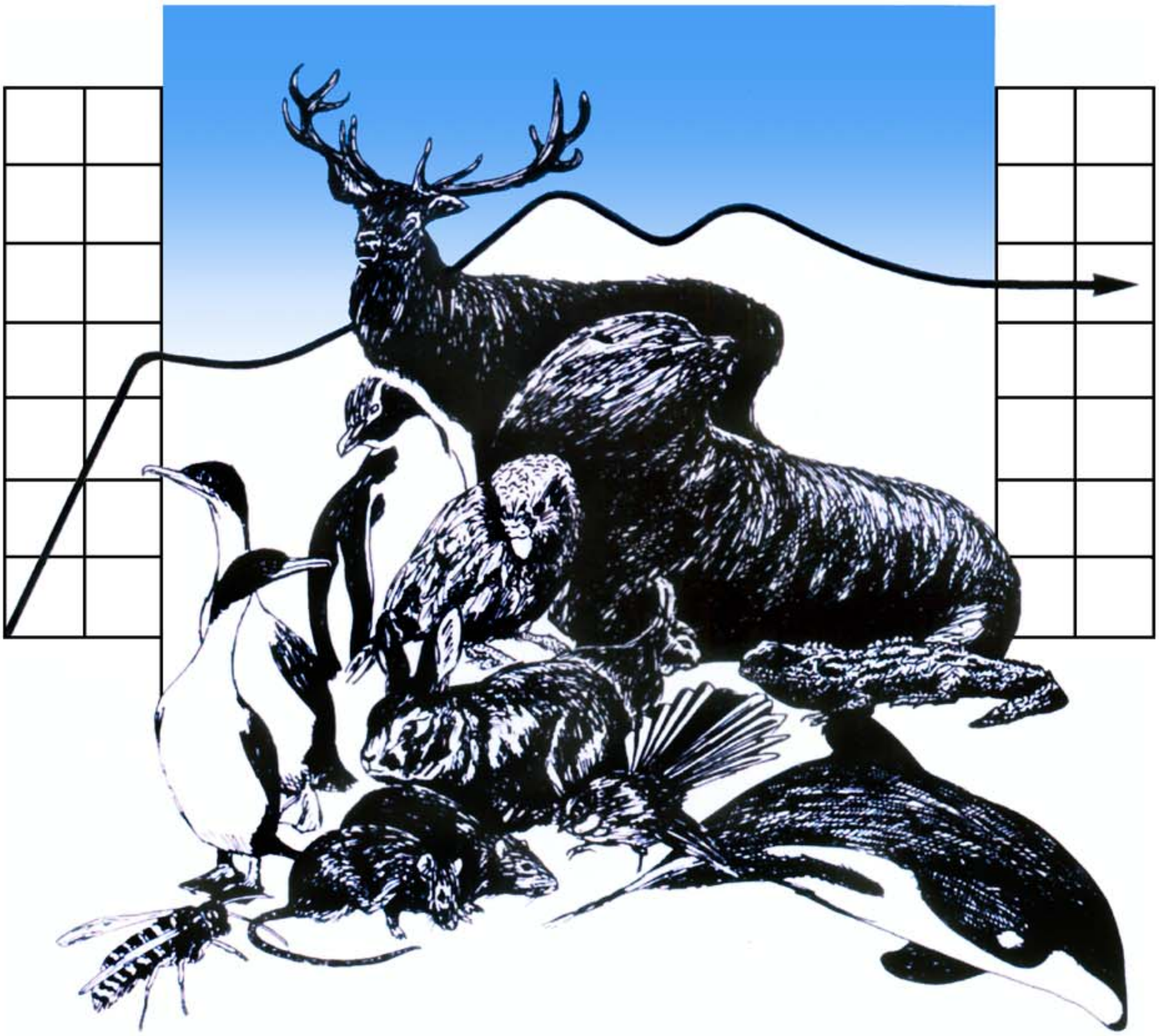
DEPARTMENT OF ZOOLOGY



WILDLIFE MANAGEMENT

Mark-recapture analysis: Is this a useful tool for three threatened braided river bird species?

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A report as partial fulfilment of the Postgraduate Diploma in Wildlife Management

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Abstract

Recent declines in population numbers of many avian species require wildlife managers to reliably estimate population numbers but also to calculate for survival and recruitment rates. A powerful method is to use mark-recapture analysis on the survey data, which allows survival and detection rates to be estimated independently. Mark-recapture analysis has been used by ecologist and biologists to address a variety of questions. Five years of data of banded individuals from three braided river bird species (wrybill, banded dotterel and black stilt) will be assessed. Sampling occurred during spring to autumn (September–February). Program MARK 5.0 was used to model factors influencing variation in survival. I used the standard Cormack-Jolly-Seber model that is based on live animal recaptures in an open population. Estimated annual survival had a probability of 0.53 (95% CI 0.29-0.75) and the estimated recapture probability was 0.75 (95% CI 0.27-0.96). Survival probability for the banded dotterels was estimated at 0.32 (95% CI 0.18-0.50) and the capture probability was 1.00. Estimated recapture probability was constant for both groups at 0.87 (95% CI = 0.69–0.95). This report aimed to address the question: are enough re-sightings being recorded to make this an effective method? Data collected on all three species was able to be analysed using mark-recapture analysis. The study is gathering sufficient re-captures to be effective.

Introduction

Since the arrival of early settlers New Zealand's avifauna have been disproportionately represented in endangered species lists. Recent declines in population numbers of many avian species require wildlife managers to reliably estimate population numbers but also to calculate survival and recruitment rates. These are essential components for assessing population viability which is a key concern of wildlife managers. Traditionally population estimates were calculated from densities or presence absence surveys of animals sighted by observers.

However, a more powerful method is to use mark-recapture analysis on the survey data, which allows survival and detection rates to be estimated independently (Lebreton et al 1993). There has been a rapid advance in mark-recapture methodology in the last 15 years, resulting in powerful methods for modelling factors affecting survival (Lebreton et al 1993).

In mark-recapture experiments, we typically sample the population under study k times where k is usually >2. Each time, every unmarked animal caught is uniquely marked, previously marked animals have their captures recorded, and all animals are released back into the population. The key assumptions are that animals in any category have the same survival and detection rates. Animals can be categorised according to sex, age, habitat or any other obvious factor likely to affect detection and survival. There are methods available for testing whether the assumptions are valid, and for correcting for heterogeneity in survival and detection rates if that heterogeneity is not extreme. The researcher can then fit alternative models to the data to determine whether different survival rates apply to particular time intervals, and if survival differs among sex or age classes or other factors differentiating individuals (Armstrong & Ewen 2001).

Mark-recapture analysis has been used widely by ecologist and biologists addressing a variety of questions. Researchers such as Pryde (2003) studying the cryptic long-tailed bat has been able to estimate survival rates and population size. While the method has also been successfully applied to addressing impacts on non-target species after wide scale poison drops (Armstrong & Ewen 2001; Davidson & Armstrong 2002). Previous studies in this field had relied on the locating of dead animals to estimate the impacts on population size. Mark-recapture techniques allow researchers to base estimates on live animals even when recapture rates are low (Armstrong & Ewen 2001). Three cryptic braided river bird species are described below. Given the recent success of mark-recapture methods for other cryptic species it is proposed that mark-recapture methods be applied to sightings data of banded individuals from these three species.

Wrybill / ngutu pare (*Anarhynchus frontalis*)

Wrybills breed in Canterbury and inland Otago on braided riverbeds, with eggs being laid from late August to January (Heather & Robertson 1996). The birds, with their cryptic colouring, match the colour of the riverbed stones, and unless they move, are very difficult to see (Moon 2002). Wrybills are most readily observed when they migrate, from late December early January, to North Island mudflats and harbours (Davies 1997).

Banded dotterel / tuturiwhatu (*Charadrius bicinctus*)

The endemic Banded Dotterel breeds primarily on gravel riverbeds of the east coast of both the North and South Islands (Heather & Robertson *1996)*. The usual clutch consists of three buff-coloured, dark brown blotch-marked eggs. The nest is a scrape in the ground, among river shingle and on short grass paddocks (Moon 2002). From about January, birds breeding inland migrate northwards to coastal areas within New Zealand, or to Tasmania and Australia from Cairns around the south coast to Perth (Blakers et al. 1984).

Black stilit / kaki (*Himantopus noveaezealandiae*)

The endemic black stilt is highly endangered making it the world's rarest wader (Moon 2002). Because of its endangered status, the species has been under intensive management for many years. The wild population numbers approximately 120 birds (Moon 2002). Adult Black Stilts are usually sedentary, not moving further than they have to and only when winter in the high country is too severe. However, juvenile stilts may go “walkabout” with a few winters may pass before they are seen again (Sibson 1982).

Each breeding season (September-February) the Department of Conservation staff in Twizel monitor the nest success of three braided river bird species: wrybill, banded dotterel and kaki described above. During the course of this work re-sightings are recorded opportunistically. This report aims to assess if mark-recapture methods can be applied to the sightings data collected during these periods. Five years of data will be assessed with the aim to specifically answer the question “are enough re-sightings being recorded to make this an effective method?”

Materials and Methods

Study site and Data Collection

Currently the Department of Conservation operate an outcome monitoring program on the Tasman River. The Tasman River is an alpine braided river flowing through Canterbury. The river's headwaters are in Aoraki/Mount Cook National Park flowing south for 25 kilometers into the top end of the glacial lake Pukaki. Each breeding season the Twizel field team locate and monitor wrybill, banded dotterel and black fronted tern nests for nest success, hatching success and fledging success. As the birds being monitored are nesting this provides a prime opportunity to catch and band individuals. This is done opportunistically for adult wrybills and banded dotterels as well as wrybill chicks that have left the nest. In addition sightings data (band combinations and GPS location) are also collected for all wrybills and banded dotterels (with leg bands). It is this additional data from the monitoring program that was chosen for analysis. All captures (banding events) and re-sightings for wrybills and banded dotterels were recorded only on the tasman river (Fig. 1). Wrybills and banded dotterels were banded and re-sighted during spring to autumn (September–February), over a 5-year period (2003-2008).

Kaki on the other hand is a part of an intensive captive rearing program. Individuals in the study were mostly raised and banded in captivity. These captive reared birds were considered for this study to meet the criteria of "captured" birds. There are some wild reared individuals included in the data set. Re-sightings of Kaki were recorded on three rivers (A) Tasman (B) Cass and (C) Ahuriri (Fig. 1).

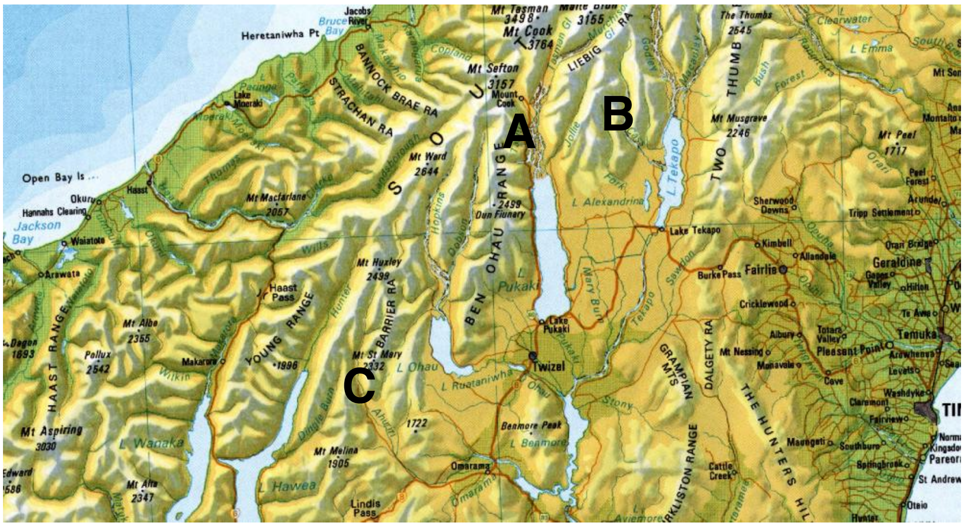

Fig. 1 Locations of (A) Tasman River, (B) Cass River, and (C) Ahuriri River study areas in Canterbury, New Zealand.

Modelling survivorship

Data from within a summer monitoring period were combined into one capture occasion. Capture histories were constructed for five occasions in the years 2003–2008. The mark-recapture analysis program, Program MARK 5.0 was used to model factors influencing variation in survival. I used the standard Cormack-Jolly-Seber model that is based on live animal recaptures in an open population (Lebreton et al. 1992). The following terminology is used. Apparent survival, (phi or ø) is the probability of an individual surviving from one year to the next and remaining in the study population. (The term "apparent" survival is used because in mobile species emigration cannot be separated from mortality. However, throughout this report I generally abbreviate the term "apparent survival" with "survival".) The recapture probability, (*p*) is the probability that an individual alive in the study population, at the time of a particular sample, will be caught in that sample (Cooch & White 2001).

The Cormack-Jolly-Seber model has four main assumptions: (1) every animal has the same probability of recapture; (2) every animal has the same probability of survival from one sample to the next; (3) marks are not lost or missed; and (4) all samples are instantaneous and each release is made immediately after the sample.

Every animal did not have the same probability of survival (Assumption 2) as both chicks and adults were banded. I would assume different age groups to have different survival probabilities. I consider that band loss (Assumption 3) was not a problem largely because of the high proportion of banded individuals re-sighted during the study. Annual samples were not instantaneous (Assumption 4), as the re-sightings and capture (banding birds) occurred at different times throughout the sampling periods.

Model construction followed the methods of Lettink and Armstrong (2003). In the wrybill and banded dotterel data, four models were assessed: (1) the global model where survival (ø) and recapture probability (*p)* varied with time (*t)*; (2) survival was constant and recapture probability varied with time; (3) recapture probability stayed constant and survival varied with time; and (4) both survival and recapture were constant. Model construction for the Kaki data was the same as that above with the addition of extra models to allow for grouping within the data. A total of 16 models were run for the

Kaki data set. The two groups used were (1) Tasman and (2) Non tasman. Individuals were assigned to each group based on their initial release site. Re-sightings of individuals were included in the capture history for that individual regardless of location sighted.

To evaluate the fit of the set of models to the data I used a simulated boot-strapping Goodness-of-Fit (GOF) test on the global model as detailed in Pryde (2003). The Akaike Information Criteria (AICc) for small sample sizes was used to rank the candidate models relative to each other and the ΔAICc (the difference between the current model and the model with the lowest AICc) was used to rank the models.

Results

Wrybill / ngutu pare (*Anarhynchus frontalis*)

Altogether, 265 wrybill captures, representing 41 individuals (54% adults, 46% chicks) were recorded during the study. The Goodness of Fit test for the global model showed that data were mildly over-dispersed. This is shown in figure 2 illustrating that MARK was unable to calculate 95% confidence intervals for

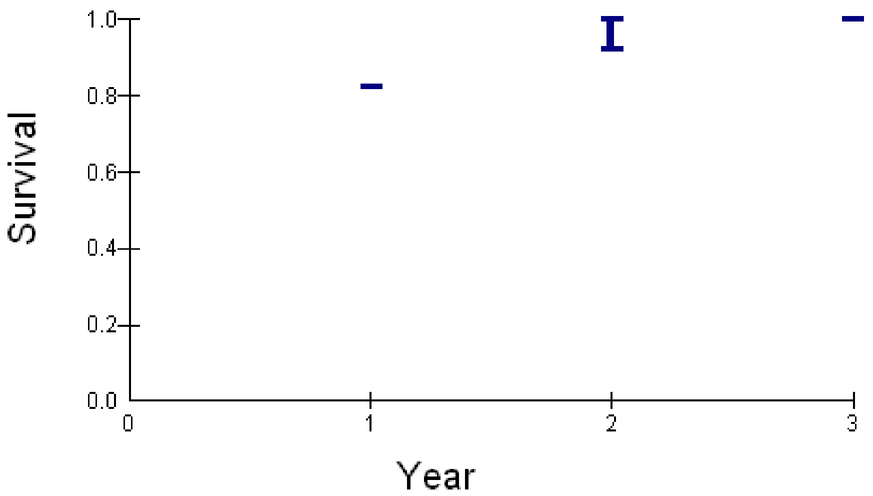

Fig. 2 Annual survival probabilities for wrybills captured on the Tasman River 2004–2007 (*n* = 40 individuals). Bars show 95% confidence intervals.

two of the periods within the study. Therefore data were adjusted ($\hat{c}$ = 1.9). All the models tested (Table 1), including the original global model (No. 3), had varying levels of support, with the constant model being the most supported (Qw = 0.65). The constant model was used to estimate the survival and recapture parameters. Estimated annual survival had a probability of 0.53 (95% CI 0.29-0.75) and the estimated recapture probability was 0.75 (95% CI 0.27-0.96) indicating that if the wrybill was alive there was a high probability the wrybill would be recaptured each year.

Table 1 Four models describing survival and recapture probabilities of wrybill, Tasman River using Program MARK where ø = apparent survival, p = recapture probability, t = time, ΔQAICc = difference in Akaike's Information Criterion between the first model and the others, Qw = Akaike's weight, K = number of parameters.

Model	ΔQAICc	Qw	K
1. Ø, p	0.00	0.65	2
2. Ø, p(t)	2.85	0.16	4
3. Ø(t), p(t)	3.86	0.09	5
4. Ø(t), p	3.87	0.09	4

Banded dotterel / tuturiwhatu (*Charadrius bicinctus*)

Altogether, 266 banded dotterel captures, representing 71 individuals (86% adults, 14% chicks) were recorded during the study. The Goodness of Fit test for the global model showed that data were mildly over-dispersed, therefore data were adjusted ($\hat{c}$ = 3.0). All the models tested (Table 1), including the original global model (No. 4), had varying levels of support. The model with both survival and recapture constant (No. 1) had the most support (Qw = 0.55). The support for this model was 1.7 times greater than for the next most supported model (No. 2). Given the level of support for the constant model this model was used to estimate survival and recapture probabilities. Survival probability for the banded dotterels was estimated at 0.32 (95% CI 0.18-0.50) and the capture probability was 1.00 indicating that if the banded dotterel was alive it almost certainly be recaptured each year. MARK was unable to calculate a 95% confidence interval for this parameter, suggesting a problem with the data.

Table 2 Four models describing survival and recapture probabilities of banded dotterel, Tasman River using Program MARK where ø = apparent survival, p = recapture probability, t = time, ΔQAICc = difference in Akaike's Information Criterion between the first model and the others, Qw = Akaike's weight, K = number of parameters.

Model	ΔQAICc	Qw	K
1. Ø, p	0.00	0.55	2
2. Ø(t), p	1.14	0.31	5
3. Ø, p(t)	3.37	0.10	5
4. Ø(t), p(t)	5.75	0.03	7

Black stilit / kaki (*Himantopus noveaezealandiae*)

Altogether, 302 individuals (46% Tasman Group, 54% Non-Tasman Group) were recorded during the study. The Goodness of Fit test for the global model showed that data were over-dispersed, therefore data were adjusted ($\hat{c}$ = 5.9). The top five models tested (Table 3), and the original global model (No. 16), had varying levels of support. The model with survival varying as a factor of group and recapture constant (no. 1) was the most supported model (Qw = 0.43). This model was used to estimate annual survival and recapture probability. Estimated annual survival for the Tasman group was 0.78 (95% CI = 0.61-0.89) and 0.56 (95% CI = 0.41-0.69) for the Non-Tasman group throughout the study. Estimated recapture probability was constant for both groups at 0.87 (95% CI = 0.69–0.95) indicating that there was a high probability that if the kaki was alive it would be recaptured each year.

Table 3 Top five models and the original global model (No. 16) describing survival and recapture probabilities of kaki, Tasman River using Program MARK where ø = apparent survival, p = recapture probability, t = time, ΔQAICc = difference in Akaike's Information Criterion between the first model and the others, Qw = Akaike's weight, K = number of parameters.

Model	ΔQAICc	Qw	K
1. Ø(g), p	0.00	0.43	3
2. Ø(g), p(g)	1.99	0.16	4
3. Ø, p	2.75	0.11	2
4. Ø(g), p(t)	2.76	0.11	6
5. Ø, p(g)	3.48	0.08	3
16. Ø(g*t), p(g*t)	15.09	0.00	14

Discussion

Data collected on all three species was able to be analysed using mark-recapture analysis. This suggests that the study is gathering sufficient re-captures to be effective.

However, all of the data sets were over-dispersed and required adjustments before further analysis could be conducted. This is indicative of problems with the way the data was collected rather than model selections. Pollock (1982) state that: "study design should be oriented around satisfaction of as many model assumptions as practically possible so that a simple and reasonably efficient model can be used for estimation". The Cormack-Jolly-Seber model has four main assumptions: (1) every animal has the same probability of recapture; (2) every animal has the same probability of survival from one sample to the next; (3) marks are not lost or missed; and (4) all samples are instantaneous and each release is made immediately after the sample (Krebs 1999).

Three of the four assumptions were violated for the wrybill data. Assumption 1 was violated as sampling occurred during the breeding season at which time females in particular are more likely to be caught. This is reflected in the data set as there are only two males included. Also the banding of chicks violates this assumption as chicks from monitored nests are caught most frequently. This could be addressed by only banding adults. Samples and releases (assumption 4) were not made instantaneously. This could be addressed in the future by allocating specific time to sampling and releases. While this would be ideal in practice a change in the methodology such as this will render the current data collected invalid. Assumption 2 was also violated although this assumption is hard to meet when analyzing biological data (Krebs 1999).

Interestingly the banded dotterel data did not violate as many of the model assumptions but the estimated survival and recapture rates are not believable. It is not clear to the author why there were problems with this data set as the sample size was large and there were fewer chicks included. Banded dotterels are one of the most common braided river birds present in this area and although their densities have historically dropped (Maloney 1999) they have not dropped significantly. It would be expected if the estimated survival rate of just 0.32 were true this species would be considered more threatened than their current status of gradual decline. An estimated recapture rate of 1.0 is also very questionable. I am without doubt that some birds would have been present and missed.

Compounding these issues is the migratory nature of wrybills and banded dotterels. Both species depart the breeding ground forming flocks during winter months. The young of both species are not expected back at the breeding ground until they have reached breeding age, usually 2-3 years. As this study was conducted over a five year period many of these juveniles would not be expected to be returning before the study finished. Any future work in this area will need to take this into account. There is also no evidence that juveniles return to their natal breeding grounds. The program MARK is capable of including migration rates in model structure and it is recommended that this be investigated further.

Unlike wrybill and banded dotterel most black stilts remain on or near their breeding grounds throughout the year (Reed et al. 1993). This factor of the species ecology makes them a better candidate for mark-recapture analysis as there is less need to factor movement between sites into models. The analysis of this data set shows a clear difference between in survival between the birds released in the Tasman and those released in other areas. As this data set did not include juveniles (birds are released at sub-adult age) these results are promising. The estimated capture rate was also high for both groups and the model did not indicate that this fluctuated by group or time. This further supports the difference in survival rates being associated with release location.

While the analysis of these data sets were not as successful as hoped they have demonstrated that mark-recapture methods are applicable. Some adjustments in study design and modelling may still be required to fully utilise programs such as MARK. The benefits of using mark-recapture methods to estimate impacts of management actions on survival compared with other methods are well illustrate by Davidson and Armstrong (2002). Similarly successful mark-recapture analysis has been conducted on long-tailed bats (Pryde et al. 2006). Like the braided river bird species in this study the long-tailed bat is also cryptic in nature. With good study design mark-recapture analyses are a powerful tool for estimating population parameters without the need for large samples or high recapture rates (Armstrong & Ewen 2001). Further mark-recapture analysis of this type will prove to be a powerful tool in the management of wrybills, banded dotterels and kaki.

Recommendations

This study has shown that sufficient re-sightings of banded birds are being obtained to utilise mark-recapture analysis. If the main model assumptions can be satisfied then mark-recapture analysis can be applied in many ways to these species. The following recommendations are made.

- Address study design to ensure data collected with meet the main assumptions of the models.
- Creating capture histories can be extremely laborious therefore prior to any further studies of this nature I would highly recommend that methods are developed to enable capture histories to be generated automatically from data records.
- With regards to the wrybill and banded dotterel populations these could be more efficiently studied at their respective wintering grounds. This would of course be dependant on the context of the question being asked.
- MARK could be used for calculating nest success. Currently the monitoring program collects nest monitoring data. This could be analysied using MARK and would then also account for nest that had not be located.
- There is also scope to utilise data collected in other rivers (i.e Cass and Ahuriri) to form comparisons between age groups, treatment groups
- MARK could also be used to compare estimated survival and recapture rates of between species within the one area.
- There are also several more complex models that could be utilised to account for many different factors that influence survival and recapture rates. These would require the knowledge of an advance MARK user.

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