

OLD DOG, NEW TRICKS: INNOVATIONS WITH PRESENCE–ABSENCE INFORMATION

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Until recently, presence–absence information for assessing temporal and spatial characteristics of animal populations has been like an unruly but loveable mutt, striving for acceptance in the realm of quantitative inference. Loveable, because of the ease of obtaining data compared to abundance information, but unruly, because presence–absence data has previously lacked the discipline and hence value of more pedigreed and prestigious data types. The problem stemmed from the questionable origins of the absence side of its lineage. Whereas presence was fairly straightforward, absence could indicate either true absence of a species or false absence because the species was actually present but not detected.

Presence–absence information has been difficult to interpret because animal detectability is not constant in time or space. There can be substantial differences in detectability between individuals and between different time periods for the same individual. Presence–absence information has typically assumed equal and complete detectability, resulting in a negative bias in the estimation of species' presence.

Whereas an ignored mutt leaves obvious consequences for its owner in the form of ripped furniture and chewed shoes, the ignored short-comings of presence–absence information result in consequences of unseen and unknown proportions. How many habitat models, species distribution maps, and resource selection functions were (and still are) erroneously based on a species' absence, when in fact the species was present but not detected? The need to bring discipline and value to presence–absence data has been long overdue.

In contrast to presence–absence information, animal abundance and density estimation has a fairly impressive history of dealing with imperfect detectability. The development of methods likely commenced in the 1930s, achieved statistical merit

in the 1960s, and became refined in the late 1970s (for a thorough history, see Buckland et al. 2004). Methods for improving presence–absence data, however, did not begin to emerge until the 1980s. I will not attempt a full history of how our loveable mutt was brought to heel, but I will mention a few noteworthy training sessions that brought us to our current state. For a more thorough treatment, see MacKenzie (2005) and MacKenzie et al. (2005).

Geissler and Fuller (1987) were perhaps the first to propose that detection probabilities could be estimated from repeated surveys to the same sites, and their computer simulations showed that detection probabilities reduced bias in their estimates of species' presence. They introduced a new concept, area occupied, to represent the presence of a species within an area defined by a detection radius when bias was adjusted by a detection probability.

Azuma et al. (1990) provided a milestone by describing repeated site visits as a series of independent Bernoulli trials with an outcome of presence (1) or absence (0). They showed how the outcome of independent Bernoulli trials across a randomized sample of sites could be used to estimate the proportion of sites occupied by a species while adjusting for imperfect detection. They also used repeated site visits to estimate the number of visits needed to obtain the first detection of a species, which in this case was the northern spotted owl (*Strix occidentalis caurina*).

Azuma et al. (1990) used the term occupancy as the parameter of interest, because this term had already been adopted in the northern spotted owl literature to describe owl presence in the context of breeding sites (U.S. Forest Service 1988). Over time, occupancy replaced presence in many recent presence–absence studies when imperfect detection was considered, and you will find this term frequently employed in the papers within this special section.

Another early application of repeated visits was the survey design for fishers (*Martes pennanti*) and American martens (*M. americana*) that

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Zielinski and Stauffer (1996) developed. They incorporated home-range size into sampling unit distribution, and they used repeated visits and the binomial model of Azuma et al. (1990) in a Monte Carlo simulation model to estimate the sample sizes needed to observe specified levels of declines in the populations of each species. They used the average number of visits until first detection as a parameter for correcting bias in the estimate of proportion of sampling units occupied, and they described this parameter as latency to first detection (Zielinski and Stauffer 1996). Similarly, Stauffer and others (2002) incorporated detectability into a binomial model for estimating power and sample size for marbled murrelet (*Brachyramphus marmoratus*) surveys.

The relationship between capture–recapture modeling and occupancy modeling was advanced when Nichols and Karanth (2002) recommended use of multiple site visits and closed capture–recapture models to estimate site occupancy by tigers (*Panthera tigris*) in India. Treating sites as individual animals, the detection–nondetection history of each site became the equivalent of capture–recapture data in the model.

MacKenzie et al. (2002) made a major contribution to presence–absence information by demonstrating that detection histories could be incorporated directly into a maximum likelihood estimation model, resulting in the simultaneous estimate of detection probabilities and occupancy rates. The latter estimate was fairly unbiased when detection probabilities were approximately >0.3 . The maximum likelihood approach was concurrently developed by T. Max, J. Baldwin, and H. Schreuder, as described by Stauffer et al. (2002).

MacKenzie et al. (2003) expanded the maximum likelihood estimation technique to multi-season or multi-year studies, enabling managers and researchers to use presence–absence information to investigate changes in occupancy rates over time. This contribution has already proven to be significant and far-reaching by providing the final legitimization of presence–absence information for monitoring purposes. The ability to estimate changes in occupancy between 2 time periods also has immense implications for exploring metapopulation dynamics, because rates of colonization and local extinction can now be estimated and relationships can be formally tested between colonization rates and isolation of landscape patches, and between extinction rates and patch size (J. D. Nichols, U.S. Geological Survey, personal communication).

The potential uses of presence–absence information have expanded greatly as a result of this recent history. The old dog can roll over and has learned other new tricks that are manifest in a host of recent publications (e.g., Royle and Nichols 2003, Tyre et al. 2003, Bailey et al. 2004, MacKenzie et al. 2004, Wintle et al. 2004, Field et al. 2005).

In recognition of these impressive, rapid advancements, *The Journal of Wildlife Management* devoted the following Special Section to recent research that is based on bias-adjusted, presence–absence information and occupancy modeling. The purpose of the Special Section is to increase awareness among wildlife professionals of the value and utility of presence–absence information and to provide examples that are relevant to wildlife conservation and management.

The Special Section begins with an invited overview paper by D. I. MacKenzie that is priority reading for anyone interested in the underlying concepts of occupancy modeling, particularly given the major role that the author has played in the development of these concepts. MacKenzie highlights the importance of accounting for detectability, describes and compares analytical methods for doing so, and provides guidance for developing useful study designs (MacKenzie 2005). The overview paper is followed by 8 papers that are drawn from a variety of geographic locations and taxonomic groups. These papers illustrate a breadth of research questions that can be investigated with presence–absence information and occupancy modeling.

In the first of these examples, L. C. Ball, P. F. Doherty, and M. W. McDonald use occupancy modeling to evaluate and refine an existing habitat model for the Palm Springs ground squirrel (*Spermophilus tereticaudus chlorus*). By specifically accounting for imperfect detectability, the authors show that ground squirrel occupancy rates differ by vegetation types and substrates, a refinement that was not apparent in the existing model (Ball et al. 2005).

J. E. Moore and R. K. Swihart investigate the effects of habitat fragmentation on several forest-associated rodents in Indiana. Their multi-scale data provide a challenge in spatial autocorrelation that has not been previously tackled in the context of site occupancy modeling. Their response to this challenge breaks new ground, and their results contribute meaningful ecological answers to questions regarding the role of landscape pattern in the habitat use of these rodents (Moore and Swihart 2005).

G. S. Olson and her colleagues investigate the effects of barred owl (*Strix varia*) presence on site occupancy rates of the northern spotted owl. They found that the current expansion of barred owls affects not only the presence but also the detectability of northern spotted owls. The implications are important for future spotted owl surveys (Olson et al. 2005).

B. R. Schmidt and J. Pellet use occupancy modeling to estimate the proportion of ponds occupied by the European tree frog (*Hyla arborea*) and the natterjack toad (*Bufo calamita*). Their results highlight the importance of current population levels in predicting whether a pond is occupied the following year. Below a threshold number of calling males in a given year, anurans are likely to be absent the following year, even if suitable habitat is present (Schmidt and Pellet 2005).

B. A. Wintle, R. P. Kavanagh, M. A. McCarthy, and M. A. Burgman explore the effectiveness of presence-absence surveys for 4 species of arboreal marsupial and 2 species of owls that are dependent on late seral forests. For each species, they characterize the rate of false absences, identify key variables that influence detectability, and provide a method for determining the number of visits required to achieve a specified level of confidence that a species is absent from a surveyed site (Wintle et al. 2005).

D. J. Finley, G. C. White, and J. P. Fitzgerald use repeated live-trapping visits to estimate the occupancy rate of swift fox (*Vulpes velox*) in eastern Colorado and to design a monitoring plan for this species. Using a sampling grid stratified by habitat type, they estimate the proportion of grid sites occupied. They then use the observed occupancy rate and detection probability to estimate the power to detect changes in occupancy rates over time (Finley et al. 2005).

T. R. Stanley and J. A. Royle investigate whether indirect detection indices such as track plates and snow tracks can be used to estimate abundance in addition to presence. Building from Royle and Nichols (2003), they incorporate length of sampling interval into the basic site occupancy model of MacKenzie et al. (2002). They use model simulations and 2 field data sets to test the performance of their model, and they explain how certain model assumptions influence the sensitivity of abundance estimates (Stanley and Royle 2005).

P. N. Manley, M. D. Schlesinger, J. K. Roth, and B. Van Horne investigate whether the Multiple Species Inventory and Monitoring protocol (MSIM) is

an effective method for monitoring changes in a host of vertebrate species over broad spatial scales. The MSIM employs a grid-based sampling design, a suite of standard vertebrate survey techniques, and multiple visits per site to estimate occupancy rates for each species. Their field test in California indicates that a high proportion of all vertebrate species, including many species with rarity characteristics, can be sufficiently sampled with the MSIM to detect a 20% change in occupancy rate with 80% power (Manley et al. 2005).

In sum, these papers effectively demonstrate the increased value of presence-absence data when detectability biases are adjusted. The potential for future uses is enormous, as discussed by D. I. MacKenzie in his overview. Nevertheless, as with any new analytical technique, the potential for misuse is probably also enormous. For example, occupancy modeling reveals limitations when detection probabilities are very low. Also, larger sample sizes are needed to detect changes in species' presence, compared to species' abundance, so even though presence-absence information has grown more useful, abundance data might be more appropriate for many situations.

As Stauffer (2002) aptly stated, researchers are quick to apply the latest and greatest analytical techniques as they emerge. We have hopped on a number of analytical bandwagons over the past 50 years, often inappropriately, before the limitations and assumptions behind the new techniques were fully understood. The emergence of occupancy modeling will likely follow the same course. Through time and experimentation, however, we will learn how best to use this new approach as one of many possible ways to expand our knowledge of animal populations. Our old dog has become a distinctive new breed, but, as with any breed, it has qualities that suit certain purposes better than others. As long as we do not forget this, our relationship with presence-absence information should be long and fruitful.

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