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Effects of Age and Culling on Movements and Dispersal Rates of Yellow-legged Gulls (*Larus michahellis*) from a Western Mediterranean Colony.

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Abstract. – This study analyses the effects of age and culling of breeding adults on the movements and dispersal rates of Yellow-legged Gulls (*Larus michahellis*) from a western Mediterranean colony (the Medes Islands) based on recaptures and resightings of birds banded as chicks. Juveniles (1year-old birds) were most frequently located in the French coast of Biscay and in the Western North Mediterranean. The presence of a large proportion of juvenile Yellow-legged Gulls on the Biscay coast did not seem to be related to a higher availability of food in that area compared to that near the colony and its surroundings (core area) but rather to the evolutionary history of this species. Older gulls became concentrated at the core area, with 3rd year sub-adult and adults accounting for more than 70% and 90% of resightings, respectively, in this area. Culling of breeding adults increased both the dispersal rate and mean distance of resightings of juvenile gulls, and favoured the displacement of gulls of this age to the French Atlantic coast to the detriment of the north-western Mediterranean. Culling also increased both the dispersal rate and the mean distance of adult resightings. This could be attributed to an increase in the number of gulls recruited to other colonies near the Medes Islands colony after the culls. The culling performed in the Medes Islands colony seems have effects at metapopulation level, conditioning the dynamics and management of other colonies.

Key Words. – Age, culling, movements, recoveries, sightings, Yellow-legged Gull

Running head: EFFECTS OF AGE AND CULLING ON GULL MOVEMENTS

Culling, because of its apparent effectiveness in the short term (Thomas 1972; Blokpoel and Spaans 1990; however see Bosch 1996, Oro and Martínez-Abraín 2007) has been used for decades to reduce possible problems linked to large populations of large gulls. The number of gulls breeding in culled colonies decreases drastically due to the direct removal of individuals, as well as due to the changes it causes in philopatry, dispersal and recruitment rates (Duncan 1978; Coulson *et al.* 1982; Coulson 1991). Consequently, culls can influence the number of gulls beyond the boundaries of the colonies treated. In this way, culling a single gullery can have unpredictable effects at the metapopulation level because it may affect dispersal rates among colonies (Coulson 1991; Defous du Rau 1995; Oro 2003). For this reason, the evaluation of the effects of a culling programme in a given colony should include an analysis of the possible changes in the movement and dispersal rate of individuals.

The Yellow-legged Gull (*Larus michahellis*) is a large gull that has shown a marked increase in its number of colonies, breeding pairs and distribution area over the last four decades (Yésou and Beaubrun 1995; Thibault *et al.* 1996; Bosch and Carrera 2004). This increase has been linked to the exploitation of anthropogenic resources, which have improved the breeding performance of pairs (Bosch *et al.* 1994, Oro *et al.* 1995, Real *et al.* 2017). From the second half of the last century, several banding programs have been implemented to study the movements of individuals of this species. They have shown that the movements of Yellow-legged Gulls vary largely depending on the area in which their colonies of origin are located. While gulls from Atlantic north Iberian coast colonies are sedentary (Munilla 1997, Arizaga *et al.* 2010), those from Mediterranean basin colonies move long distances, especially when they are young, and follow very different routes. Thus, Yellow-legged Gulls from the

Adriatic area move to the Baltic and North Sea coasts (Kralj *et al.* 2014), while those from Eastern Iberian and Southern French coasts (or nearby islands) as well as the Balearic Islands mainly move to Atlantic coasts from the Bay of Biscay to Portugal (Isenmann 1973, Carrera *et al*. 1993, Martinez-Abrain *et al.* 2002, Rodríguez and Muntaner 2004, Galarza *et al.* 2012). Individuals from southern Iberia disperse along the southern and eastern Iberian coasts (Cuenca and Delgado 2014) and those from the Algerian coast follow two distinct routes (one to the Balearic Sea and Bay of Biscay and the other from southern Iberian coasts to the Atlantic coast of northwestern Iberia (Baaloudj *et al.* 2012). The large increase in the population of this species has led to the performance of culls by management agencies on several of its colonies, some of them included in banding programs (e. g., Medes Islands, Ebro Delta and Balearic Islands). However, data reflecting the effects of culling on the movements and dispersal of Yellow-legged Gulls are lacking. On the other hand, juveniles of some colonies of this species have been resighted at large distances from the natal colonies, in contrast to older individuals (Carrera et al 1993). This could be due to a reduction of the dispersal rates as the age increases, although studies about this are lacking.

The aim of this study is analyse the possible effects of age and culling on the movements and dispersal rates of Yellow-legged Gulls from a western Mediterranean colony based on the recapture or resighting of birds banded as chicks.

METHODS

Study Area

The Medes Islands archipelago (42°03′00″N 3°13′15″E; NE Spain) holds a large breeding colony of Yellow-legged Gulls that was subjected to annual culls from 1992 to

1996 (for a detailed description of the colony see Bosch and Sol 1998). During those years, 25,000 breeding gulls were killed using baits of bread with butter mixed with a-chloralose and secobarbital placed in their nests (Sargatal *et al.* 1992). Culling greatly reduced the size of the colony within a short time, i.e., from 14,000 pairs in 1991 to 5,400 in 1997 (Bosch *et al.* 2000). The colony slowly increased to 7,700 pairs by 2008, but since then, numbers have declined to 4,673 pairs currently (authors, unpublished data). Preliminary data on the movements of gulls from the colony banded with metal bands in the 1970s and 1980s have been analysed in previous studies (Carrera *et al.* 1981; Carrera 1987; Carrera *et al.* 1993).

We studied the movements and dispersal rates of Yellow-legged Gulls from the colony using recoveries and resightings (hereafter, all referred to as resightings) of individuals marked as chicks with metal or engraved darvic bands in the colony from 1976 to 2003. During this period, 15,595 gull chicks were banded: 11,082 with a hard metal band before the culls (prior to 1992) and 4,513 afterwards (1997 onwards; 4,274 of them with both metal and engraved darvic bands). Four types of resightings were excluded: those reported as “not freshly dead”, those with “unknown find conditions”, those of fledglings found dead at the colony, and duplicate findings of individual in the same geographical zone and same age group (Coulson and Nève de Mévergnies 1992; Oro and Martinez 1994). After discarding these, the number of resightings was 1,618 referring to 1,259 individuals.

Resightings were grouped by three factors: age of gulls at resighting, geographical region of resighting and pre- or post-culling period. Four age classes were distinguished: juveniles (in their first year of life), two-year-old sub-adults, three-year-old sub-adults, and adults. Gulls sighted after the 1st May were considered to belong to the next age class (Martinez-Abrain *et al.* 2002). Eight large geographical areas (hereafter referred to as regions) were considered when locating resightings: R1, northwestern Mediterranean (between Cap de la Nao, Alicante, and Toulon, Golfe du Lion); R2, French coast of the Bay of Biscay (between Hendaye and Ploudalmézeau, Bretagne); R3, English Channel (between Ploudalmézeau and Oostende, Belgium, including the English coast on the other side of the channel); R4, North Atlantic Iberian (between Hendaye and Cape Fisterra, Galicia); R5, North Sea (between Oostende, Belgium, and Niebüll, German–Danish border); R6, Western South Mediterranean (between the Cap de la Nao and the Cape of San Vicente, Portugal. A resighting from Morocco was included); R7, Central Mediterranean (from Toulon to Terracina, East Coast of Central Italy); R8, Central Europe (comprising the eastern part of Central France, Switzerland, Austria and the South of Germany). A "core area" consisting of the Medes Islands colony and the surrounding area within 40 km was also identified. Two culling periods were distinguished: pre-culling (until the onset of culls initiated in 1992) and post-culling (from after the last cull of 1996 to 2004); resightings recorded during the culling years were excluded, thus excluding possible resightings of individuals (mainly subadults) that were out of the colony during the first culls. As in other studies, it was not possible to quantify any possible bias linked to differences in observation effort among regions (Kralj *et al.* 2014).

Effects of Age and Culling Period on Geographical Distribution of Gulls

The effects of age and culling period on the distribution of resightings among different geographical areas were first tested by multifactorial Chi square test. This test rejected the independence between these two factors (χ^2_{12} = 693.2, P< 0.001), so the age effect was analysed independently for each culling period, and the culling effect was analysed separately in each age group. The effects were tested using the Chi-square or Fisher exact tests. Resightings in regions 3 to 8 were not included in the analysis because they had very low expected frequencies (less than 3%). Moreover, the resighting frequencies of juveniles and two-year-old sub-adults were grouped in multifactorial Chi square test.

Effects of Age and Culling Period on Dispersal of Gulls

Dispersal rates were calculated by grouping resightings according to successive concentric 100 km circular zones extending outwards from the colony. The percentage of gulls resighted within each zone, grouped by age and culling period, was plotted on a log scale against distance to show whether a constant proportion (dispersal rate, r) of the gulls entering a zone remained within it (see Coulson and Brazendale 1968, Parsons and Duncan 1978, Coulson and Nève de Mévergnies 1992, Oro and Martínez 1994). Resightings within the breeding colony were not included in this analysis. Seasonal periods were not distinguished to avoid some dispersal rates being calculated from small samples. Variations of dispersal rates among age groups and between culling periods were tested using the Kruskal-Wallis and Mann Whitney U tests. As in previous analyses, the age effect was analysed independently for each culling period, while the culling effect was analysed separately in each age group.

Effects of Age and Culling Period on Mean Distance Moved by Gulls

The distance between the colony and the location of resightings was calculated, and mean distances were calculated, distinguishing between ages and culling-periods. Resightings performed within the colony (distance zero) were included in this analysis since mainly adult Yellow-legged Gulls tend to stay closer to the breeding colonies (Sol *et al.* 1995; Kralj *et al.* 2014). Mean distances were compared using the Kruskal-Wallis and Mann Whitney U tests. Again, the age effect was analysed independently for each culling period, while the culling effect was analysed separately in each age group.

RESULTS

Gulls were unequally distributed among the eight defined regions: three of the regions (0, 1 and 2) contained more than 95% of the resightings (Fig. 1, Table 1).

Effects of Age and Culling Period on Geographical Distribution of Gulls

The geographical distribution of resightings varied with the age of the gulls (pre-culling period excluding two- and three-year-old birds: χ^2_2 = 63.1, P< 0.0001; post-culling period: χ^2_6 = 545,2, *P* < 0.0001). Consequently, the distribution of resightings was analysed separately for each age group. Juvenile distribution did not vary among the three main regions (Regions 0, 1 and 2) before culling (χ^2_2 = 1.1, *P* = 0.575), but did vary after culling (χ^2_2 = 18.2, P= 0.0001), with a larger resighting frequency of gulls along the French coast of the Bay of Biscay (Region 2) (*a posteriori* tests) (Table 1). The distribution of two-year-old gulls did not vary significantly among the three main regions (χ^2_2 = 5.3, *P* = 0.072). Three-year-old gulls showed significant differences in their distribution among the three main regions after culling (χ^2_2 = 473.8, *P* < 0.0001), with a larger resighting frequency in the colony and nearby (*a posteriori* tests).

Adult gull distribution varied significantly among the three main regions, both before and after culling (before: χ^2_2 = 148.1, *P* < 0.0001; after: χ^2_2 = 1289.4, *P* < 0.0001) due to a high resighting frequency of individuals in the core area (*a posteriori* tests). To ascertain whether this simply reflected the need to stay in the colony for breeding (or, the analysis was repeated only considering data from the non-breeding season (from July to February) during the post-culling period (data from the pre-culling period were not included because of the small sample). Again, significant differences were detected due to a higher frequency of adults in the core area (post-culling period: χ^2_2 = 570.5, *P* < 0.0001).

The geographical distribution of resightings varied significantly between the pre-culling and post-culling periods in the case of adult gulls (χ^2_2 = 13.5, *P* = 0.001) due to a higher frequency of individuals near the colony after culls (*a posteriori* tests). In the other age groups, there were no significant differences between periods (juveniles: χ^2_2 = 3.2, *P* = 0.201; 2nd year sub-adults: Fisher Exact test grouping areas 0 and 1: *P* = 0.629, 3rd year sub-adults: Fisher Exact test grouping 0 and 1 areas, *P* = 0.547) although in the case of three-year-old gulls, it may be due to the small sample size in the preculling period.

Effects of Age and Culling Period on Dispersal Rate of Gulls

The dispersal rates of gulls varied significantly among the age groups, both before and after culling (before: H= 9.88, *P* = 0.0197; after: H= 19.94, *P* < 0.001) (Table 2). *A posteriori* tests showed that adult gulls had a lower dispersal rate than the other age groups, both before and after culling (Table 2, Fig. 2).

On other hand, dispersal rates also varied between the culling periods. Thus, juvenile and adult gulls showed a significantly higher dispersal rate after the culls (juvenile: Z= -2.6, P= 0.010; adults: Z= 2.5, *P* < 0.014); two-year-old gulls showed the same tendency, although it was not significant (Z= -1.5, $P = 0.142$), possibly due to the small sample of resightings for this age class before culling. Three-year-old gulls showed the opposite tendency, although the differences in the rates of dispersal between periods were not significant (Z= 1.0, $P = 0.336$) (Table 2 and Fig. 2).

Effects of Age and Culling Period on Mean Distance Moved by Gulls

The mean recovery distance decreased significantly with age, both before and after the culls (H = 126.9, $P < 0.0001$; H = 1427, $P < 0.0001$) (Fig. 3). Mean distances increased significantly after culling both in juvenile gulls (Z= -2.71, $P = 0.007$) and adult gulls (Z = 5.38, $P < 0.0001$) (Fig. 3). In contrast, for the three-year-old gulls, the mean recovery distance decreased significantly after the culls (Z = 3.24, $P = 0.002$); no significant differences were detected in two-year-old gulls.

DISCUSSION

The results of this study show that both gull age and massive culls have a significant effect on the movements and dispersal of Yellow-legged Gulls. With regard to age, juveniles were more frequently located along the French coast of Biscay, Region 2, (as previously described by Carrera 1987, Carrera *et al.* 1993), especially in the post-culling period, and also in the northwestern Mediterranean (Region 1). In contrast, older gulls were concentrated in the colony and its surroundings (core area). In this way, more than 70% of resightings of three-year-old sub-adults were in this area; when considering adult resightings, the percentage exceeded 90%. Data from this study show that juveniles arrive at the Biscay coast not only through the Loire and

Garonne valleys (as previously described by Carrera 1987 and Carrera *et al.* 1993) but also through the Ebro Valley. The presence of a large proportion of juvenile Yellow-legged Gulls along the Biscay coast has been reported since 1970s and they come from a large number of colonies along the Mediterranean coast (or nearby islands) of Spain and France and the Balearic Islands, as well as some colonies in Sardinia and along the Atlantic North Spanish coast (Isenmann 1973, Yésou 1985, Carrera *et al.* 1993, Rodriguez and Muntaner 2004, Martinez-Abrain *et al.* 2002, Arizaga *et al.* 2010, Galarza *et al.* 2012). Such a concentration of juveniles has been linked to the high availability of food in the region (linked to its high fishing productivity) relative to the Mediterranean Sea during summer (Le Mao and Yesou 1993). Moreover, juvenile Yellow-legged Gull movements begin on the onset of post breeding period (Carrera 1987), when the food competition is expected to be larger. However, the main food resource of the gulls of the Medes Islands colony (i. e., garbage from dumps) is largely available throughout the year, and the dependence on this resource has been very high for more than 50 years (Carrera and Vilagrasa 1984, Bosch *et al.*, 1994, 2000, Bosch 2010). This could support the hypothesis that the patterns of the Yellow-legged Gull movement are not a recent development nor linked to circumstantial factors but result from its evolutionary history (Kralj *et al.* 2014), although more data are needed to test this.

As gull age increases, individuals become concentrated in the colony and surroundings, showing decreasing dispersal rates and mean distances of resightings, and thus a return to this area. In fact, among the 116 gulls sighted in more than one geographical area, 79% were last sighted in the colony or its surroundings. Moreover, the high proportion of adults in the core area was sighted not only in the breeding season, but also outside it (as observed by Sol *et al.* 1995), so it was not due only to breeding requirements.

Culling affected the geographical distribution of resightings, as well as dispersal rate and mean distance of resightings. The dispersal rate and mean distance of resightings of juvenile gulls increased after culls. Furthermore, in this period the proportion of juveniles dispersing throughout the north-western Mediterranean decreased significantly in favour of the French Atlantic Coast. This is supported by the significant differences in resighting frequencies in these two areas between culling periods. On other hand, culling also increased both the dispersal rate and the mean distance of adult resightings. These results could be explained by an increase in the numbers of gulls recruited to other colonies near the Medes Islands colony after the culls (such as Cap de Creus, Aiguamolls de l'Empordà or Sant Feliu de Guíxols, all of which located less than 40 km away). This hypothesis is supported by the fact that 263 out of 725 adults (i.e., 36%) sighted after the culls in the core area were never sighted in the colony; furthermore, 19 adults (2.6%) sighted in the colony, were sighted in the core area in the two years after their last resighting in the colony. In fact, since culls of the colony were performed, the number of new colonies as well as the size of the colonies that already existed has greatly increased (Bosch *et al.* 2000, Bosch and Carrera 2004). The most noted case is the Ebro Delta colony, which increased from 1,100 to 10,500 pairs within 9 years, since the start of culls in the Medes Islands colony (Parc Natural del Delta de l'Ebre, unpublished data). Consistent with this, previous studies on other colonies of gulls subjected to culling showed an increase in the frequency of recovery of individuals that were breeding in a colony other than that in which they had hatched (Chabrzyk and Coulson 1976, Coulson 1991). In turn gull movements can condition the management of other colonies (Duncan and Monaghan 1977, Gabrey 1996). In this way, the large increase in size of the yellow-legged gullery of the Ebro Delta has resulted in massive culls since 2016 (Parc Natural del Delta de l'Ebre, unpubl. data). Thus, the culling performed in the Medes Islands ended up necessitating more culling in other colonies, expanding in turn its effects beyond what was expected. In conclusion, culling in the Medes islands colony may have led to uncontrollable effects at the metapopulation level, consistent with Brooks and Lebreton (2001), and this should be taken into account when planning new gull management measures.

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TABLES

Table 1. Percentage of resightings of Yellow-legged Gulls from the Medes Islands colony in each geographical region for each age class. Data are distinguished by culling period. n: number of resightings.

Region	Pre-culling				Post-culling			
	juvenile	2-year-old	3-year-old	adult	juvenile	2-year-old	3-year-old	adult
Core	25,9	35,7	55,6	86,7	17,0	39,3	83,9	94,7
1	36,2	35,7	22,2	8,0	28,4	24,3	5,9	2,1
2	34,5	14,3	--	4,4	44,7	29,3	8,2	2,5
3	--	--	11,1	--	5,0	2,1	1,8	0.3
4	1,7	--	--	0.9	2,8	3,6	0.3	0.4
5	--	7,1	--	--	1,4	0.7	--	--
6	1,7	--	--	--	0.7	--	--	--
7	--	--	11,1	--	--	--	--	--
8	--	7,1	--	--	--	0.7	--	--
n	58	14	9	113	141	140	392	751

Table 2. Dispersal rates of Yellow-legged Gulls banded as chicks in the Medes Islands colony and resighted out of the colony, distinguished by age and culling period. Data do not include resightings performed in the colony.

Period	Age	n	$\bar{x}$	SD
Pre-culling	juvenile	54	0.626	0.060
	2-year-old	13	0.633	0.082
	3-year-old	8	0.634	0.146
	adult	23	0.317	0.166
Post-culling	juvenile	139	0.712	0.064
	2-year-old	108	0.688	0.065
	3-year-old	143	0.604	0.105
	adult	371	0.388	0.163

FIGURE CAPTIONS

Figure 1. Location of the resightings of yellow-legged gulls ringed as chicks in the Medes Islands (#). The areas distinguished in the study are shown; location of the Medes Islands is shown by an arrow.

Figure 2. Percentage of yellow-legged gulls moving beyond consecutive 100 km ranges from the Medes Islands, plotted on a logarithmic scale against distance. 1a: pre-culling 1b post-culling.

Figure 3. Mean distance ((± standard error, vertical bar) moved by yellow-legged gulls from the Medes Islands colony according to age group and culling period.

FIGURES

Figure 1.

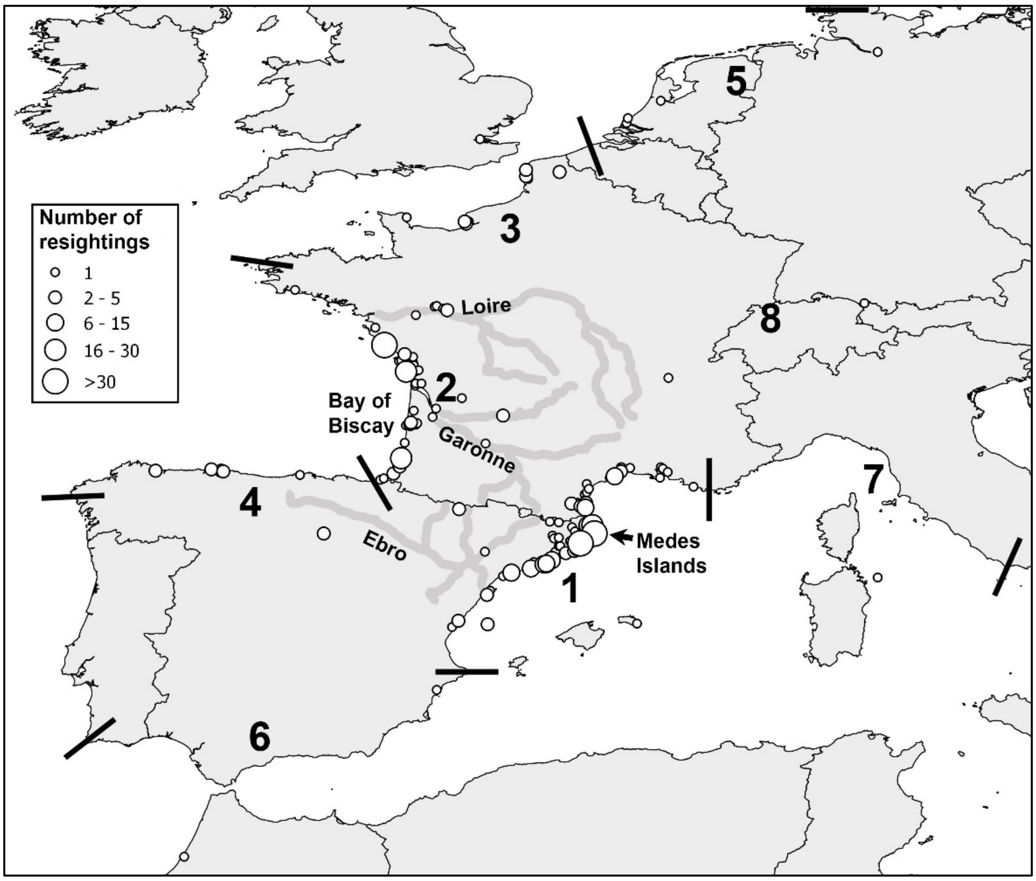


Figure 2.

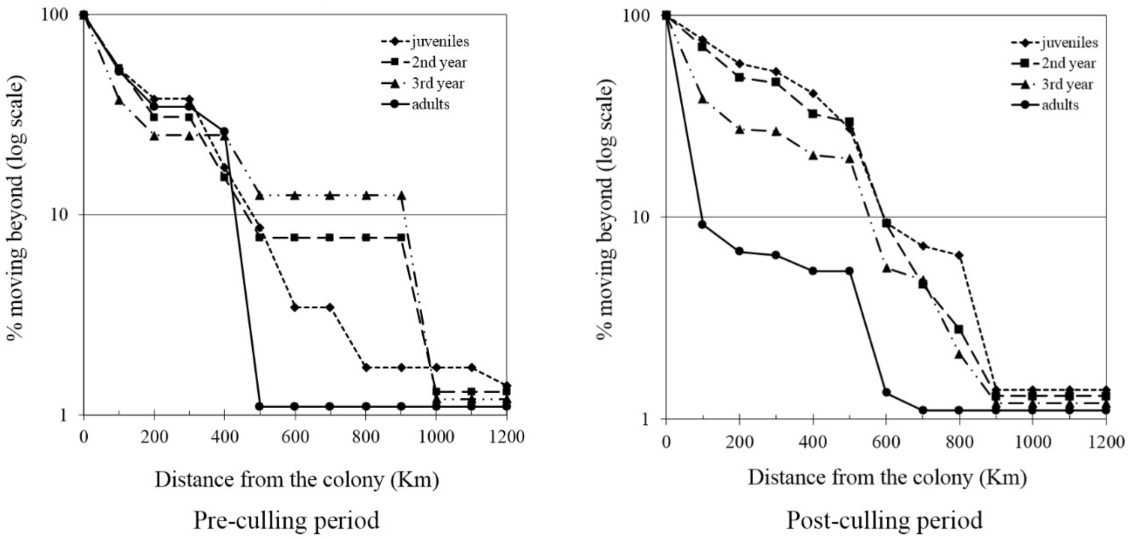
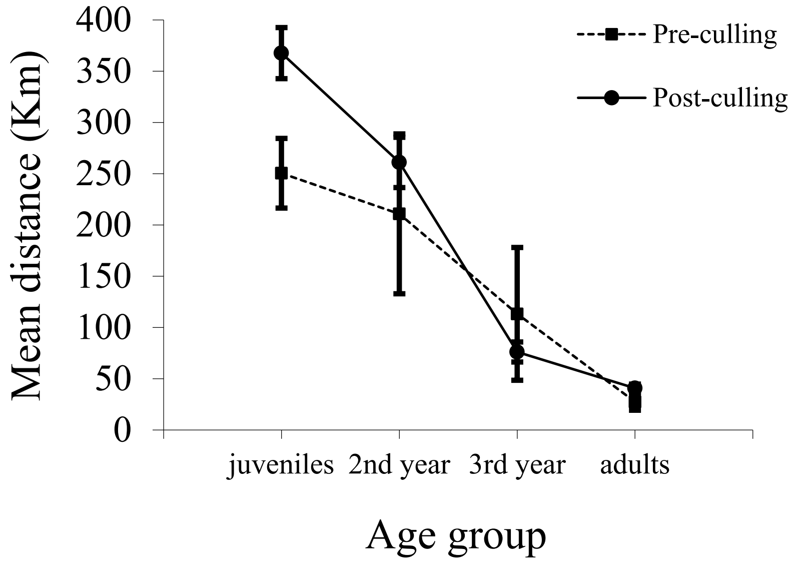

100
10
1
% moving beyond (log scale)
juveniles
2nd year
3rd year
adults
0
200
400
600
800
1000
1200
Distance from the colony (Km)
Pre-culling period
100
10
1
% moving beyond (log scale)
juveniles
2nd year
3rd year
adults
0
200
400
600
800
1000
1200
Distance from the colony (Km)
Post-culling period

Figure 3.



Mean distance (Km)
400
350
300
250
200
150
100
50
0
Pre-culling
Post-culling
juveniles
2nd year
3rd year
adults
Age group