
Presence–Absence versus Abundance Data for Monitoring Threatened Species

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Abstract: *Effective detection of population trend is crucial for managing threatened species. Little theory exists, however, to assist managers in choosing the most cost-effective monitoring techniques for diagnosing trend. We present a framework for determining the optimal monitoring strategy by simulating a manager collecting data on a declining species, the Chestnut-rumped Hylacola (*Hylacola pyrrhopygia parkeri*), to determine whether the species should be listed under the IUCN (World Conservation Union) Red List. We compared the efficiencies of two strategies for detecting trend, abundance, and presence–absence surveys, under financial constraints. One might expect the abundance surveys to be superior under all circumstances because more information is collected at each site. Nevertheless, the presence–absence data can be collected at more sites because the surveyor is not obliged to spend a fixed amount of time at each site. The optimal strategy for monitoring was very dependent on the budget available. Under some circumstances, presence–absence surveys outperformed abundance surveys for diagnosing the IUCN Red List categories cost-effectively. Abundance surveys were best if the species was expected to be recorded more than 16 times/year; otherwise, presence–absence surveys were best. The relationship between the strategies we investigated is likely to be relevant for many comparisons of presence–absence or abundance data. Managers of any cryptic or low-density species who hope to maximize their success of estimating trend should find an application for our results.*

Keywords: Chestnut-rumped Hylacola, economics, *Hylacola pyrrhopygia parkeri*, IUCN Red List, occupancy data, optimal monitoring, species detectability, threatened species management

Datos de Presencia-Ausencia versus Abundancia para el Monitoreo de Especies Amenazadas

Resumen: *La detección efectiva de la tendencia de una población es crucial para la gestión de especies amenazadas. Sin embargo, existe poca teoría para asistir a los gestores en la selección de las técnicas más rentables para el monitoreo de una tendencia diagnosticada. Presentamos un marco de referencia para determinar la estrategia óptima de monitoreo mediante la simulación de un gestor que recolecta datos de una especie en declinación, *Hylacola pyrrhopygia parkeri*, para determinar si la especie debiera estar enlistada bajo los criterios de la IUCN (Unión Mundial para la Conservación). Comparamos la eficiencia de dos estrategias para detectar tendencia—monitoreos de presencia-ausencia y de abundancia—bajo limitaciones financieras. Se podría esperar que los monitoreos de abundancia sean superiores porque se recolecta más información en cada sitio. Sin embargo, los datos de presencia-ausencia se pueden recolectar en más sitios porque el observador no debe estar un tiempo fijo en cada sitio. La estrategia óptima de monitoreo fue muy dependiente del presupuesto disponible: Bajo algunas circunstancias, los monitoreos de presencia-ausencia fueron mejores que los de abundancia para diagnosticar las categorías de la Lista Roja IUCN rentablemente. Los monitoreos de abundancia fueron mejores si se esperaba que la especie fuera registrada más de 16 veces por año; de lo contrario, los monitoreos de presencia-ausencia fueron mejores. Es probable que la relación entre las estrategias que investigamos sea relevante para muchas comparaciones de datos de presencia-ausencia o abundancia. Los gestores de cualquier especie críptica o de baja densidad que esperan maximizar su éxito en la estimación de tendencias deben encontrar una aplicación para nuestros resultados.*

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Palabras Clave: datos de ocupación, detectabilidad de especies, economía, gestión de especies amenazadas, *Hylacola pyrrhopygia parkeri*, Lista Roja IUCN, monitoreo óptimo

Introduction

Effective detection of population trend is important for managing threatened species. For example, evidence of trends can provide compelling evidence for making listing decisions under the IUCN Red List system (IUCN 2001). Although such decisions are most often made on the basis of total size and geographic distribution (Regan 2003), such data do not always inform us about the threat of extinction (Abrams 2002). For example, some small populations that would be listed on the basis of small size or restricted distribution may in fact be very stable and not actually be under significant threat. Time-series data, especially when combined with some ecological information about the likely factors driving the trend, represent a preferred method for evaluating threat (Abrams 2002). Consequently, the development of improved methods for extracting ecologically meaningful conclusions from time-series monitoring data is an active area of research (Jassby & Powell 1990; Yoccoz et al. 2001; Williams et al. 2002).

To date such studies have focused on two issues: (1) statistical methodology, including understanding which of the many statistical techniques should be used in a given situation (e.g., linear, polynomial, additive, or rank methods [e.g., Thomas 1996] to improve the statistical power of the analysis to detect ecological effects [e.g., Peterman 1990; Taylor & Gerrodette 1993; Shea & Mangel 2001]) and (2) achieving the right balance between statistical significance and power (Mapstone 1995; Di Stefano 2003; Field et al. 2005). Despite the fact that managers tasked with monitoring threatened species are constrained by their budgets, most of these types of studies ignore the economic constraints. More recently, attempts to improve monitoring have also included consideration of the relative economic cost of different monitoring designs (Carlson & Schmiegelow 2002; Field et al. 2005; Pollock 2006).

One problem that remains relatively rarely studied is how to choose among alternative monitoring methods; for example, whether to monitor trends in population size with abundance estimates or simply to track changes in occupancy or distribution with presence-absence data. At first, one might imagine that abundance surveys will always perform better because the data collected contain more information per site. Yet a surveyor collecting presence-absence data may be able to visit more sites because they are not obliged to spend a fixed amount of time at each site, and once they have observed the

species, they can move to another location. Which survey type is better depends on how widespread and abundant the species is to begin with, how difficult it is to detect, and the level of resources available to implement the monitoring. Currently, there is no theoretical framework to evaluate the effects of these variables and thus assist managers with the task of deciding what kind of data to collect.

To address this deficiency, we developed a method to explicitly compare the relative economic efficiencies of presence-absence and abundance data as the basis for listing decisions for species that occur at low densities. We simulated the population dynamics of the Chestnut-rumped Hylacola (*Hylacola pyrrhopygia parkeri*, Schodde & Mason 1999), a declining species, and used the two monitoring methods to estimate the magnitude of decline and assign a threat category (IUCN 2001). We then compared how often each survey technique assigns the species to the correct category. On the basis of our results, we recommend that presence-absence data be used when the species are expected to be observed at 16 or fewer sites. This rule simultaneously considers species ecology and budget available for monitoring.

Methods

To determine the optimal monitoring strategy for declining species, we simulated monitoring of the Mount Lofty Ranges' Chestnut-rumped Hylacola to estimate rate of decline and assign an IUCN category of threat (Fig. 1). Our investigation entailed four steps: (1) simulation of a declining population based on information on current distribution and abundance of the Chestnut-rumped Hylacola; (2) simulation of two different monitoring methods aimed at detecting the population decline over a 10-year period: presence-absence and abundance surveys; (3) trend analysis (i.e., estimation of the rate of decline based on both sets of data analyzed with nonlinear regression); and (4) determination of the IUCN Red List category of threat based on Rule A2b (decline in population size) or Rule A2c (area of occupancy). We repeated each step 5000 times and calculated the fraction of the simulations that correctly diagnosed the threat of extinction for each of the survey methods.

Study Region and Species

The Mount Lofty Ranges' Chestnut-rumped Hylacolas are cryptic birds, inhabiting rocky, inaccessible heath and

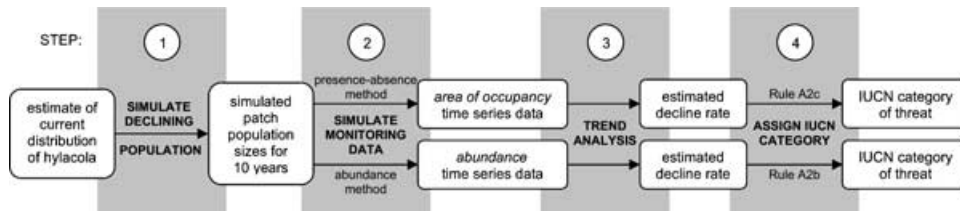


Figure 1. The four steps of the simulation of the monitoring methods and evaluation of threat. The data used and/or produced in the steps of the simulation are in white boxes.

dense undergrowth of eucalypt forests, and woodlands in South Australia (Garnett & Crowley 2000). This subspecies is threatened by habitat fragmentation because of extensive land clearing throughout the region, feral predators, invasions by woody weeds, and residential development (Garnett & Crowley 2000). The species has been nominated for listing as endangered on the basis of Rule B of the IUCN criteria, because it is thought to have a small population and distribution and it is continuing to decline (Garnett & Crowley 2000). We know little about changes over time, however, so information about trend in population size or distribution is required to assess the risk of extinction more accurately.

We used a combination of historical records, survey data, a habitat suitability model (South Australian Department of Environment and Heritage), and expert opinion to obtain approximate values for the current distribution and patch population sizes of the Chestnut-rumped Hylacola as of 2004. From an original area of approximately 686,000 ha, only 13% of the Mount Lofty Ranges is now covered by native vegetation. The landscape is highly fragmented landscape, with only 12 patches >1000 ha and 56% of the remaining vegetation occurring in patches <500 ha in size. We estimated that approximately 377 pairs of the Chestnut-rumped Hylacola occur in 21 of the remaining patches. We defined a patch as a region of relatively continuous suitable habitat. The total area of occupancy is about 14,600 ha and patches range in size from 76.6 to 2777.3 ha, with between 2 and 70 pairs/patch.

Simulation

STEP 1: SIMULATION OF POPULATION DECLINE

We used a simple spatially structured population model to simulate declines in the patch population sizes:

$$N_{i,t+1} = N_{i,t}\lambda, \quad (1)$$

where $N_{i,t}$ is the population size of patch i at time t and λ is the rate of change. A decline of 65% was implemented over 10 years by assigning an annual rate of change (λ) of close to 0.9003. We implemented probabilistic rounding of the population size in each patch at each time step

to avoid the population size reaching an asymptote at or above zero. This introduced a small degree of stochasticity. However, the resulting rate of decline was always well within the range to meet the criterion for the endangered category (i.e., a decline of 50–80%). The resulting rate of decline in area of occupancy (mean = 0.04% over 10 years, ranging from 0 to 22%) was much smaller than the rate of decline in total population size (mean = 65% over 10 years, ranging from 60 to 70%).

STEP 2: SIMULATION OF MONITORING DATA

We simulated the two types of surveys (abundance, which tracked the total population size, and presence-absence surveys, which tracked the area of occupancy) at 1-year intervals. We simulated a range of time budgets available for monitoring, from 5 to 200 person days/year (5, 10, 15, 20, 25, 50, 75, . . . , 200 person days/year), where the surveyor worked for a maximum of 6 hours/day.

Abundance survey. For the abundance surveys we simulated multiple, active, timed area searches (e.g., 20 minutes in 2-ha plots; Loyn 1986) in each of the patches and recorded count data. The number of plots per patch depended on the size of the patch and the total budget available to do the surveys, with the proportion of surveys done in each patch roughly proportional to the square root of patch area. At least three plots were surveyed in each patch. If the time budget was too small to allow three plots in all 21 patches, then fewer patches were visited and patches were prioritized on the basis of size. Larger patches were visited first. Each survey was allocated 45 minutes (20 minutes for the survey and an additional 25 minutes for travel time; i.e., driving between patches and walking to sites).

The number of hylacolas observed in each patch each year was calculated as follows. Chestnut-rumped Hylacolas are frequently found in pairs (Higgins & Peter 2002), and the probability of finding more than one pair in a 2-ha plot is negligible. Consequently, a binomial probability distribution can be used to describe the number of plots in a patch in which a pair of birds is observed. We assumed the bird has uniform density across the entire patch. Hence, the probability of a pair of birds being present in a 2-ha plot (occupancy) for a given patch i at

time t , $\psi_{i,t}$, is equal to two times the number of pairs per hectare (number of birds found in patch i at time t , $N_{i,t}$, divided by the area of the patch, A_i):

$$\psi_{i,t} = 2N_{i,t}/A_i. \quad (2)$$

The conditional probability of seeing a pair of birds given that it is present, p_c , is referred to hereafter as “detectability” (MacKenzie et al. 2002; Royle & Nichols 2003). Detectability was a constant elicited from data and expert opinion, $p_c = 0.4$ for hylacola. The probability of actually observing a bird in a plot in patch i and year t during a 20-minute period, $p_{i,t}$ (hereafter, referred to as the probability of unconditional detectability or “observability;” Royle & Nichols 2003), was the product of the probability of occupancy, $\psi_{i,t}$, and its conditional detectability, p_c :

$$p_{i,t} = \psi_{i,t}p_c. \quad (3)$$

Assuming independence between each survey, the probability of observing x plots as being occupied from k surveys in patch i at time t is

$$P(x) = \binom{k}{x} p^x (1-p)^{k-x}. \quad (4)$$

The estimated number of pairs, $\tilde{N}_{i,t}$, in patch i at time t was the product of the proportion of surveyed plots, $k_{i,t}$, found to be occupied, $x_{i,t}$, and the area, A_i , of patch i :

$$\tilde{N}_{i,t} = A_i x_{i,t} / k_{i,t}. \quad (5)$$

Every year an estimate of the number of pairs in each patch was recorded. We corrected the count data for detection error by multiplying each data point by the inverse of the estimated detectability ($1/p = 2.5$) and doubling to convert data from pairs to individuals. The patch population sizes were summed to calculate the estimate of total population size.

Presence-absence survey. In the simulation of the presence-absence survey, a patch was systematically searched until a bird was observed or a time cap was reached and then the next patch was searched. We assumed it took 1 hour to travel to and from a patch to conduct a presence-absence survey. Survey time was measured in 20-minute segments and was added on to the travel time. Because the abundance method required travel time between discrete surveys (e.g., 20-minute segments), whereas for the presence-absence method surveys, time was continuous, the travel time for each of the methods was allocated differently. Patches were prioritized on the basis of size. Larger patches were visited first. Patches were surveyed until the total time allocated to conduct surveys was met or all patches were surveyed. We assumed that a surveyor could search for birds across approximately 2 ha in a 20-minute period. The probability of seeing a pair of birds in patch i over a 20-minute

period in year t , $p_{i,t}$, was the same as that used for the abundance survey.

If a pair was detected, then the patch was recorded as occupied, and the time spent surveying the plot was recorded as 20 minutes. If a bird was not detected, then the next 20-minute period began, and the random process was continued until a presence was detected or a time cap was reached. At either point the patch was recorded as being occupied or not and the time spent surveying the plot was recorded. Every year an estimate of the number of patches occupied was recorded. The estimate of occupancy was not corrected for detection error. We used the presence-absence data to estimate area of occupancy by summing the area of the occupied patches each year.

STEP 3: TREND ANALYSIS

We estimated the rate of decline in population size or area of occupancy for 10 years of simulated data collected from the abundance and presence-absence survey methods. We used a constant decay rate to calculate rate of decline with a nonlinear regression.

STEP 4: ASSIGN IUCN CATEGORY OF THREAT

We used the rate of decline to categorize the subspecies on the basis of Rule A of the IUCN threatened species list criteria. We used the point estimate for the rate of decline and did not consider the precision of the estimate. Sufficiently large declines in population size and area of occupancy triggered listing under Rule A2b and Rule A2c, respectively. Decline rates of greater than or equal to 30%, 50%, and 80% over 10 years will meet criteria for listing as vulnerable (VU), endangered (EN), and critically endangered (CE), respectively. If the species declined at a rate of <30% over 10 years, then it was assigned to near threatened or of least concern (NT/LC). If a trend could not be fitted on the basis of the decline model, then the species was assigned to data deficient (DD). Because the mean rate of decline in total population size was 65% over 10 years, the correct IUCN category, based on Rule A2b (i.e., decline in population size), is endangered. Correspondingly, because the decline in area of occupancy was 0.04%, implementing Rule A2c (i.e., decline in area of occupancy) resulted in the correct category of threat being not threatened/of least concern.

STEP 5: COMPARISON OF SURVEY METHODS

For both survey methods the fraction of the 5000 repeat simulations that met the criteria for the five IUCN categories (DD, NT/LC, VU, EN, & CE) was recorded. We explored the effect of budgets on relative accuracy of the survey methods by comparing the proportion of simulations that correctly assigned the IUCN categories for the range of budgets (5–200 person days/year). In addition,

we compared the proportion of simulations that correctly identified the largest decline (i.e., assigned the endangered category) irrespective of the type of data collected.

Sensitivity Analysis

Our estimate for the mean probability of seeing a Chestnut-rumped Hylacola in a period of 20 minutes, p , was 0.0247 (mean, $\psi = 0.06$, $p_c = 0.4$). We explored the effect of variation in observability, p , on the optimal strategy by varying it from 0.01 (birds rarely present and/or rarely detected) to 0.2 (birds more often present and/or better detection; i.e., 0.01, 0.02, 0.05, 0.1, and 0.2). It is possible to vary the observability by changing either the conditional detectability and/or number of individuals. We manipulated the conditional detectability, p_c , to generate changes in observability. However, in theory changes in the number of individuals would have the same effect.

Results

Budget and Success of Monitoring Programs

For the abundance method, the fraction of simulations that correctly assigned the IUCN endangered category was positively correlated with budget (Fig. 2a). However, the relationship between budget and the success of the presence-absence strategy of correctly assigning the species to the category of not threatened was not always positive (Fig. 2b). Specifically, the relationship was negative for small budgets but positive for large budgets. Furthermore, the presence-absence method performed relatively poorly at identifying the decline in area of occupancy (i.e., applying Rule A2c), and, at small budgets, it was considerably better at tracking the decline in population size (i.e., Rule A2b). The budget that maximized the success of the presence-absence method at tracking changes in population size was approximately 55 person-days/year (67% of the simulations assigning the endangered category). The variation in the estimated rate of decline based on the abundance method (Fig. 3a) was larger than the variation in estimated decline based on the presence-absence method (Fig. 3b) for all budgets. Nevertheless, the variation in estimating the rate of decline decreased with budget for both monitoring methods.

Comparison of Survey Methods

The presence-absence survey method more reliably assigned the endangered category than the abundance method for budgets of <73 days/year (Fig. 4). Conversely, the abundance survey method outperformed the presence-absence method for budgets >73 days/year. We refer to this point as “the switching point” (i.e., the budget at which the optimal strategy switched from the presence-absence method to the abundance method).

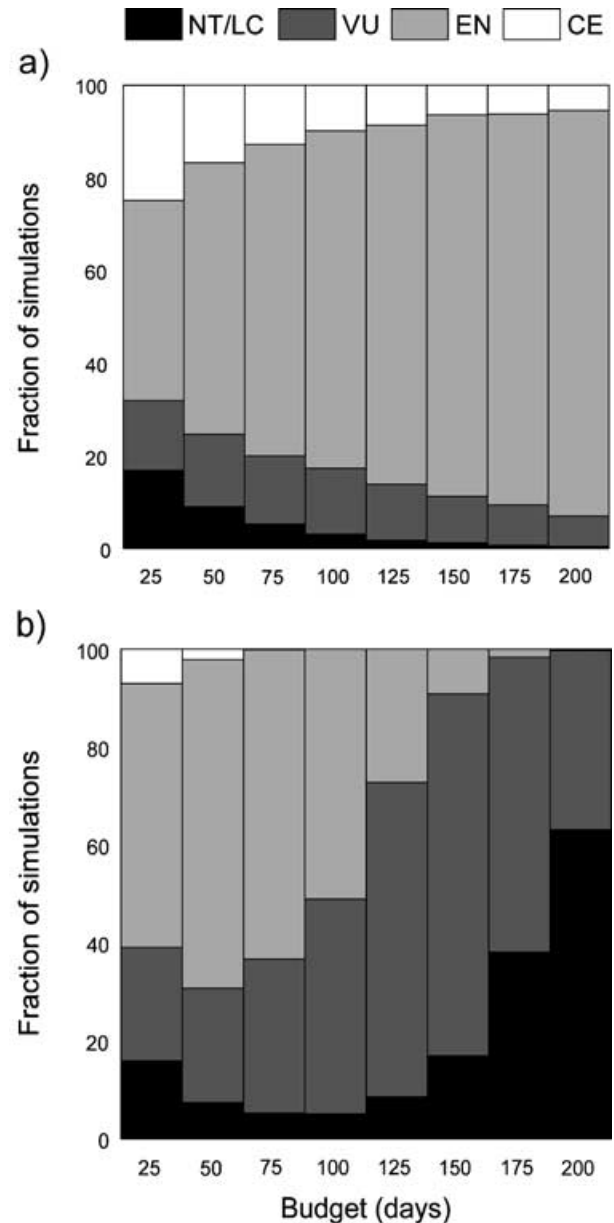


Figure 2. The fraction of 5000 simulations that predicted each category of threat with the (a) abundance survey method and (b) presence-absence survey method. The actual decline in total population size was 65% over 10 years; hence, the true threat classification was endangered (EN) when employing Rule A2b. The actual decline in the area of occupancy was 0.04%, and when employing Rule A2c, the true threat classification was not threatened or of least concern (NT/LC respectively). The abbreviations for the other threat categories are as follows: VU, vulnerable; CE, critically endangered.

Influence of Observability

The optimal choice of survey method depended on the observability of the species, p . For the abundance method,

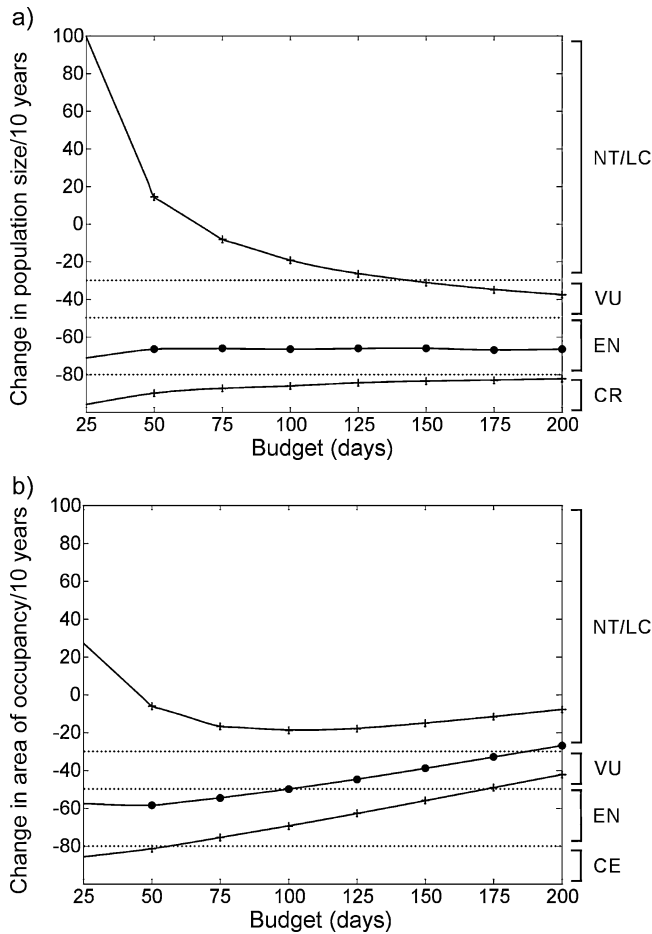


Figure 3. The mean (circles) and 95% confidence intervals (crosses) of the estimated rate of change in (a) population size for the abundance survey method and (b) area of occupancy for the presence-absence survey method. The boundaries for each of the IUCN categories (NT/LC, not threatened or of least concern; VU, vulnerable; EN, endangered; CE, critically endangered) are marked (dotted lines).

as observability of the species increased, so did the success of the survey method. Nevertheless, the relationship between the success of the presence-absence method and budget was not always positive, and the maximum (i.e., point at which the relationship moved from positive to negative) depended on the observability of the species, p . This meant that the switching point also depended on observability, p . Specifically, the point at which the optimal choice changed from presence-absence to abundance occurred at a lower budget for scenarios where the probability of observation was higher (e.g., higher p values). We illustrate this relationship in Fig. 5. The fitted line was effectively described by ($r^2 = 0.99$)

$$B_{sw} * p = 2. \tag{6}$$

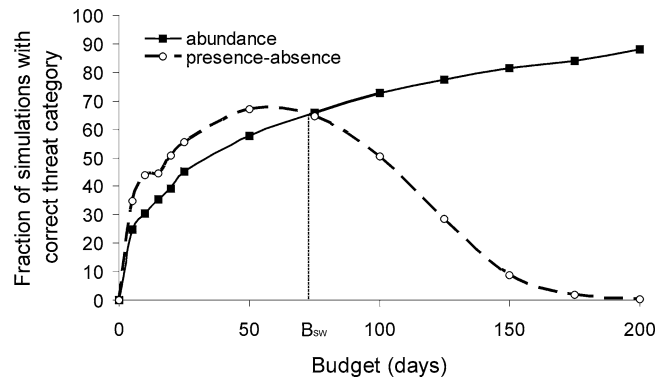


Figure 4. Comparison between the fraction of simulations of each survey method (abundance and presence-absence) that correctly diagnosed the IUCN Red List category of threat as endangered. The switching point, B_{sw} , for the optimal survey is the dotted line ($B_{sw} = 73$ days/year).

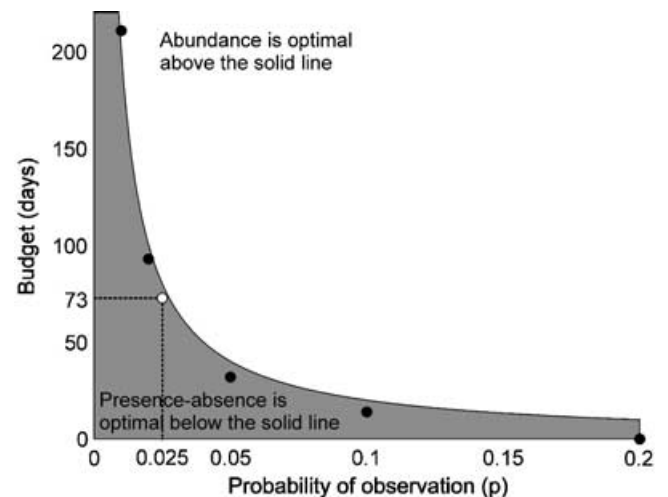


Figure 5. Optimal survey method (abundance or presence-absence surveys) as a function of the budget and the probability of observation, p . The points and solid curve indicate the switching points (B_{sw}) from presence-absence to abundance being optimal. The fitted line is described by $B_{sw} * p = 2$ ($r^2 = 0.99$). The white point and dotted lines indicate the switching point ($B_{sw} = 73$ days) for the Chestnut-rumped Hylacola, for which the mean probability of observation, p , is 0.0247. Abundance and presence-absence surveys are optimal in the unshaded and shaded areas of the graph, respectively.

Thus, the switching point occurred when birds were present in 2 days worth of eight abundance surveys/day (i.e., 16 surveys had nonzero data). The meaning of this relationship was clearer when we converted the units of the switching point to total number of abundance surveys per year, C_{sw} . Accordingly, the general rule (now in

the units of occupied abundance surveys per year; e.g., the number of abundance surveys conducted that have nonzero data), was

$$C_{sw} * p = 16. \quad (7)$$

Discussion

Presence–Absence Survey Methods and IUCN Classification

Our results demonstrated that presence–absence survey methods can successfully assign IUCN Red List categories of threat and are particularly useful for monitoring programs with small budgets. Nevertheless, as the budget allocated to monitoring and hence the effort per site increased, the presence–absence method was worse at detecting change in population size. This counterintuitive result stemmed from a combination of two processes: (1) the rate of decline in population size was different from the rate of decline in area of occupancy and (2) the presence–absence method tracked either decline depending on the budget available.

Spatial Pattern in Decline and IUCN Rules

The various IUCN criteria are informative under different circumstances and hence are triggered at different times. Criteria that relate to total population size (i.e., Rule A2b) may be sensitive to a wide variety of declines that differ in the spatial pattern (e.g., declines that occur uniformly across space and those that occur through a multitude of local extinctions) but may not be able to distinguish between them. Criteria that relate to area of occupancy or extent of occurrence (i.e., Rule A2c) may inform us on how a species' distribution changes spatially. Our decline model (exponential decay uniform across patches) resulted in rates of declines in total population size and area of occupancy of different magnitudes. When the mean rate of decline in total population size was 65% over 10 years the mean decline in area of occupancy was only 0.04%. Therefore, the correct risk categories based on Rule A2b and Rule A2c are endangered and not threatened, respectively.

Presence–Absence Methods and Changes in Abundance

The decline rate (e.g., total population size or area of occupancy) that the presence–absence method tracks depends on the budget available for monitoring. Although one would intuitively expect presence–absence data to be best for monitoring changes in the area of occupancy, when the survey budget (and hence effort per site) was low, it instead tended to reflect changes in population size. Surprisingly, the presence–absence method diagnosed the true decline in the area of occupancy poorly at most budgets. A large budget (allowance of 200 person

days/year, e.g.) was necessary to diagnose the correct category of threat on the basis of Rule A2c > 50% of the time. That presence–absence data track population size at small budgets and area of occupancy at large budgets is illustrated in Fig. 3b, where the mean rate of change swung from 58% (close to the true population decline of 65%) at 25 person days/year to 27% (approaching the true decline in area of occupancy of 0.04%) at 200 person days/year.

The disparity in the actual decline that was being measured by the presence–absence method at different budgets results from the fact that both the budget and population size influenced the number of patches observed as occupied. This occurred because the number of birds recorded in the simulation depended on the observability of the species and the time spent looking (i.e., budget). Concomitantly, the observability of the species was directly proportional to the number of birds available to be seen (population size). Hence, as the population size declined the observability of the species decreased. When the budget was high and more time was taken for surveys, however, a bird was almost always found, so population size became irrelevant. At these budgets, the presence–absence method accurately measured patch occupancy, and hence, area of occupancy. In contrast, when the available budget and the monitoring effort were constant and low, as the total population declined over time, the few birds left were found less often, and the proportion of patches observed as occupied declined—even if the actual number of patches occupied remained constant. In this way, low budgets ensured that presence–absence surveys were sensitive indicators of underlying declines in population size.

Often managers, including those who follow the IUCN guidelines, adhere to traditional analysis techniques of presence–absence data and assume the trend they are measuring is in area of occupancy. Others have shown that presence–absence data can be used to estimate population size (Royle & Nichols 2003). Here we demonstrated that both are valid, and what the presence–absence data represent is related to the amount of effort per site or the time allocated to searching a site. Managers with small to medium budgets, or spending short time periods per site, should be aware that presence–absence data are likely to reflect trends in population size. They may benefit from using other analysis techniques that use presence–absence data to estimate annual population size (Farnsworth et al. 2002; Royle & Nichols 2003), rather than the traditional techniques, when attempting to diagnose level of threat. In this way they may increase the power of the monitoring strategy to detect the trends they endeavor to measure. This will result in more informative assignment of IUCN threat categories. Nevertheless managers should be aware that for low density and cryptic species, the optimal time for sample units could be days rather than minutes (e.g., for the hylacola, the optimal time was approximately 50 days across the 21 patches or

2.5 days/patch). Any less than the optimal time is likely to give imprecise results when estimating rate of decline in abundance. Any longer than the optimal time and the precision will improve; however, the accuracy of the estimate of rate of decline in abundance will decline.

THE OPTIMAL METHOD

A surprising result was that presence-absence methods tracked changes in population size and assigned the correct IUCN category as well as or better than abundance methods when budgets available for monitoring were small. This can be explained by the fact that there was less variation in the estimate of decline rate when presence-absence data were used. At low budgets, the estimated decline rate from presence-absence data was reasonably good and the variation was much lower than that obtained from abundance data.

The conclusion that presence-absence methods are superior to abundance methods at low budgets will only exist for low density or cryptic species. We found that as density or detection probability increased, the budget at which the switching point occurred decreased; consequently, the abundance method was superior to the presence-absence methods for lower budgets. This is the case because the success of the presence-absence survey method at correctly estimating the decline in patch occupancy increased with increasing density or detectability. The proportion of occupied patches correctly recorded as occupied was a function of the amount of time spent looking for the species (proportional to budget) and the probability of observing the species. Hence, presence-absence survey methods may only be sensitive to changes in population size when population size and/or detectability are low.

RULE OF THUMB

A key factor in deciding which monitoring technique to use for monitoring a species with low density or low detectability was how much money is available for monitoring. Presence-absence surveys can be useful when budgets are small, and because we know managers often have limited budgets, the presence-absence surveys may more often than not be the most appropriate method. We propose a general rule with which to determine whether it is best to use abundance or presence-absence methods: $C_{sw}p = 16$. The abundance method should be used when birds are expected to be observed in ≥ 16 sites/year; otherwise, the presence-absence methods should be used. Future research is required to determine whether this rule of thumb is sensitive to other aspects of the species' ecology, such as the initial spatial distribution and the temporal and spatial pattern of decline.

Conclusion

Our paper focuses on the best monitoring method for accurately listing a species. We recognize that there is increasing interest not just in correct listing but also in monitoring that determines the best management decision to be made. Future work could answer the question of how much of each monitoring method (if any) is required to make the best management decision for a species of concern (Field et al. 2004).

We demonstrated the use of a novel framework for comparing two or more monitoring methods. We present a simple way to illustrate the patterns in our results by employing the IUCN Red List framework; however, our results are relevant to a far broader field of monitoring. The relationship between the strategies we investigated is likely to be relevant for most presence-absence or abundance data comparisons. Managers of any cryptic or low-density species who hope to maximize their success of estimating trend should find an application for our results.

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