Assessing site occupancy modelling as a tool for monitoring Mahoenui giant weta populations

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ABSTRACT

Previous monitoring efforts for Mahoenui giant weta (*Deinacrida* n. sp.) have relied on simple counts of the number of weta observed along transects in the Mahoenui Scientific Reserve, central North Island, New Zealand. However, it is difficult to interpret what a change in such an index value really means—is it due to changes in the population size, or caused by the ability of observers to count weta? Such concerns have led to a need by people managing this insect to implement a statistically robust monitoring programme. One appropriate low-cost alternative to monitoring actual population size may be to estimate the proportion of an area occupied by weta. Computer simulations suggest that, given the available monitoring resources, recently developed site occupancy models should give estimates with reasonable levels of precision if the probability of detecting weta during a survey of an occupied site is approximately equal to or greater than 0.5. A monitoring programme is proposed that will require 75 sites to be surveyed up to 3 times within a week. Because of the difficult terrain, sites will be randomly located in the more easily accessible regions of the reserve. It is recommended that the monitoring design described in this report be viewed as a pilot programme and be conducted for at least 3 consecutive years, after which the information gathered can be used to determine the level of resources required for an efficient full-scale monitoring programme.

Key words: abundance, detection, index, Mahoenui giant weta, monitoring, occupancy, population.

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1. Introduction

The Mahoenui giant weta (*Deinacrida* n. sp.) is naturally found at two sites in the central North Island of New Zealand—Mahoenui and Otangiwai (Sherley 1998). The weta currently occur at low densities and are mainly found in gorse habitats. The Mahoenui site is protected by the Department of Conservation (DOC) as a scientific reserve. The reserve covers 240 ha, and consists of two main catchments with steep hillsides and gullies. The predominant vegetation is gorse, with some rejuvenating native forest in the gullies. The reserve is mostly surrounded by farmland, with the Mokau River on its eastern border. Two firebreaks divide the reserve into three unequally-sized areas.

Attempts to monitor the weta population were made in 1994 (Sherley 1994), 2001 (Thurley 2001) and 2002 (Thurley 2002). Two to four south–north transects were travelled by two observers, and the number of weta observed were recorded. The number of weta seen per person hour of searching was used as an index of weta abundance (see Sherley 1994 for further details of the monitoring methods). However, it is difficult to interpret changes in the values of indices such as this (Yoccoz et al. 2001). Are any changes observed between surveys due to a change in the population size, or in the observers' ability to detect the weta during the monitoring surveys? Because of such uncertainties, a more statistically robust monitoring programme for the Mahoenui giant weta is desirable (Greg Sherley, pers. comm.). Providing a more scientific basis for monitoring should also provide an opportunity for increased learning about weta biology.

The monitoring of low-density populations is generally difficult. The more commonly accepted methods, such as distance sampling or mark-recapture, often require large amounts of survey effort to observe enough individuals to make reasonable estimates of population size. Funding and personnel constraints may make such surveys unfeasible, and make alternatives to such costly methods desirable. One alternative approach is to consider the proportion of area occupied by the species under consideration.

Recently, MacKenzie et al. (2002, 2003) have developed new methods that enable unbiased estimation of site occupancy levels, provided multiple presence / absence surveys are conducted at some of the monitoring sites within a reasonably short time frame. MacKenzie et al. (2002) describe a single-season model which uses straightforward probabilistic arguments to model the probability of observing at a site any given sequence of detections and nondetections. The method uses two types of parameters: the probability a site is occupied by a species; and the probability of detecting the species in a survey, given the species is present. MacKenzie et al. (2003) extend the method to multiple seasons by considering the dynamic processes of local extinction and colonisation, enabling changes in the occupancy state of sites to be modelled.

In effect, these methods borrow the information on species detectability obtained from the sites where the species was observed at least once, to estimate the probability of occupancy at those sites where the species was never observed. In essence, they attempt to separate the false and genuine absences. There are two main assumptions involved with this approach. Firstly, the detection function constructed from the sites with at least one species detection is valid for sites with no detections, i.e. there is no unmodelled heterogeneity in detection probability across sites. Secondly, during the period of repeated surveys (a season), sites are closed to changes in the occupancy state, i.e. sites are either always occupied or always unoccupied by the species, although changes may occur between seasons. This closure assumption may be relaxed if the probability that the species is actually present at a monitoring location during the surveying is completely random, i.e. 'tossing a coin' to determine whether it will be at the monitoring site on any given day, in which case the proportion of area occupied should be interpreted as the proportion of area used by the species during the surveying period. More mechanistic violations of the closure assumption will create unknown biases in the estimates.

The methods of MacKenzie et al. (2002, 2003) do not require constant monitoring effort to be expended across all sites, which enables a great deal of flexibility in monitoring design. Also, covariate information which may be routinely collected as part of the monitoring programme can also be included in the modelling (e.g. habitat types and weather conditions). This is a very important aspect for the Mahoenui giant weta, given that previous research has indicated that the insects display habitat preferences within the scientific reserve (Sherley & Hayes 1993).

This report has been commissioned to determine the suitability of site occupancy models to be used as monitoring tools for Mahoenui giant weta, and to provide advice on how a monitoring programme using such models should be established. As part of the reporting process, the author visited the Mahoenui Giant Weta Scientific Reserve in February 2003, and held discussions with key DOC personnel including Avi Holzapfel, Tertia Thurley, Leigh Marshall (all Waikato Conservancy) and Ian Westbrooke (Statistician, Science & Research Unit). Greg Sherley (Principal Regional Scientist, Central Region Office) was also consulted during the preparation of this report.

2. Considerations for a monitoring programme in Mahoenui Scientific Reserve

The terrain within the reserve could be politely described as 'unfriendly'. Movement can be difficult because of the dense gorse and steep hillsides, although goat tracks and stream beds allow easier movement in some areas. There are, therefore, practical limitations on the area that a monitoring team can cover during a single day. This raises the question of whether, at least initially, the entire reserve should be monitored.

Monitoring should have as little impact on the habitat as possible. Seventy-five percent of the Mahoenui giant weta encountered by Sherley & Hayes (1993) were found in the dead foliage of gorse bushes. Given the fragility of this dead foliage, there is a considerable likelihood of habitat degradation / destruction if the monitoring protocol requires individual weta to be removed from the bushes, e.g. in order to measure or place identifying marks on them. Similarly, bushes should be searched in a manner that limits the level of disturbance. This may lessen the chances of observing weta, even when they are present at a site, but should avoid any long-term changes in the habitat (and weta population) resulting from the act of monitoring. Also, the habitat should be monitored too, as it is not static and is subject to change over time. This is important, as it may allow some changes in the population status of the weta to be explained by observed changes in the structure of available habitat, which may invoke a different management response to those for unexplained changes.

Experienced field personnel report that weta are more visible during cooler weather, particularly during or soon after moderate rainfall (Phil Bradfield, Waikato Conservancy, pers. comm.), although Greg Sherley suggests this is mainly due to increased humidity. This experience suggests that monitoring during hot, dry weather should be avoided as much as possible.

3. Outcome of discussions held at Maniapoto Area Office

It was decided that, initially, only part of the Mahoenui Scientific Reserve would be monitored. Monitoring would focus on the large central block of the reserve between the two firebreaks, with sites randomly placed within 30 m of the block edge. Monitoring would also be performed along a central corridor running approximately east–west, largely following a stream bed, with sites randomly placed within 30 m of either side of the corridor centre line. This decision was made to ensure that reasonably accessible sites were chosen in the difficult terrain. Such an approach seems acceptable given the circumstances, with the caveat that even using the assumption that the monitored area is representative of the entire reserve, there is no statistical basis for generalising the monitoring results beyond the area being surveyed.

It was decided that a monitoring site would consist of a circle of 3 m radius (approximately 28 m^2). Subsequently, a second option of short transects 10–15 m long by 2 m wide (20–30 m^2) was also suggested. Both configurations have their relative advantages, although at the time of writing this report, no decision as to which to use had been reached. Given the clumpy distribution of the gorse within the reserve, it seems likely that the habitat within a circle of 3 m radius would be more similar than that within a short transect of 10–15 m and that it would therefore be easier to categorise the habitat characteristics of circular plots than of transects. Better habitat categorisation could enable occupancy to be modelled as a function of habitat types, which may be important given the earlier work of Sherley & Hayes (1993) in identifying potential habitat preferences by weta. Any apparent change in occupancy could then be explained by changes in habitat composition. From a management perspective, being able to identify habitat preference could be useful, as it may be used to guide appropriate management action (e.g. restoration / improvement of the habitat). However, a drawback of using this option could be that we may lessen the chance of detecting weta because of a shortage of 'ideal' habitat within a randomly chosen circle. Conversely, by using transects we may be more likely to intersect the 'ideal' habitat more often, thus increasing our ability to detect weta at a site (relative to a circular site), and fewer monitoring sites may be required. Although, it may then be more difficult to categorise sites into habitat types, so that modelling occupancy as a function of habitat may be more difficult, and it may not be possible to provide information on habitat preferences to management. The major assumption here is that a randomly chosen circular plot will contain more homogeneous habitat than a short transect of similar area, which may or may not be true. It is suggested that this assumption be tested in the field.

Which type of monitoring site to use is, primarily, a management decision. Assuming there is a substantial difference in the level of variation in habitat composition within the two monitoring site configurations, then management must decide whether the possible ability to relate changes in occupancy to changes in habitat that may arise from the use of circular monitoring sites would be useful and informative. Alternatively, it could be decided that measuring occupancy at a lower resolution, as provided by transects, would be sufficient (although it needs to be noted that, even if circular sites are chosen, the habitat information gathered need not be used). If the level of variation in habitat composition is similar for the two monitoring configurations, then this whole line of argument is irrelevant.

The only other pertinent point about the configuration of monitoring sites relates to how they will be randomly located. Given that the monitoring is to be conducted in only a small part of the total reserve, the use of transects may create some problems. Each transect should have a random start position, and head off in a random direction. However, if the start of a transect is near the edge of the area to be monitored, there may be a reasonable chance that the randomly chosen direction would result in some of the transect extending beyond the monitoring area, so a different transect should be selected. This would cause some regions of the monitoring area to be more likely to be sampled than others, e.g. points on the edge of the monitoring area are less likely to be sampled. A similar situation holds for using circular sites, although to a much lesser degree.

Regardless of the monitoring site configuration chosen, all bushes would be searched, but grass areas within the sites would not be searched as weta are not believed to occupy these areas. Search effort should be as consistent as possible, with a timed count being suggested. However, this may not be practical as it may result in sites with little gorse cover actually being searched more intensively. Another option might be to have graduated effort depending upon the level of gorse cover. For example, if the level of cover was classified as < 33%, 33–67%, or > 67%, searches might be timed at 3, 6, or 9 minutes respectively. The number of weta observed would be recorded, with weta classified by gender and adults v. juveniles (young of the year). No measurements of weta are required, hence it will not be necessary to remove them from the gorse bushes, which reduces the likelihood of damage to the insects and their habitat.

The total level of effort available for the survey is approximately 10 person-days. As the monitoring region naturally divides into 3 areas (northern border, southern border and central corridor), a crew of 3 people monitoring over 3 days would likely be the best approach in order to survey the region as quickly as possible. Each person would survey each of the areas once.

4. Assessment of the suitability of site occupancy models

A simulation study was conducted to examine the performance of the single-season site occupancy model (MacKenzie et al. 2002). A wide range of scenarios was considered, as there was a great deal of uncertainty as to the likely levels of occupancy and detectability that would be encountered in the field (Table 1). A review of previous studies in the reserve provided some assistance in the determination of these scenarios. A simple model that assumes both the probability of occupancy and detection probability was constant across all sites was used to generate the data. Detection probability was also assumed to be constant across different surveys. Given the constraints on available effort described above, it was assumed that three repeated surveys could be conducted. A model with the same structure as the generating model was fitted to each simulated set of data and the estimated parameter values (and standard errors) were recorded. Two thousand sets of data were generated for each scenario.

The results of the simulation study (Figs 1–2, see end of report) suggest that unless the probability of occupancy is high (approximately 0.8), when the probability of detection is low (approximately 0.3) occupancy will be overestimated and standard errors will be large, with only 3 surveys per site. Otherwise, the simulation study results seem generally reasonable, indicating that the occupancy estimate will have little bias and moderate standard errors in

TABLE 1. FACTOR LEVELS USED IN SIMULATION STUDY TO ASSESS THE SUITABILITY OF THE OCCUPANCY MODELS TO THE MONITORING OF MAHOENUI GIANT WETA.

FACTOR	LEVELS
Probability of occupancy	0.2, 0.4, 0.6 or 0.8
Probability of detecting weta in a survey of a site (given presence)	0.3, 0.5, 0.7 or 0.9
Number of sites monitored	30, 45 or 60
Number of repeat surveys (per site)	3

situations similar to the scenarios considered. For the simple model fit to the generated data there is minimal gain in using 60 monitoring sites rather than 45; however, this is unlikely to hold if more complicated models are used.

From the magnitude of the standard errors (Fig. 2), it seems that the modelling should be able to identify absolute changes of approximately 10% in the proportion of area occupied by weta from a short time-series of monitoring data (approximately 3 years), and smaller changes from long-term monitoring data.

5. A suggested monitoring protocol for weta at Mahoenui Scientific Reserve

Based upon the work of Sherley & Hayes (1993), weta numbers appear to peak in the summer months, hence it seems prudent to suggest the monitoring be conducted in January or February each year. And, as mentioned above, there is anecdotal evidence to suggest that weta are more obvious during cooler / wet / humid weather, hence surveys should not be conducted on hot / dry days. Monitoring may be conducted on consecutive days, or in as short a time frame as possible (preferably all three surveys should be conducted within a week). It is also possible that weta activity may vary with time of day, making them more or less detectable. Therefore, as much as possible, individual sites should be surveyed at different times of day. This can be achieved by, for example, alternating which end of the route observers start from, or otherwise changing the order in which sites are surveyed. Observers should also record (with each survey) the conditions at each site which they assess as being able to affect their ability to detect the weta. A list of such variables should be established prior to the monitoring with the input of relevant experts.

It is my recommendation that circular sites of 3 m radius be used. This would avoid unintentional biases that may be introduced by using transects, as discussed earlier. The use of circular sites is assumed in the following text; however, a final decision on which type of monitoring site to use needs to be made with management input.

A total of 75 sites should be monitored. This is greater than the number of sites considered in the simulation study, but the greater number may make it possible to identify the weta habitat preferences indicated by Sherley & Hayes (1993). Such higher resolution will be needed to determine whether any changes in the level of occupancy observed are in response to subtle, site-specific changes in habitat quality rather than the result of a widespread change across the entire monitoring region. Within each of the three areas mentioned above (northern border, southern border and central corridor), 20 sites will be monitored on each of the three survey days. By rotating which sites are actually surveyed on each day the effective coverage of the monitoring can be increased (see Appendix 1). This design will result in 30 sites being surveyed three times and 45 sites surveyed twice, which should give acceptable results provided detection probabilities are approximately equal to or greater than 0.5 (see Figs 3 and 4, end of report).

Sites could be randomly placed within the area to be monitored by using the following method: From a recent aerial photograph, identify the monitoring region and the three sub-areas. Overlay a rectangle such that the monitoring region is completely within its boundaries. Within the rectangle, use the uniform distribution to select random northing and easting values. If the random coordinate lies within one of the three sub-areas, keep the point; otherwise, it can be discarded. Repeat the process of drawing random northings and eastings until 30 random coordinate points are obtained for each sub-area. For each coordinate, determine the bearing and distance to an easily identifiable landmark or access point, these will be used to locate the monitoring sites in the field and to avoid any unintentional bias that may be introduced by use of handheld G.P.S. units. Selecting an initial 30 sites provides 5 additional sites that may be required should some of the 25 sites (that are subsequently randomly selected from the 30) be inappropriate for weta monitoring (i.e. the site may be all grass or swamp). Alternatively, these additional sites may also be surveyed if resources permit.

Prior to monitoring, all sites should be surveyed to measure and categorise habitat using a number of rigorous criteria. While the development of criteria may require additional effort, the advantage may be greater consistency in habitat surveys between different years. As part of these criteria, some minimum level of required appropriate habitat should be established, in order for the site to be monitored for weta, e.g. at least 10% of gorse cover. The temptation may be to set very stringent criteria so that only 'good' sites will be monitored. The danger of this, however, is that if the monitoring starts with only 'good' sites (with a high level of occupancy) then it is more likely that a decrease will be observed. The difficulty is then in determining whether a decline over time is due to some random movement of the weta away from 'good' sites that are no longer suitable, or a more widespread decline.

During each survey all appropriate habitat will be searched for weta using a standard protocol. Searches may have a constant time limit, or time limits may vary for different habitat categories. It may also be practical to impose a limit on the height to which gorse bushes will be searched. The number of weta observed will be recorded and classified by gender and age (adult v. juveniles).

6. Recommendations

There are a great many unknowns in relation to the monitoring of Mahoenui giant weta. Because of these, it is recommended that the above protocol should be regarded as a pilot monitoring programme, and run for at least three consecutive years. It is suggested the field data from the first year of monitoring be analysed prior to the second year to assess the probability of detecting weta at a site (given weta are present). If the detection probability appears to be as low as 0.3, then the monitoring protocol will require some modification so that additional surveys of sites can be completed within the limited resources. After the three years, a full review of the monitoring programme should be conducted. The field information collected during the pilot programme will provide valuable guidance in determining the amount of effort required for an efficient full-scale monitoring programme.

7. Acknowledgements

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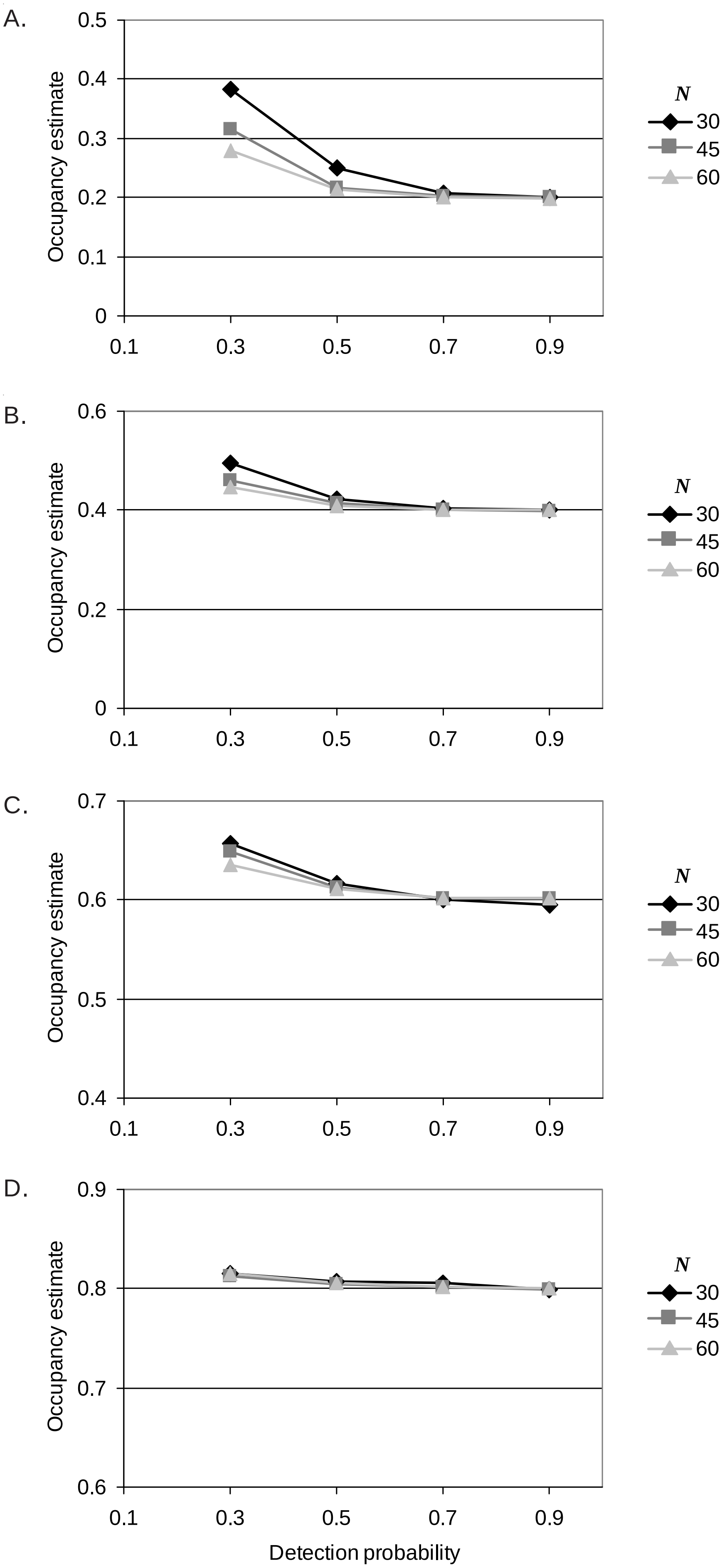
Appendix 1

A monitoring design (for a single area) which rotates the sites to be surveyed each day, with 'X' indicating the sites to be surveyed. Note: a different person should conduct the surveys each day within an area to allow potential observer effects to be identified. This design will be replicated in all three areas.

Site	Day 1	Day 2	Day 3
1	X	X	X
2	X	X	X
3	X	X	X
4	X	X	X
5	X	X	X
6	X	X	X
7	X	X	X
8	X	X	X
9	X	X	X
10	X	X	X
11	X	X	
12	X	X	
13	X	X	
14	X	X	
15	X	X	
16	X		X
17	X		X
18	X		X
19	X		X
20	X		X
21		X	X
22		X	X
23		X	X
24		X	X
25		X	X

Figures 1–4

Figure 1. Average estimate of occupancy from simulation study at various levels of detection probability (per survey) and number of monitoring sites (*N*).
The true probability of occupancy is 0.2 in A, 0.4 in B, 0.6 in C, and 0.8 in D.



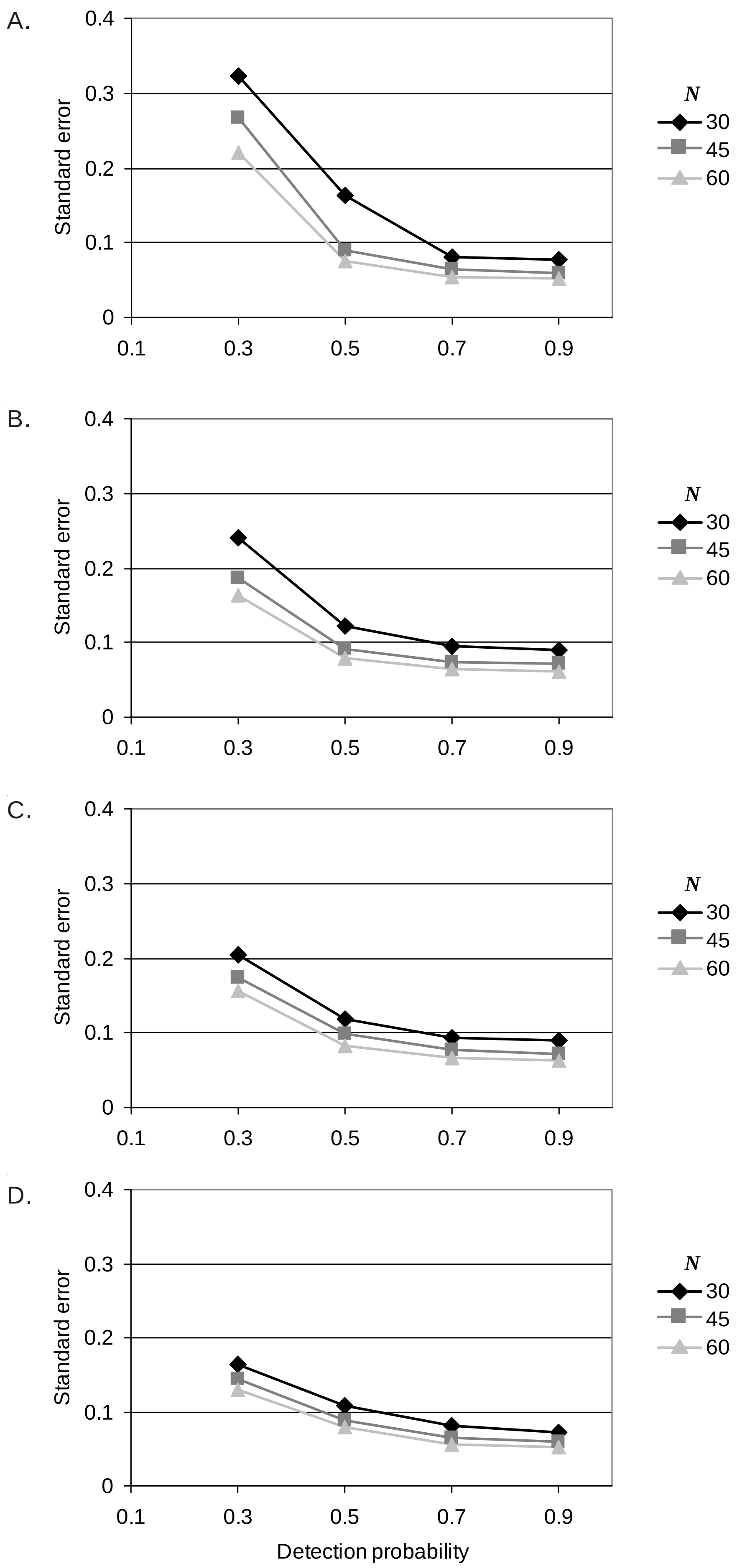


Figure 2. Standard error of occupancy estimate obtained via simulation study at various levels of detection probability (per survey) and number of monitoring sites (*N*). The true probability of occupancy is 0.2. in A, 0.4 in B, 0.6 in c, and 0.8 in D.

Figure 3. Average estimate of occupancy (via simulation) for proposed monitoring programme with 30 sites surveyed three times and 45 sites surveyed twice, for various levels of detection probability (per survey) and true occupancy probability (*Occ.*).

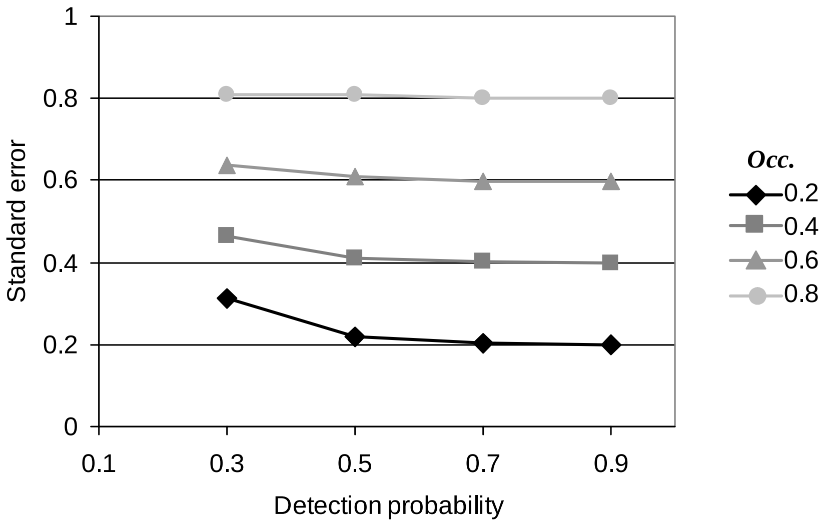


Figure 4. Standard error (via simulation) of occupancy estimate for proposed monitoring programme with 30 sites surveyed three times and 45 sites surveyed twice, for various levels of detection probability (per survey) and true occupancy probability (*Occ.*).