

Evaluation of Mist-netting, Nest-searching and Other Methods for Monitoring Demographic Processes in Landbird Populations

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Abstract — Demographic processes (reproductive success, survival of young and adults, recruitment of young into the breeding population) are critical to monitoring and managing landbird populations. We discuss different techniques that have been used to monitor these demographic processes in landbird populations, focusing on constant-effort mist-netting (CEM). We assess whether CEM can provide valid measures of year-to-year variation in fecundity, by comparing fledgling production (determined from intensive nest-searching and -monitoring) with mist net captures of Hatching Year birds. In addition to assessing bias in capture and recapture of Wrentit adults, we consider whether estimates of adult survival obtained from mist net capture-recapture data are accurate.

Among Wrentits the number of locally-born young caught in nets mirrored the local production of fledglings, but the overall number of HY birds caught did not track local production of young. In contrast, the number of HY Song Sparrows caught reflected local production of Song Sparrow fledglings, thus demonstrating variation between species in the ability of CEM to track changes in local productivity. With regard to Wrentit adults, mist nets tended to catch mostly non-breeders (floaters), as opposed to breeders. Recapture probability (within season and between seasons) was high among breeders (71% recapture probability between years) but low among non-breeders (5% recapture probability between years). Survival was accurately estimated from capture/recapture data, provided that breeders could be distinguished from non-breeders. Breeders were very likely to be recaptured, thus providing no evidence of net-avoidance. Results suggest that a low rate of recapturing adults in subsequent breeding seasons (obtained in some CEM studies) reflects inclusion of transient non-breeders with more philopatric breeders.

We recommend: 1) That the choice of monitoring techniques be tailored to match the objectives of the monitoring program. 2) That more work is needed in developing and

validating different monitoring methods, especially with regard to constant-effort mist-netting. 3) That calculations of adult survivorship using mist net capture-recapture data be restricted to (presumed) breeders. 4) That monitoring programs adopt a multi-level, integrated approach, especially if species of special concern have been identified.

INTRODUCTION

Our starting point is the question: What does a manager need to know to manage a species or a set of species? In our opinion, **A manager needs to identify problems (or potential problems), to devise possible solutions, and to monitor these species to determine success of the management action.** To accomplish these objectives requires detailed information on demographic processes (Temple & Wiens 1989). Four critical components of demography are:

- 1) Adult survivorship
- 2) Reproductive success (i.e., production of young or productivity),
- 3) Recruitment of young into the breeding population, and

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- 4) Population size or density (especially breeding population size).

There is widespread consensus that monitoring population density of neotropical migrant birds is critical, but the same consensus has not been reached with regard to the first three demographic components. We focus on these three components because the change in breeding population size from year to year, representing decline or recovery of a species, can be directly attributed to a combination of the first three components and only these components (provided that immigration balances emigration). Our goal is not so much to persuade managers that measuring productivity and survivorship is critical for species of concern (see, for example, DeSante [this volume]), but to consider how to carry out a program of monitoring demographic processes.

The Point Reyes Bird Observatory (PRBO) has been involved in research and monitoring of migrant and resident landbird populations for over two decades (Geupel & Nur, this volume). Building on the work of L. Richard Mewaldt, C. J. Ralph, David DeSante, and others at the Observatory, PRBO has developed an integrated, four-level approach to the study of avian population processes. The levels, in order of increasing precision and/or scale of resolution, are:

- 1) Point counts, to assay breeding population density over a large area,
- 2) Constant-effort mist-netting (CEM), to provide indices of productivity (specifically, production of independent young) over a moderately large area and, potentially, to provide information on survivorship,
- 3) Nest-searching and -monitoring, to provide site-specific and habitat-specific information regarding success at producing young, and
- 4) Spot-mapping of color-banded individuals, to determine breeding status, absolute breeding density and survival of adults.

We recognize that not all managers will be able to implement all the enumerated levels of monitoring, but we wish to encourage adoption of as many as feasible. One of our goals is to provide a persuasive argument that implementing all four levels will provide superior information about the population dynamics of a species of concern and mechanisms underlying observed dynamics.

These monitoring methods can potentially provide critical data for managers, yet their accuracy, utility, and even, in some cases, validity, remain to be established. This is especially true for constant-effort mist-netting, a new monitoring technique that forms the basis of a North American monitoring program (DeSante this volume). CEM has attracted much interest because it can provide information on demographic processes, yet is not as labor-intensive as other methods, e.g., nest-searching (Martin & Geupel in press). Nevertheless, there has been little work to date to validate CEM as a monitoring technique nor to examine assumptions underlying its use - and these are our two overall objectives in this paper. Some more specific questions that we wish to address are:

- 1) Does the variation in number of Hatching Year birds caught during CEM accurately reflect production of young and other demographic variables? Is there variation among species?
- 2) Which individuals (among adults) are likely to be caught in nets? How likely are they to be recaptured? Are there biases in capture and recapture of individuals?
- 3) Can capture-recapture data obtained from CEM provide accurate measures of annual adult survival?

We wish to emphasize that in this paper we are evaluating methods to measure year-to-year variation in demography, that is **temporal variation**. Using these methods a manager would be able to monitor trends in time. However, managers will often be interested in variation between patches - even between habitats - that is, **spatial variation**. No one, to our knowledge, has attempted to validate constant-effort mist-netting with respect to spatial variation, though we are currently collecting data that will address this point (Nur & Geupel, unpublished). It would be rash to infer that CEM is valid, or invalid, for monitoring spatial variation, on the basis of its ability, or inability, to monitor temporal variation.

STUDY SPECIES AND STUDY SITE

To evaluate CEM, we have concentrated our efforts on two species, the Song Sparrow (*Melospiza melodia*), a widespread and well-studied species (Nice 1937), and the Wrentit (*Chamaea fasciata*), a much more localized species, restricted to California, Oregon and Baja California, the subject of little study to date (Erickson 1938, Geupel & DeSante 1990).

Field work has been conducted at PRBO's Palomarin Field Station, located just within the southern boundary of Point Reyes National Seashore and adjacent to the Pacific Ocean. On our

main study site, 36 ha in size, we carry out all four levels of monitoring: point counts, constant effort mist-netting, nest searches and intensive spotmapping (and behavioral observations) of color-banded bird. Spotmapping of color-banded birds allows us to establish the identity of territory holders. Here we discuss data from the last three mentioned levels only. Fourteen permanent mist net locations have been established in one portion of the 36 ha study grid (Fig. 1), and netting is conducted throughout the year, in a standardized fashion, for three to seven days per week (depending on season). The study site and methods are described in DeSante and Geupel (1987) and Geupel and DeSante (1990). Suffice it to say that we attempt to locate all nests of study species and follow the fate of those nests. Nearly all successful nests (those fledging

one or more young) are found before fledging and their young individually color-banded. Additional individuals are color-banded when first caught in mist nets as hatching year (HY) or as after-hatching year (AHY) birds.

Both species are year-round residents at Palomarin. The Wrentit is particularly sedentary (Erickson 1938, Johnson 1972) and thus well suited for estimating survivorship on the basis of capture/recapture data (adults are unlikely to disperse between years). The Song Sparrow shows intraspecific variability in dispersal and migratory tendencies, though the Palomarin population appears fairly sedentary. It is precisely in sedentary populations such as these that we would expect constant-effort mist-netting to be most accurately track the local production of young.

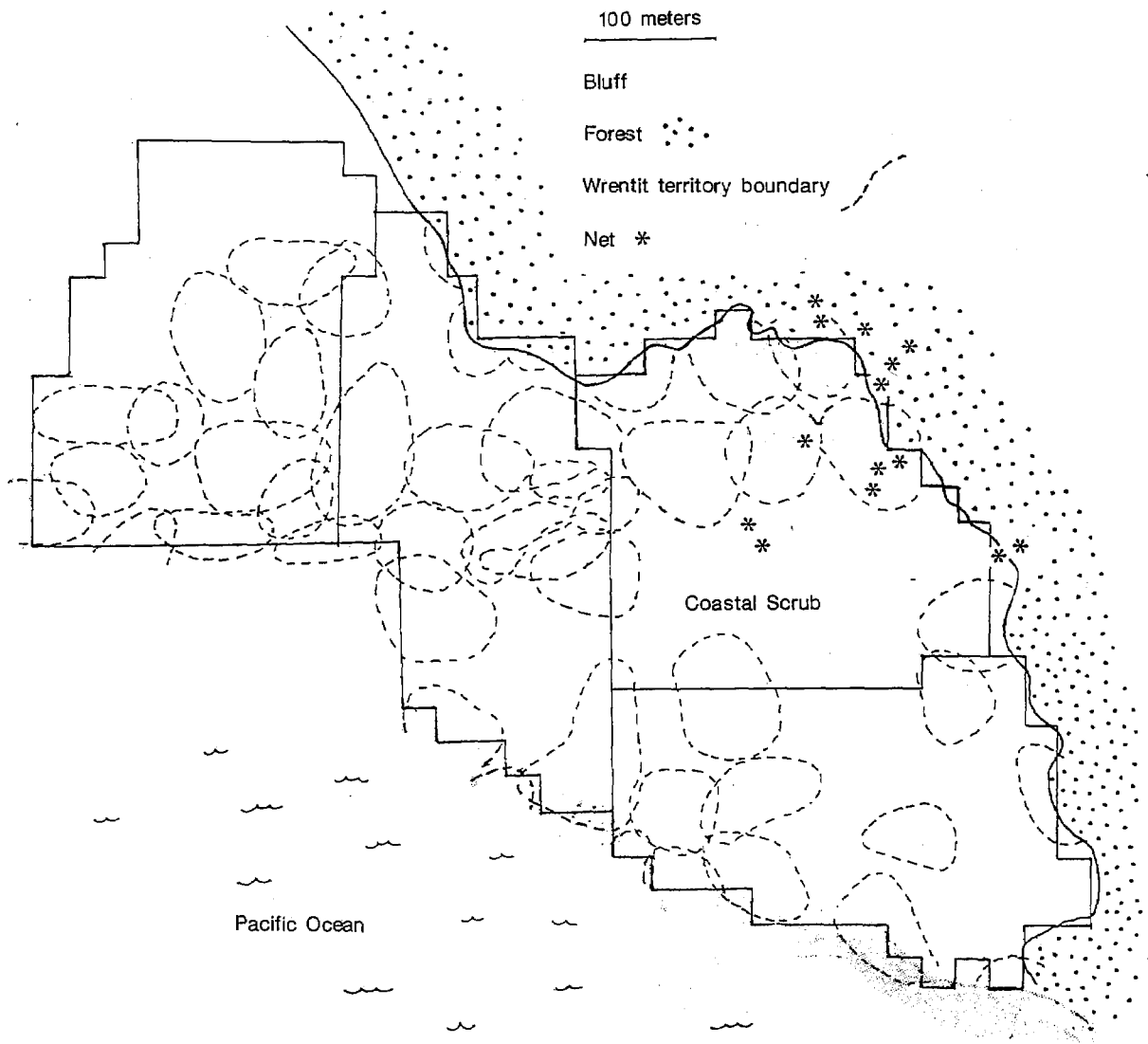


Figure 1. — Map of the study area, Palomarin Field Station, Point Reyes National Seashore. Nest-searches and spot-mapping of color-banded birds took place in the four contiguous areas marked by solid, rectilinear lines, totalling 36 ha in area. Constant effort mist-netting was conducted at nets marked with asterisks. Dotted lines enclose Wrentit territorial boundaries (1985 shown).

RESULTS

Monitoring productivity using mist nets

The more Wrentit fledglings produced on the plot, the more locally-hatched young were caught in our CEM program, conducted during the breeding season (Fig. 2). Almost fifty per-cent of year-to-year variation in number of locally-hatched young caught in nets can be accounted for by variation in number of fledglings produced. This finding confirms that mist nets are indeed measuring local production of young. Another way to view this result is to consider the proportion of fledged young which were caught in nets. Over a ten-year period, 24.2% of Wrentit fledglings were caught in nets during the summer months ($n = 714$). In most years, a fairly consistent percentage of Wrentit fledglings were caught, usually between 19% and 28%, but there were exceptions, especially 1983, during which only one of 57 fledged young was caught (1.8%). That year was one of unusually heavy rainfall (a record-breaking El Niño event), which may have depressed post-fledging survival of Wrentits.

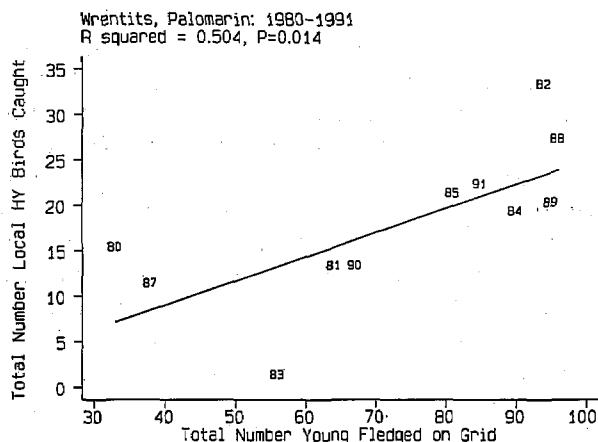


Figure 2. — Number of locally-born Hatching Year (HY) Wrentits caught in each breeding season in relation to total number of Wrentit young fledged on the study grid (see text). '80' refers to 1980 breeding season, etc. The solid line is the best least squares fit to the data; regression statistics are provided in the figure. The more young are produced in the study grid in a year, the more of these locally-hatched young are caught in the standardized array of mist nets.

Of wider interest, though, is the question, Did the total number of HY Wrentits caught in nets—no matter what their origin—provide a good measure of Wrentit fledgling production? This answer is disappointing. There was only a weak, non-significant relationship between production of fledglings on the 36 ha study grid and the total number of HY birds caught. The relationship is marginally improved by considering the ratio of HY birds to AHY birds caught in the nets as the dependent variable (the same measure of productivity used by the MAPS

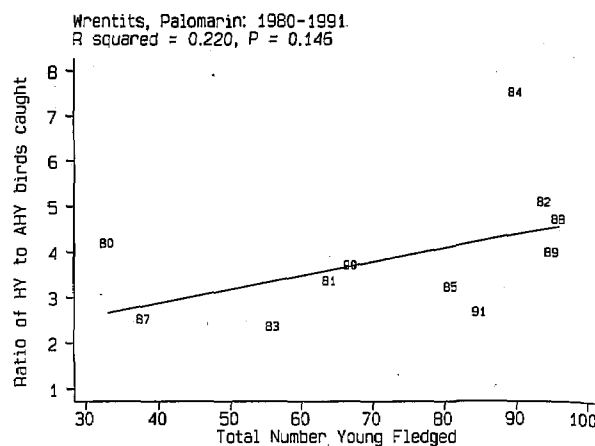


Figure 3. — Ratio of Hatching Year (HY) Wrentits to After Hatching Year Wrentits caught in each breeding season in relation to total number of Wrentit young fledged on the study grid. There is only a weak relationship between productivity as measured by the nets (shown on the Y-axis) and productivity as measured by direct observations of fledgling production (shown on the X-axis). The statistical results were similar when we substituted total HY birds caught for the ratio HY/AHY, confirming the pattern seen in this Figure. '80' refers to 1980 breeding season, etc. The solid line is the best least squares fit to the data; regression statistics are provided in the figure.

program), rather than simply the total number of HY birds, but we are still left with a result that is clearly non-significant ($P > 0.1$; Fig. 3).

This result presents a paradox. To resolve it, we note that the total number of HY birds is the sum of locally born young and those which are non-local (born outside the study grid). Above, we showed that the number of locally born young caught in the nets correlated with fledgling production, but it turns out that the number of non-local young caught in the nets had nearly nothing to do with local fledgling production ($r = +0.065$, $P > 0.8$). One explanation for this last result is that the production of local young is not correlated with the production of non-local young, in other words, reproductive success for Wrentits is very variable from one plot to another. An alternative explanation is that the number of non-local young caught reflects dispersal tendencies of those young more than it reflects reproductive success elsewhere.

Whereas HY captures did not predict local productivity well, they did predict a different demographic parameter, the proportion of Wrentits breeding the next year that were one year of age. This parameter is an index of success of a cohort in recruiting the following year. The greater the ratio of HY to AHY birds caught during the breeding season, the greater the proportion of one-year old birds breeding in the next year ($R^2 = 0.444$, $P = 0.035$). In fact, the mistnet-based measure of productivity did a slightly better job at predicting next year's age structure than did productivity as measured by nest-searches (that criterion being the number of fledglings reared per pair), $r = +0.666$ vs. $r = +0.608$, respectively. Why might that be? Our answer is that mist nets performed well in predicting recruitment

because they sample juveniles at a later stage in life—a few weeks post-fledging, rather than at the time of fledging, as is the case for nest-searches. Thus mortality in the period soon after fledging is not reflected by data from nest-monitoring, but is reflected in CEM captures.

Turning to Song Sparrows we see a different picture: there is a very good relationship between fledgling production on the grid (total number of Song Sparrows fledged) and number of HY birds caught in the nets (Fig. 4A). In fact, 67% of the between year variation in HY captures can be accounted for by differences in local fledgling production and vice versa. We stress that the very same comparison for Wrentits is unambiguously not significant ($P > 0.4$) and the corresponding R^2 is only 6% (Fig. 4B). In other words, there is marked variation between species in the ability of mist nets to track year to year changes in the local production of young.

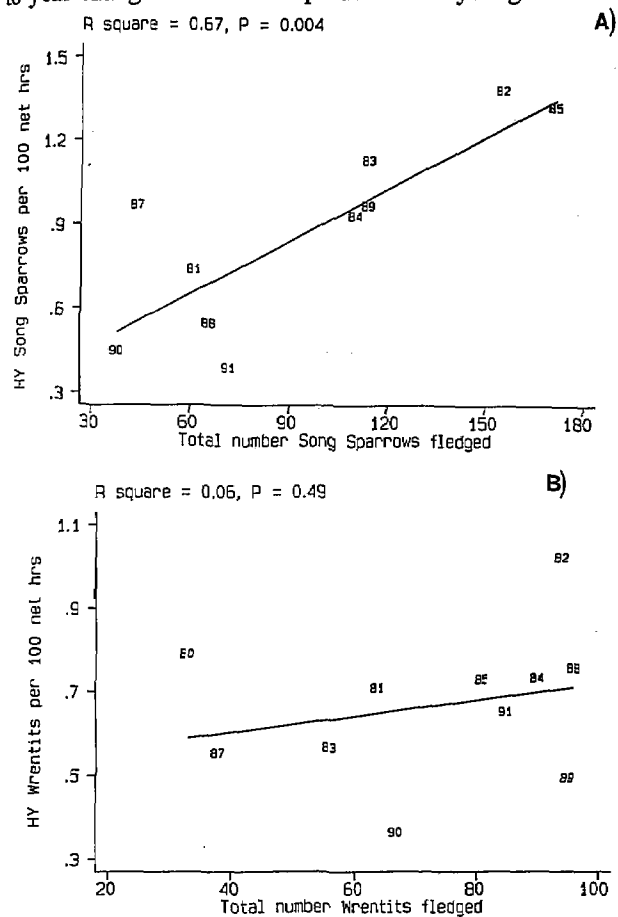


Figure 4. — A) Number of Hatching Year (HY) Song Sparrows caught in each breeding season (regardless of origin) per 100 net-hours in relation to total number of Song Sparrow young fledged on the study grid (see text). '80' refers to 1980 breeding season, etc. The solid line is the best least squares fit to the data; regression statistics are provided in the figure. B) Same variables and same years of data as in part A), but for Wrentits. The solid line is the best least squares fit to the data; regression statistics are provided in the figure. For Song Sparrows, there is a very good relationship between productivity as determined by mist nets and productivity determined from nest-monitoring. The same relationship does not hold for Wrentits.

Captures of Adults: Breeders vs. Floaters

Considering the capture and recapture of adults, we found that most Wrentits caught in mist nets were apparently non-breeders, that is, floaters (O. Williams, G. Geupel & N. Nur, unpublished; Geupel et al. 1992). Non-breeders were defined as individuals not known to hold a territory. Since all territory holders within 200 m of the mist nets were known, and since Wrentit breeders more than 200 m from the nearest net were almost never caught ($<1\%$, $n = 389$, Nur & Geupel 1993), we inferred that individuals caught who did not hold a territory were non-breeders.

On average about two floaters were caught for every breeder caught ($\bar{X} = 18.9$ non-breeders per year vs. $\bar{X} = 9.1$ breeders caught per year, $n = 10$ years). This difference arose not because floaters outnumbered breeders, but because breeders stayed put; only breeders with territories near mist nets—one or at most two territories away—were caught (Nur & Geupel 1993). Breeders further away were not caught. In contrast, non-breeders were very transient. Over the course of the breeding season a high number "passed through" our study site. The degree of transience is indicated, first of all, by the fact that of 188 non-breeders captured over a 10-year period, only 18 (9.6%) had been previously banded at Palomarin in their first summer or fall of life. Four individuals caught were locally-born (out of more than 700 banded fledglings) and the other 14 had been first caught as independent juveniles in their first fall. Moreover, once caught, most nonbreeders were never seen again. Only 20% of nonbreeders were caught again in the same year ($n = 274$; Table 1), and another 8% were seen and identified by means of their color bands (Williams, Geupel & Nur, unpublished). In contrast, most breeders were caught repeatedly during the breeding season. Seventy-eight percent of breeders were recaptured in the same year ($n = 78$), some repeatedly (Table 1). This result implies little net-avoidance among breeding Wrentits, even though these birds had ample opportunity to learn where nets were placed.

In short, within a season, breeders were much more likely to be recaptured than non-breeders. The same pattern held between seasons. Many breeders (40.6%) were recaptured in the following season, whereas few non-breeders were (only 1.8%). In other words, breeders were twenty times as likely to be recaptured in a subsequent season as were non-breeders (G test, $P < 0.0001$). Such a difference in recapture rates can, in theory, represent differences in survival and/or differences in recapture probability (i.e., the probability an individual is recaptured the next year, given that it has survived). We have used the statistical program SURGE (Lebreton et al. 1992) to estimate these two parameters,

Table 1. — Same-Year recaptures of Wrentit breeders and non-breeders at Palomarin (1981-1991). Wrentit breeders are often recaptured in the same year, providing no evidence of net-avoidance. Non-breeders are much more transient and thus rarely recaptured.

Breeders			Non-breeders		
Number of Captures	Frequency ¹	Percent	Number of Captures	Frequency ¹	Percent
1	22	29	1	196	78
2	14	18	2	37	15
3	10	13	3	9	4
4	12	16	4	3	1.2
5	5	7	5	3	1.2
6	3	4	6	1	0.4
7	6	8	7	2	0.8
8-14	4	5	-	-	-
Total	78	100	Total	251	100

¹ - The same individual is included more than once if it was caught in different years.

survival and recapture probability. Recapture probability was estimated to be 71% for breeders, vs. 5% for non-breeders (G test, $P < 0.0001$); whereas, survival probability did not differ significantly between the two groups (G test, $P > 0.3$; Nur & Geupel 1993).

SURGE analysis indicated survival probability of breeders to be 57% (95% confidence interval, 47% - 67%), similar to estimates of adult survival derived from re-sightings of color-banded birds, 59% (females) and 64% (males) ($n = 523$, Nur & Geupel, unpublished). However, had we made no distinction according to breeding status in the mist net analysis, thus pooling breeders and non-breeders, estimated survival probability would have been 31% (95% confidence interval, 22% - 41%), significantly lower than the estimate obtained from breeders alone. Thus we conclude that **capture-recapture data collected with constant effort mist-netting can provide a good index of survival—among breeders**. The difficulty is to distinguish breeders from non-breeders, which cannot be determined in Wrentits by the presence or absence of brood patch or cloacal protruberance (unpublished data). One suggestion is to calculate survival rates using only adults caught twice or more in the same breeding season, since most breeders (62%) were caught more than once, whereas most non-breeders (72%) were not.

CONCLUSIONS AND RECOMMENDATIONS

To summarize, among Wrentits the number of locally-born young caught in nets mirrored the local production of fledglings, but the overall number of HY birds caught did not track local production of young. In contrast, the number of HY Song Sparrows caught as part of a CEM regime did mirror local

production of young. Thus, there is variation between species in the ability of CEM to track changes in local productivity. Our results are similar to those of Feu & McMeeking (1991) who found that in Eurasian Blackbirds (*Turdus merula*), the number of juveniles caught with CEM (part of the Constant Effort Sites Scheme of the British Trust for Ornithology) was correlated with local productivity, but that in Song Thrushes (*Turdus philomelos*) there was no such relationship.

With regard to Wrentit adults, we found that mist nets tended to catch non-breeders (floaters) rather than breeders, and that recapture probability (within season and between seasons) was strongly related to breeding status. Survival was accurately estimated from capture/recapture data, provided that breeders could be distinguished. Breeders were very likely to be recaptured, thus providing no evidence of net-avoidance. Our results suggest that a low rate of recapturing adults in subsequent breeding seasons (obtained in some CEM studies) reflects inclusion of transient non-breeders with more philopatric breeders, rather than being due to avoidance of mist nets.

We recommend:

1) **Before implementing a monitoring program, determine one's objectives.** For example, some monitoring programs may be geared toward studying temporal trends whereas others may focus on spatial variation in demographic parameters. Our own attempt to validate mist netting and that of Feu & McMeeking (1991) have investigated temporal variation. The limited data gathered to date suggests that mist nets might provide a valid index of productivity, albeit with species-to-species variation in their efficacy. It remains to be seen, though, whether mist nets provide a good index of spatial variation. The answer would depend on degree of patchiness,

extent of spatial coverage by mist nets, differences in catchability as a function of habitat, etc. With nest-searching, spatial variation presents a different sort of problem: the connection between nesting success and the patch sampled is clear, but the problem may be that nesting success in an investigated patch may not easily extrapolate to other patches, whether nearby or far away. Other objectives to be considered are the identity of the demographic parameters (all? just productivity? just survivorship?) and the spatial scale (tens of acres or thousands of acres?)

2) **More work is needed in developing and validating different monitoring methods.** This holds for all methods but we feel it is particularly true for mist-netting. Mist-netting has been a method for trapping birds for several decades, but has only recently been adopted and promoted as a means for monitoring bird populations. Even in England, where the British Trust for Ornithology has been conducting the Constant Effort Sites Scheme for about a decade, there has been little work on validation. This omission applies, for example, to the report by Baillie et al. (1986), which evaluates the Constant Effort Sites Scheme, but does not attempt to validate results. Other points requiring fine-tuning are, Which months to run nets in? Where best to place nets? How many days to run nets per standard, ten-day period? What is the effect of habitat on efficacy and validity of mist-netting data? What is the catchment area for juvenile and adult birds (O'Connor 1992)?

3) **Calculations of adult survivorship from mist net capture-recapture data be restricted to (presumed) breeders.** If non-breeders cannot be distinguished on the basis of brood patch, we recommend restricting survivorship analysis to adults caught twice or more in the same breeding season. One implication of our work is that those who wish to infer survivorship from capture-recapture data should run the same set of nets relatively often (thereby increasing the sample of birds caught twice in the same season).

4) **Adoption of multi-level, integrated monitoring, especially if species of special concern have been identified.** Our study at Palomarin indicated ways in which a multi-level approach to monitoring is the most powerful. Our point is that using several techniques in concert, rather than being redundant, provides information that could not otherwise be attained. In other words, the whole is greater than the sum of the individual parts. Consider these two examples from our field study. First, fledgling production of Wrentits in 1983 was fairly high but only one independent, locally-born fledgling was caught in the nets. With only nest-monitoring to go on, we would have thought productivity was reasonably good that year. With only mist-netting to go on, we would have identified low productivity of the 1983 cohort (Figure 4B) but we would have had little idea as to cause. From mist-netting data alone we could not separate poor nesting success (e.g. high nest-predation) from poor post-fledging survival.

The second example of the power of a multi-level, integrated approach is our ability to track abundance of non-breeders (floaters). Through spot-mapping or point counts

we can potentially track the number of breeders, but floaters are an important component of Neotropical migrant demography, yet are hard to observe in the field due to their secretive nature. Mist-netting allowed us to track the total number of adults (whether breeding or not), but by itself could not tell us which were breeders (as mentioned above, in Wrentits, neither brood patch nor cloacal protruberance are indicators of breeding status). Putting both together (total adult abundance and breeder abundance) allows inference as to non-breeder abundance. The ability of a population to respond to disturbance might well be related to the existence and abundance of non-breeders (as exemplified by the Northern Spotted Owl (*Strix occidentalis caurina*), Verner 1992).

A multi-level monitoring program is more labor-intensive and expensive than a single-level approach (e.g., point counts), but if such a program can alert us to problems and help identify solutions *before* a species is certifiably endangered, the effort will represent an economical investment.

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