum chord, to the nearest 0.5mm, according [84]) and weight (to the nearest 0.1gr). Wing-length instead of tarsus-length was used to assess body size (see [40]) and body mass was used to assess body condition (see [41, 42]). Weight was assessed again in a sample of 38 retrapped birds. Bearded Reedlings were aged as juveniles according plumage features [84] and birds of longer age as immatures and/or adults in autumn according iris colour [21, 85] and sexed by bill colouration before or during post-juvenile moult in summer and autumn following [84]. In the analysis of social structures, captures from March to October were assumed be in summer and from November to February as in winter, upcoming resemblances with the seasonal

habitat distinction of this species [23] and also appropriate to the diet turnover of this species [26]. For the analyses of daytime activity of the flocks, morning sampling alone does not give an accurate estimate of relative abundance and age structure of reed passerines in mist-netting [86], so sampling included evening birds and all of them were grouped in morning-catches (7-10 hours GMT) and evening-catches (11-21 hours GMT). I calculated the group size as the number of individuals trapped in the same capture event (hour and day). Therefore each group size was given as *solitary* (if only one bird was trapped at the same event); *pairs* (if two birds were trapped at the same event) and *flocks* (if more than two birds were trapped at the same event). Under this classification it was calculated: 1) the frequency of items, as the number of times which each event was given and 2) the number of individuals implicated in each item.

2.5. Statistical Analysis

Observed flock frequencies were not normally distributed (Kolmogorov-Smirnov-Test, $Z = 3.934$, $P < 0.001$, $N = 143$) and were adjusted to Poisson equation [87] to obtain expected frequencies. I used Chi-squared-tests by contingency tables to test observed captures against expected/similar frequencies in each case (SPSS 2001). Body masses did meet criteria for normality (Kolmogorov-Smirnov Test: $Z = 0.990$, $P = 0.280$, $N = 268$) but not wing-lengths ($Z = 2.334$, $P < 0.001$, $n = 236$). Due to this, I used overall non-parametric tests (Mann-U-Whitney and Kruskal-Wallis) to compare differences among means (\pm SE) in the samples. All data were analysed using the SPSS v. 11 statistical package [87]. Significant values ($P < 0.05$) were two-tailed.

3. Results

3.1. Flock Structure

A total sample of 246 Bearded Reedlings ringed was obtained. The overall dataset was composed of 144 samples of 1 to 8 individuals each and contained 109 adult males/61 adult females; 42 juvenile males/34 juvenile females. Mean flock size was composed by 1.72 ± 0.11 individuals (range 1-8). The frequency of solitaires and pairs (90/34) did not meet the expected frequencies (44/38) obtained from the Poisson equation ($X_1^2 = 7.77$, $P > 0.05$). Flocks were more frequent in summer (Mean: 1.73 ± 0.14 , range 1-8) than in winter (Mean = 1.71 ± 0.18 , range 1-5) but not significantly (Mann-Witney Test U-Test = 2165.5, $N_1 = 98$, $N_2 = 45$, $P = 0.922$). Groups were significantly bigger during evening (3.24 ± 0.26 , range 1-8) than during morning (2.52 ± 0.15 , range 1-8) ($U = 5715.8$, $N_1 = 82$, $N_2 = 164$, $P = 0.047$). Males were predominantly more abundant in groups than females and adults were more abundant than juveniles in pairs. Analysis of recaptures were surprisingly low ($N = 38$) and shows a significant probability of males to be more often recaptured than females (29/9, $X_1^2 = 10.52$; $P < 0.001$) and adults more

recaptured than juveniles (30/8, $X_1^2 = 12.73$, $P < 0.001$).

3.2. Flock Dynamics

Body masses of solitaires, pairs and flocks did not differ among them, although solitaires were in better condition (solitaires: 12.92 ± 0.12 , pairs: 12.84 ± 0.13 , flocks: 12.87 ± 0.11 ; Kruskal-Wallis: $X_2^2 = 0.092$, $N_1 = 83$, $N_2 = 62$, $N_3 = 88$, $P = 0.955$). Wing-lengths did not also differ among groups (solitaires: 58.25 ± 0.25 , pairs: 58.10 ± 0.34 , flocks: 57.65 ± 0.25 ; Kruskal-Wallis: $X_2^2 = 4.02$, $N_1 = 88$, $N_2 = 62$, $N_3 = 86$, $P = 0.134$). Birds were significantly lighter in the morning than in the evening (morning: 12.65 ± 0.08 , evening: 13.37 ± 0.11 , $U = 3489.5$, $N_1 = 159$, $N_2 = 74$, $P < 0.001$) experiencing an overnight loss of 6 % of their body mass. It was found that the majority of birds (87%, $N = 246$) were "transients", staying for short periods and never being recaptured but only 13% ($N = 38$) of birds captured at the study sites became "resident", being caught on more than one ($N = 36$) or two ($N = 2$) occasions after ringing. Residents attained higher body masses (13.26 ± 0.27) than transients (12.84 ± 0.07), ($U = 1442$, $N_1 = 20$, $N_2 = 214$, $P = 0.016$). Wing-length for residents (58.98 ± 0.43) was also significantly longer than transients (57.89 ± 0.17) ($U = 1599.5$, $N_1 = 20$, $N_2 = 214$, $P < 0.05$).

3.3. Habitat Preferences

Frequency of individuals tended to decrease not significantly as the reedbed grows in density and management perturbation, from cleared (2.18 ± 0.60) to dense reed (1.61 ± 0.16) (Kruskal-Wallis: $X_2^2 = 0.929$, $N_1 = 11$, $N_2 = 84$, $N_3 = 49$, $P = 0.628$) in similar form that individual's abundance (Table 1). Body masses were greater in the heavily managed plot in summer (Summer; dense: 13.08 ± 0.08 , cleared reed: 12.60 ± 0.27 , saltmarsh reed: 12.51 ± 0.009 , Kruskal-Wallis: $X_2^2 = 7.63$, $N_1 = 38$, $N_2 = 12$, $N_3 = 110$, $P = 0.022$). In winter, control areas supported birds in better condition (cleared-reed: 13.70 ± 0.22 , dense: 13.36 ± 0.15 , saltmarsh-reed: 13.19 ± 0.19 , Kruskal-Wallis: $X_2^2 = 3.42$, $N_1 = 12$, $N_2 = 38$, $N_3 = 23$, $P = 0.180$). Larger wing-lengths were found in dense habitat (dense: 59.16 ± 0.21 , cleared-reed: 58.42 ± 0.43 , saltmarsh-reed: 57.24 ± 0.22 , Kruskal-Wallis: $X_2^2 = 27.95$, $N_1 = 77$, $N_2 = 24$, $N_3 = 135$, $P = 0.180$). The percentage of resident Bearded Reedling's was not significantly higher in the cleared reed areas (26/12/16, $X_2^2 = 5.02$, $N = 38$, $P = 0.081$). Recaptures among habitats occurred in 9% ($N = 2$) of birds.

4. Discussion

This study reveals that Bearded Reedling at El Hondo, as an example of a semi-isolated wetland complex, is basically a solitary and nomadic bird or conform small flocks of small to moderate size similar to another findings [28]. Overall mean frequency of individuals is lower than reported for central Spanish localities [88] which reflect strong differences among Iberian populations and the use of different methodological

approaches, but flock numbers seem comparable to the observations found in winter in Poland [89]. This study confirms the not significant differences in body condition among those forming small groups (colonial) and solitaires [19]. Social status seems not to be determined by age and sex or body condition but the habitat preferences and management actions show major importance on flock dynamics. I found that the habitat heterogeneity and frequency of management actions are seasonally dependent and might account for social dynamics. Individuals in better condition and size stay at heavily managed reed habitats that might have better invertebrate quality and diversity because are wetter areas [24, 103]. The frequency of trips between reedbed sites is low (9%) as ringing recaptures among ringing places show, proving that Bearded Reedlings are mobile inside the succession line, depending on the Arthropods density [104] and seed availability, expressing similar social characteristics of Bearded Reedlings in The Netherlands [24] and England [4] with short trips of 100-800 m between nesting and foraging areas. This variability in dispersal occurs in other marshland passerines [13, 15] and illustrates the importance of not manage earlier successional stages of reed to improve passerines movements. It is found that, on average, overnight weight loss was high and is lower than reported in other Tits of related size and mass [89]. Such loss weight might aid to explain why Bearded Reedling's movements are nocturnal from nesting to roosting areas starting during sunset and stopping on arriving at the roosts, probably associated to the advancement of high flying flights peaks at the sunrise pointed by [4, 21]. This period of the day is when researchers are rarely active or not monitoring mist-nets and it is highly recommended when surveying populations of marsh passerines, because greater numbers are found in the morning [86]. Birds of longer age, transients (in this study, adults) move over bigger areas and are in poorer condition than residents (in this study, birds of the year or juveniles) [90]. Transients benefit from residents for finding food by "local enhancement" (i.e. differential use of foragers for residents of previous knowledge for other area than make transients) and suffer more mortality [91]. This might help to explain why some scarce observations in Alicante and Murcia have been obtained [64, 65, 106]. Due to overnight mass losses is considered that methodology used on earlier surveys [62] can result inadequate because they to offer low estimates of individuals sampled at unappropriated times of day. The absence of observations of Bearded Reedlings in surveys at reed corridors [92] supports the use of alternative methodologies as telemetry, geolocators [93, 94] and use of sunset times at roosts to survey more properly its populations.

Bearded Reedlings population dissimilarities between South-east and Central-Spain and similarities with small isolated populations placed at similar latitude in Turkey [95] and Italy [96, 97] indicates that distant study populations from the same species are exposed to similar regional

climates and they may have different characteristics in social organisation due to the populations sizes involved in each site and that seasonal cycle of climatic regimes could exert a major importance on them [69, 98]. Also, some populations may have a higher tendency to disperse than others [99] or different populations may vary in composition and behaviour, perhaps reflected in age-specific or sex-specific avoidance behaviour [7, 8]. At difference of other cohabiting reedbed passerines in El Hondo of similar moult patterns and wing shapes like Moustached warbler (*Acrocephalus melanopogon*) with longer movements [94] the Bearded Reedling's possess shorter movements [100] related to different age-related wing shapes [101] and long-tail, that in spite to be an ornament implied in sexual and natural selected processes [102], has an important role for habitat choice as balancing organ among reed-stems [25].

The management actions carried out in El Hondo seem to have a differential effect on the dispersal and the survival of this species. First, wet managed reeds in the core of the wetland have proved to be helpful for the development of the Bearded Reedling because birds staying at these areas are composed mostly by transients in poorer condition and size. The saltmarsh areas surrounding the belts of reed are used mostly by resident Bearded Reedlings in good condition so maybe are using these sites as foraging sites, and these sites remain as unmanaged control areas with a good reed seed production, with young reeds seeds, that are preferred by Bearded Reedlings [24]. For this reason the settlement of residents in the periphery of reeds might favour dispersal towards another wetlands favouring by reed corridors with similar characteristics of unmanaged reeds.

5. Conclusions

Conservation measures should offer added nesting sites by nest-box provision at dense wet reeds in the core of wetlands to favour the recruitment rates and the reinforcement of the population. Dry sparse-reed sites should be supplied as gritting tray areas. This should to favour the seasonal changes in the diet of this species enhancing a higher condition of the bird residents situated at periphery areas. Also management purposes should keep in mind the maintenance of saltmarsh plots in the periphery of wetlands to favour rich areas with Groundsel *Senecio* spp, a pioneer saltmarsh seed plant strongly linked to the first successional steps of reed *Phragmites australis* invasion and following expansion of Bearded Reedling. This implies that more study is need with this species in similar wetlands with low population sizes to understand the underlying behavioural demography-related mechanisms such as nestling survival, fledgling productivity, dispersal and demographic rates by using mist nets as a highly recommendable research tool.

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