A COMPARISON OF TWO METHODS TO ESTIMATE BREEDING PRODUCTIVITY IN A COLONIAL GROUND-NESTING GULL *LARUS CACHINNANS*

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SUMMARY

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We compared two methods commonly used to estimate breeding productivity of ground-nesting gulls: mark-recapture of ringed chicks and counts of flocks of fledglings resting at sea. Counts of the number of nests were also recorded to estimate productivity as average number of fledglings per breeding pair. Our field study was done at two locations at the western Mediterranean (Columbretes and Benidorm Islands) where small and isolated colonies of Yellow-legged Gulls (*Larus cachinnans michahellis*) occur. Estimates derived from direct counts were assumed to be relatively unbiased because of the small size of the study islands. We found that mark-recapture provided accurate results (similar to those obtained by counting flocks) only when mortality of chicks between capture and counts was low. Whenever both methods are applicable we recommend using flock counts to estimate productivity because it requires less input from the researcher and has little or no disturbance cost for the gulls.

Key words: Yellow-legged Gulls, *Larus cachinnans*, census counts, mark-recapture estimates

INTRODUCTION

Monitoring changes in annual productivity or breeding success (i.e. the average number of chicks raised per breeding pair per year) is important to study bird population dynamics (Caswell 2001). This is especially true for the Yellow-legged Gull (Larus cachinnans), because this species has been considered a pest in the Mediterranean region during the last few decades (Vidal *et al.* 1998, but see Bosch 2000).

Obtaining productivity estimates per nest is difficult for ground-nesting gulls having semi-nidifugous chicks (Erwin & Custer 1982) such as Yellow-legged Gulls. Some of the methods usually employed to obtain productivity values per nest [e.g., enclosing nests (Reid 1987, Bolton 1991, Bosch *et al.* 2000) or direct observations (Butler & Trievelpiece 1981, Brouwer *et al.* 1995, Brown *et al.* 1995, Oro *et al.* 1995)], have been considered reliable, but can be biased (e.g. Mineau & Weseloh 1981). For instance, ringing and resighting hatchlings during their growing period within a colony (e.g., Hébert & Barclay 1988, Cavanagh & Griffin 1993, Buckley & Kelly 1994, Bukaciƒska *et al.* 1996) may be biased because gull chicks can move hundreds of meters from their natal territory or hide in the vegetation. This is especially true when collecting data causes disturbance so that chicks move further away (Erwin 1989, Sydeman *et al.* 1991, Hario 1994, authors personal observations). Fences can eliminate this problem, but they can also either increase or decrease chick mortality (e.g., Mineau & Weseloh 1981, Bradbury & Griffiths 1999, Bosch *et al.* 2000). Direct observations from a closed blind, and especially from a distance, may reduce disturbance (Pugesek & Diem 1983, Pons & Migot 1995), but chicks still may move out of the boundaries of the observation area (Oro & Genovart 1999). Alternatively, colony-wide methods can be applied, although no measurement of variability can be obtained from these data unless several counts are performed (e.g. Erwin & Custer 1982). Mark-recapture of chicks can also be employed to estimate productivity in gulls. However, this method has to be applied several weeks before chicks fledge because chicks of older age cannot be captured so that bias is created if late mortality of chicks is high.

We compared results obtained using mark-recapture with those obtained at the end of the breeding season counting flocks of fledglings resting at sea in colonies of a ground-nesting gull species. Fledglings of the Yellow-legged Gull were easily distinguishable from adults since their overall appearance is brownish instead of white and silver. The study was carried out during two consecutive years in two small colonies where high and low chick mortality was expected after initial marking.

METHODS

Colonies were located at the Columbretes archipelago and on Benidorm Island. The Columbretes archipelago is formed by a 19 ha volcanic outcrop, comprising 4 major islet groups, located ca. 57 km off the coast of Castellón (39º 54'N, 0º 41'E), western Mediterranean. Yellow-legged Gulls breed mainly on Columbrete Gran, the largest (ca. 13 ha.) island. The dominant vegetation on the main island is nitrophilous annual plants and a dense cover of small shrubby species. A sudden decrease of food availability occurred between the application of the mark-recapture method and flock counts during one of the study years, because a trawling fishing moratorium was initiated at that time (during the month of June 2000). This moratorium severely reduced the food available for the gulls, which largely exploit this feeding resource (see Oro *et al.* 1995, Martínez-Abraín *et al.* 2002).

The island of Benidorm (6.5 ha.) is a limestone outcrop located approximately 3 km off the coast of Benidorm (38º30'N, 0º08'E), Alicante, Spain, 165 km south of the Columbretes Islands. The vegetation is dominated by nitrophilous annual species and shrubs with abundant exotic vegetation (*Opuntia* spp.) and some scattered wild olives (*Olea europaea*). Food availability was high between the application of the two methods as trawler activity did not change, although food availability was low early in the breeding season (May) owing to a one month trawling fishing moratorium.

Mark-recapture

The breeding phenology of Yellow-legged Gulls is well known in the western Mediterranean (e.g. Bosch *et al.* 1994a, 2000; Oro *et al.* 1995) and colonies are monitored annually in the study sites by knowledgeable wardens. When most chicks were about 4-6 weeks from fledging (on 12 May 2000 and 21 May 2001 at the Columbretes islands and 16 May 2000 and 20 May 2001 at Benidorm), all chicks found of appropriate age were ringed with metal numbered and plastic darvic rings in sectors of the islands where highest nest densities were recorded. Sectors were identified prior to the count of nests (see below) and were equivalent to sub-colonies. Sectors were chosen distant from other sectors or sub-colonies to avoid movements of chicks between them, which could bias the estimation of the number of chicks. A second ringing session was carried out each year 1 and 2 days later at Columbretes and Benidorm respectively, recording the number of chicks that were already marked. The second ringing-recapture session was done with the same number of ringers and in the same sector as for the first one (i.e. two teams of two people each) except for Columbretes in 2001 with only three ringers. From these data, the total number of chicks was estimated (after Seber 1982) by:

$$\hat{N} = \frac{(M+1)(C+1)}{R+1} - 1$$

where M is the number of chicks ringed during the first visit, C is the total number of chicks captured during the second visit and R is the number of chicks captured during the second visit that were already ringed during the first visit. This is a modified version of the Lincoln-Petersen method (Nichols 1992), which can be very biased for small samples and tend to overestimate the actual population (Erwin & Custer 1982, Krebs 1989). The estimator is unbiased if $(M + C) \geq N$ and nearly unbiased if there are at least seven recaptures of marked chicks $(R > 7)$. The estimator $\hat{N}$ is accurate only if the following assumptions are true: (a) the local population is closed, (b) all chicks have the same probability of being caught during both visits, (c) ringing chicks does not affect their catchability, and (d) chicks do not lose rings between the two visits (Cavanagh & Griffin 1993).

Obtaining confidence intervals (CI) is important to give an idea of the precision of the $\hat{N}$ estimator and allow for comparisons. The estimation of CI depends on the parameters of our sample (see Krebs 1989 for explanation). If the fraction of marked chicks (R/C) is less than 0.10, and the number of recaptures (R) is less than 50, Poisson CI should be used; if $R > 50$, normal approximation CI should be used. If the fraction of marked chicks (R/C) is more than 0.10, as it was in our case (see Table 1), binomial CI should be used (Krebs 1989).

Counts of flocks

Counts of flocks (i.e., groups composed of a variable number of fledglings resting at sea close to colonies) were performed 4-6 weeks later than the mark-recapture method, because flocks are only formed when fledglings are able to fly and leave the colony. As the colonies under study were located far from other such colonies, we assumed that fledglings counted originated solely from these two colonies. Also, the counts were done immediately after fledging to reduce the chances of young having emigrated out of the colonies. At the end of June 2000 and 2001, all fledglings observed forming flocks at sea were counted three times at Columbretes and twice at Benidorm. The largest number was used if it was obtained from the last count, assuming that more fledglings were gathering at sea. If the number of fledglings did not increase as counts progressed we used the average of the counts. This approach has the advantage of providing measures of variability and precision of the estimate, although a large number of counts is required. The sea surrounding the island of Benidorm was divided in several sectors that were counted simultaneously by several observers. At Columbretes, the survey was done either from a boat by two observers (in 2000) or by two observers surveying the whole perimeter of the island together from land (in 2001). The small size of the islands prevented counting the same birds more

TABLE 1

Main parameters used to estimate productivity of Yellow-legged Gulls by mark-recapture and counts of flocks of fledglings at sea

Colony	Year	Nests (total)[1]	Fledglings at sea	Nests (sectors)[2]	M[3]	R[4]	C[5]	R/C	Chicks estimated
Columbretes	2000	346	305	230	95	18	72	0.25	368
Columbretes	2001	363	290	195	101	30	59	0.51	196
Benidorm	2000	365	146	237	48	24	55	0.44	109
Benidorm	2001	659	290	310	49	16	54	0.30	161

[1] number of nests counted in the whole islands
[2] number of nests counted in those sectors of the two islands where chicks were captured for the mark-recapture method.
[3] Chicks ringed in first visit.
[4] Chicks recovered.
[5] Chicks captured in second visit.

than once. We counted early in the morning or late in the evening and always with winds <2 Kph. The entire sea surrounding both colonies could be observed.

Counts of nests

Counts of nests for the whole islands were done by the same number of people involved in the ringing (two teams of two people on both islands) moving in a line back and forth through the nesting areas. The counts were recorded by sectors to use some of them for the estimation of productivity by capture-recapture (see below). Nest counting efficiency for ground-nesting gulls may vary depending on the laying synchrony, size of the sub-colony, location of the sub-colonies, and number of people involved in the counts. Yellow-legged Gulls are relatively synchronous at laying and similar techniques carried out at other colonies with similar habitat characteristics and population size yielded a small survey error (±4%, see Bosch *et al.* 1994b). Nest counts were carried out at the end of the incubation period of the species (7-13 April 2000 and 16-18 April 2001 at Benidorm Island; 21-25 April 2000 and 18-19 April 2001 at Columbretes), when most pairs had laid eggs but few broods had hatched (e.g. Wanless & Harris 1984, Green and Hirons 1988).

Estimates of productivity

In mark-recapture, the ratio of chicks per breeding pair (i.e. our estimate of productivity) was calculated as the number of chicks estimated from the equation, divided by the number of nests previously counted in those sectors of the two islands where chicks were captured. Since 95% confidence intervals were provided (Krebs 1989), no overlap between the confidence intervals of two estimates meant that they were significantly different at statistical level with alpha < 0.05. Productivity from the flock counting method was calculated as the total number of fledglings counted at sea divided by the total number of nests counted in the whole colony.

RESULTS

Estimates of productivity at Benidorm Island were similar in both years, and estimates from flock counts were within the range of values estimated from mark-recapture (Table 2). Conversely, the estimates from flock counts in one of the study years (2000) at Columbretes were well below the lowest 95% CI of the mark-recapture estimates (Tables 1 and 2).

DISCUSSION

Accurate values of productivity are difficult to obtain for ground-nesting gulls because: (a) estimates must be commonly derived from a sample, (b) if no previous knowledge of the colony is available and a stratified random sampling design is not applied, estimates can be biased by sampling error resulting from sub-colonies formed by gulls having different parental quality, and (c) most methods tend to either overestimate (mark-recapture) or underestimate (counts of flocks) actual productivity of the colony (see Erwin & Custer 1982). Hence, information about the degree of bias is important in obtaining the best possible estimate of productivity.

Mark-recapture, although commonly used, could be a highly biased method, especially when chicks are ringed at a young age, because mortality up to fledging can be high especially when food availability is low. Indeed, according to our results, mark-recapture can give similar estimates to those obtained from flock counts, after chicks have already fledged. The consistency between methods for both years at Benidorm suggests that mark-recapture can provide useful productivity estimates, assuming that flock counts in small and isolated colonies are a reliable estimate of true productivity, as counts in these colonies are subject to negligible sources of error. This assumption probably was valid in our study because flock counts were carried out at the end of the breeding season (i.e. once surviving chicks are fledglings) and the colony was small and isolated from other large gull colonies. Flock counts may underestimate the number of fledglings if the survey is done too early in the season, before all chicks have fledged, or if done too late after some fledglings have already left the colony. In addition, not all chicks fledge at the same time, despite Yellow-legged Gulls being quite synchronous at laying. However, although the effect of synchrony is likely to be an important source of bias in big colonies (i.e. on large islands), this is less likely to be true for small colonies. Thus, any of the two methods (but always the same) can be useful when the research goal is to examine inter-annual variability in productivity. To address possible differences in fledging timing across years flock counts should be repeated often during each breeding season.

The fact that estimates obtained from both methods roughly coincided at Benidorm during two consecutive years but not at Columbretes during one of the study years (where a 45% productivity drop occurred) suggests that there was, as expected, heavy mortality of chicks after ringing at Columbretes in 2000, when a trawling-fishing moratorium took place between the mark-recapture estimate and the flock count. The mortality was likely due to reduced food availability (see Oro *et al.* 1995).

Although mark-recapture and counts of flocks can give similar results when low mortality of old chicks occurs, the former method has a higher cost for gulls in terms of disturbance and requires more effort from researcher. So, when both methods are applicable it is more advisable to use flock counts. However, in islands where local features prevent the use of flock counts (e.g. large islands) mark-recapture is a good alternative. Moreover, mark-recapture allows the researcher to have individually marked animals for the estimation of demographic parameters such as survival and recruitment.

TABLE 2
Breeding success (number of chicks or fledglings per pair) of Yellow-legged Gulls (*Larus cachinnans*) estimated by two different methods

	Mark-recapture		Flock counts	
Island	2000	2001	2000	2001
Columbretes	1.60 (1.16-2.04)[a]	1.00 (0.82-1.18)[1]	0.88	0.80
Benidorm	0.46 (0.36-0.56)[a]	0.52 (0.38-0.66)[1]	0.40	0.44

[1] 95% lower and upper binomial Confidence Interval

When causes of high mortality of chicks of old age may operate, counts of flocks at sea late in the breeding season (in small and isolated colonies) may provide reliable estimates of true annual productivity. Estimates of productivity counting chicks before departure from the colony under an scenario of high late chick mortality will inevitably be inaccurate estimates of true productivity. Hence, when faced with estimates of productivity the researcher must first weight the likelihood and magnitude of late chick mortality before choosing among these two field methods.

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